REPORT OF THE INVESTIGATION COMMITTEE ON THE POSSIBILITY OF SCIENTIFIC MISCONDUCT IN THE WORK OF HENDRIK SCHÖN AND COAUTHORS

September 2002

TABLE OF CONTENTS

I. Executive Summary

In late May 2002, the management of Bell Labs formed a committee to investigate "the possibility of scientific misconduct, the validity of the data and whether or not proper scientific methodology was used in papers by Hendrik Schön, et al., that are being challenged in the scientific community". The members of the Committee were M.R. Beasley (Chair), S. Datta, H. Kogelnik, H. Kroemer and D. Monroe.

The first task of the Committee was to establish the specific allegations. This task was complicated by the public nature of some of the allegations and by additional allegations that came to the attention of the Committee as the investigation progressed. By the time this initial process was ended on June 20, 2002, allegations had been made about 25 papers, involving 20 coauthors. Of these allegations, the Committee selected 24 Final Allegations for detailed examination.

These Final Allegations can be grouped into 3 classes:

- *Substitution of data* (substitution of whole figures, single curves and partial curves in different or the same paper to represent different materials, devices or conditions)

- *Unrealistic precision of data* (precision beyond that expected in a real experiment or requiring unreasonable statistical probability)

- *Results that contradict known physics* (behavior inconsistent with stated device parameters and prevailing physical understanding, so as to suggest possible misrepresentation of data)

In examining the allegations, the Committee sent questionnaires to all coauthors and interviewed Hendrik Schön and his three principal coauthors (Zhenan Bao, Bertram Batlogg and Christian Kloc). The Committee also examined drafts of many of the papers in question, which were available in electronic form, including the embedded, processed data files used to plot the figures. These data files permitted detailed, quantitative examination of the data in the figures. The Committee requested primary (raw) data files for some of the papers but was unable to examine them because they no longer exist, as discussed below.

The Committee's main findings and conclusions can be summarized as follows.

By all accounts, Hendrik Schön is a hard working and productive scientist. If valid, the work he and his coauthors report would represent a remarkable number of major breakthroughs in condensed-matter physics and solid-state devices.

Except for the provision of starting materials by others, all device fabrication, physical measurement and data processing in the work in question were carried out (with minor exceptions) by Hendrik Schön alone, with no participation by any coauthor or other colleague. None of the most significant physical results was witnessed by any coauthor or other colleague.

Proper laboratory records were not systematically maintained by Hendrik Schön in the course of the work in question. In addition, virtually all primary (raw) electronic data files were deleted by Hendrik Schön, reportedly because the old computer available to him lacked sufficient memory. No working devices with which one might confirm claimed results are presently available, having been damaged in measurement, damaged in transit or simply discarded. Finally, key processing equipment no longer produces the unparalleled results that enabled many of the key experiments. Hence, it is not possible to confirm or refute directly the validity of the claims in the work in question.

The most serious allegations regarding the work in question relate to possible manipulation and misrepresentation of data. These allegations speak directly to the question of scientific misconduct. The Committee carefully investigated each of these allegations and came to a specific conclusion in each case.

The evidence that manipulation and misrepresentation of data occurred is compelling. In its mildest form, whole data sets were substituted to represent different materials or devices. Hendrik Schön acknowledges that the data are incorrect in many of these instances. He states that these substitutions could have occurred by honest mistake. The recurrent nature of such mistakes suggests a deeper problem. At a minimum, Hendrik Schön showed reckless disregard for the sanctity of data in the value system of science. His failure to retain primary data files compounds the problem.

More troublesome are the substitutions of single curves or even parts of single curves, in multiple figures representing different materials or devices, and the use of mathematical functions to represent real data. Hendrik Schön acknowledges these practices in many instances, but states that they were done to achieve a more convincing representation of behavior that was nonetheless observed. Such practices are completely unacceptable and represent scientific misconduct.

One of the most troublesome cases is that of superconductivity in polythiophene. Here, identical curves appear multiple times in whole or in part in a single figure. Hendrik Schön acknowledges that these data are not valid but cannot explain how they arose. In the view of the Committee, it is not possible that this set of curves represent real data and therefore this is a clear, unambiguous case of scientific misconduct.

In the end, the Committee concluded that, of the 24 Final Allegations examined, Hendrik Schön committed scientific misconduct in 16, some of which were interrelated. Of the remaining 8, 2 were judged to have no clear relationship to publications, while 6 were troubling but did not provide compelling evidence of scientific misconduct.

The Committee finds all coauthors of Hendrik Schön in the work in question completely cleared of scientific misconduct. The Committee also finds no evidence that the laboratory practices of any coauthor of Hendrik Schön in the work in question are outside the accepted practices of their fields.

In addition to addressing the question of scientific misconduct, the Committee also addressed the question whether the coauthors of Hendrik Schön exercised appropriate professional responsibility in ensuring the validity of data and physical claims in the papers in question. By virtue of their coauthorship, they implicitly endorse the validity of the work. There is no implication here of scientific misconduct; the issue is one of professional responsibility.

The Committee found this to be an extremely difficult issue, which the scientific community has not considered carefully. Therefore, no clear, widely accepted standards of behavior exist. In order to proceed, the Committee adopted, for working purposes, a minimal set of principles that it feels should be honored in collaborative research. At its core, the question of professional responsibility involves the balance between the trust necessary in any collaborative research and the responsibility all researchers bear for the veracity of the results with which they are associated. The Committee does not endorse the view that each coauthor is responsible for the *entirety* of a collaborative endeavor: the relative responsibility of researchers with very different expertise, seniority and levels of participation must be considered.

The Committee examined this question for each coauthor, considering the nature of their participation and their differing degrees of responsibility. The Committee concluded that the coauthors of Hendrik Schön in the work in question have, in the main, met their responsibilities, but that in one case questions remain that the Committee felt unqualified to resolve, given the absence of a broader consensus on the nature of the responsibilities of participants in collaborative research endeavors.

II. Background

In late May 2002, the management of Bell Labs, Lucent Technologies, formed a committee to investigate "the possibility of scientific misconduct, the validity of the data and whether or not proper scientific methodology was used in papers by Hendrik Schön, et al., that are being challenged in the scientific community". The full Charge to the Committee is attached in Appendix A. The members of the Committee were M.R. Beasley (Chair), S. Datta, H. Kogelnik, H. Kroemer and D. Monroe. Biographies of the Committee members can be found in Appendix B.

In consultation with the Bell Labs management, the Committee elected to use the U. S. *Federal Policy on Research Misconduct* as its guiding set of principles, definitions and recommended practices in conducting its investigation. The research in question was not Federally funded, and therefore the Federal policies are not legally binding on Lucent Technologies. Nonetheless, the Committee and Lucent agreed that these policies represent, in effect, a consensus view of the U.S. scientific community on the issue of scientific misconduct. A copy of these guidelines is attached in Appendix C.

III. Allegations

A. Establishing the Allegations

The first task of the Committee was to establish the specific allegations pertaining to the possibility of scientific misconduct, the validity of the data, and whether or not proper scientific methodology was used in the papers being questioned. This task was complicated by the public nature of some of the allegations, and by additional allegations that came to the attention of the Committee as the investigation progressed.

In order to proceed in an orderly and fair manner, the Committee assembled a comprehensive set of Allegations and Observations about the work in question, based on (1) the report transmitted to the Committee by Bell Labs of their initial inquiry into the allegations, (2) written communications sent directly to the Committee, and (3) verbal communications taken to be credible by the Committee. All of these allegations and observations can be tracked to an identified individual (or individuals) and in most instances were accompanied by significant documentation.

The Allegations and Observations document was intended as a thorough, straightforward compilation of the allegations and observations received by the Committee. It contains both entries that directly suggest scientific misconduct and entries that note scientific or procedural issues that can reasonably be taken to raise questions as to the validity of the data in the works in question. These allegations and observations were organized into categories that reflect both their character and their pertinence to the questions raised in the Charge to the Committee.

The document was not intended to reflect any rank ordering or any other judgment by the Committee regarding the allegations. Because allegations continued to come to the attention of the Committee well into the investigatory process, this Allegations and Observations document was updated continually as needed, based on the judgment of the Committee. However, in view of the need to proceed systematically, allegations brought to the Committee's attention after June 20, 2002, were not included in the investigation.

Importantly, the Allegations and Observations document served to establish a specific list of papers and coauthors that were the focus of the investigation.
The final version of the Allegations and Observations document developed by the Committee is attached in Appendix D. A Table of papers, coauthors and associated allegations by category derived from this document is shown below; the papers are also listed in Appendix F.

Papers in Question (PDF)

B. Informing the Authors of the Papers in Question

In concert with the management of Bell Labs, all authors of the papers in question were provided with a list of the allegations pertinent to them, along with a redacted copy of the associated documentation that was consistent, to the greatest extent possible, with confidentiality. This notification process was first comprehensively performed in late June, and was subsequently performed in particular instances, as warranted.

IV. Procedures Followed in the Investigation

A. Refinement of the Allegations

As the investigation proceeded, the Committee distilled the full list of Allegations and Observations into a smaller Final List of Allegations based on its sense of the importance and relevance of the allegations, and in light of the elements of its charge. The Committee also eliminated allegations that could not be reasonably adjudicated by the Committee, or were of a character best left to the scientific community through its normal processes, or were of lesser importance in the context of this investigation.

This Final List of Allegations is shown below. It contains 24 Final Allegations. The Committee examined in detail each of these Final Allegations as described below. An elaborated version of this List is attached in Appendix E. It includes for each allegation a summary of the relevant evidence, the responses of the authors of the papers in question (mainly Hendrik Schön) and a statement of the conclusions reached by the Committee. The complete list of Papers in Question is attached in Appendix F.

FINAL LIST OF ALLEGATIONS

I. Data Substitution: Triode characteristics
II. Data Substitution: Ambipolar triode characteristics
III. Data Substitution: Inverter characteristics
IV. Data Substitution: Ring oscillator time dependence
V. Data Substitution: Normal-state resistivity of polythiophene
VI. Data Substitution: Space-charge limited I-V
VII. Data Substitution: Laser emission spectrum
VIII. Data Substitution: Superconducting T_c versus charge
IX. Data Substitution: Magnetotransport
X. Unrealistic Precision: Normal-state resistance of gated C_{60}
XI. Unrealistic Precision: Normal-state resistance of gated C_{70}
XII. Unrealistic Precision: Resistance of $CaCuO_2$
XIII. Unrealistic Precision: Pentacene mobility
XIV. Unrealistic Precision: Ballistic transport
XV. Unrealistic Precision: Conductance quantization statistics
XVI. Unrealistic Precision: SAMFET Dilution series
XVII. Unrealistic Precision: SAMFET width series
XVIII. Unrealistic Precision: Characterization of sputtering process
XIX. Contradictory Physics: Unipolar inverter characteristics
XX. Contradictory Physics: SAMFET subthreshold swing
XXI. Contradictory Physics: Hysteretic planar Josephson junctions
XXII. Contradictory Physics: Low sub-gap conductance
XXIII. Contradictory Physics: Squid results
XXIV. Contradictory Physics: Sharp 2-D superconducting transitions

B. Questionnaire

As a first means of collecting input from the various authors, the Committee sent questionnaires to all coauthors. Using the information in the Table above, the Committee defined three classes of coauthors: 1) Hendrik Schön, 2) Primary Coauthors (Zhenan Bao, Bertram Batlogg, and Christian Kloc) and 3) Secondary Coauthors (all others). Copies of the questionnaires sent to each class are attached in Appendix G. Responses were received from all coauthors.

C. Interviews

During the week of 22 July 2002 the Committee visited Bell Labs and conducted interviews related to its investigation.

Extensive interviews were carried out with four of the coauthors of the papers in question: Zhenan Bao, Bertram Batlogg. Christian Kloc and Hendrik Schön. Prior to the interviews, letters describing the interview process, and the areas in which the Committee was specifically seeking information, were sent to each interviewee.

The interviews were divided into two parts. In the first part, the Committee discussed the written responses to the questionnaire provided by each of these coauthors. In the second part, the Committee described each of the relevant final allegations, presented in detail the supporting evidence and discussed the allegations and supporting material with each interviewee. The interviews were both transcribed and recorded, with the consent of the interviewees.

The Committee also interviewed other individuals that it felt had useful information to offer relevant to the investigation. They included John Rogers, Art Ramirez, Horst Störmer, Ananth Dodabalapur and Ernst Bucher – the latter two by telephone. These informational interviews were neither transcribed nor recorded. The Committee also conducted an additional interview by telephone with Bertram Batlogg. This telephone interview was recorded but not transcribed.

D. Review of the Report

All coauthors of the papers in question, and the management of Bell Labs, were provided the opportunity to review the report of the Committee prior to its formal submission and to submit written comments for inclusion in the report. Responses were received from Hendrik Schön and Bertram Batlogg, and are included in Appendix H.

V. Findings

Based on an examination of all available evidence, the Committee arrived at the following findings.

A. General Findings

1) By all accounts, Hendrik Schön is a hard working and productive scientist. Many coworkers, both from Konstanz and from Bell Labs, have attested to his long hours in the lab, the many samples wired for measurements, extensive use of deposition and measurement apparatus, and extended periods analyzing data at the computer. They have also commended his modest and unpretentious style, and his deep understanding of many aspects of condensed-matter physics. Moreover, Hendrik Schön has undeniably demonstrated an ability to write coherent, stimulating papers at a remarkable rate, an average of one paper every 8 days during 2001.

Unfortunately, none of the authors of the testimonials was familiar with the experiments being performed. None are therefore able to attest to the validity of the data in the papers in question.

2) The works in question report accomplishments that, if valid, would represent a remarkable number of major breakthroughs in condensed-matter physics and solid-state devices, including organic field-effect transistors, organic single-molecule transistors, organic junction lasers, field-induced high-temperature superconductivity in various materials, plastic Josephson junctions and tunable superconducting weak links.

The works in question represent less than a quarter of Hendrik Schön's publications as first author over the past five years. Many of the other papers also claim significant breakthroughs.

3) The devices used in the work in question were (with a few exceptions) fabricated by Hendrik Schön alone, with no participation by any coauthor or colleague, either at Bell Labs or at the University of Konstanz, where much of the work in question was physically carried out.

The starting materials used to fabricate devices for measurement were obtained from various sources. The high-quality single crystals of organic materials that enabled many of the experiments were grown by Christian Kloc, with the exception of haloform-intercalated C_{60} *crystals, which were prepared by Hendrik Schön himself in Konstanz. The* $CaCuO_2$ *crystals were provided by the coauthors from France. Zhenan Bao provided and in some cases synthesized molecules for self-assembled monolayers; other molecules were obtained by Hendrik Schön. For some of the SAMFET work and the polythiophene work, thin-film layers were deposited by Zhenan Bao as part of devices otherwise fabricated by Hendrik Schön. Similarly, some thin films were deposited by Christian Kloc. Another exception is the data in Figure 3 of the paper by Schön and Bao, Paper XVI, for which the device was both fabricated and measured by Zhenan Bao.*

Hendrik Schön was working at Konstanz while he was waiting for a visa to take up a full-time position at Bell Labs. Also, the sputtering system used to make the Al_2O_3 *gate insulators critical to many of his devices was located there. At times, when Hendrik Schön was at Bell Labs, he provided samples to Ortwin Schenker, who deposited* Al_2O_3 *gate insulators and returned the samples for further processing and measurement.*

4) Physical measurements of the significant devices underlying all papers in question were (with one exception) carried out by Hendrik Schön alone, with no participation by any coauthor or other colleague.

The one exception is the set of measurements by Zhenan Bao in the paper mentioned in the preceding finding.

5) No measurement or demonstration of a significant physical effect or device characteristic (e.g., transistor action, quantum Hall effect plateau, light emission, superconducting transition or Josephson junction behavior) was witnessed by any coauthor or other colleague (with one exception), despite repeated requests in at least two cases (laser action and superconductivity).

The one exception is the observation of Shubnikov-deHaas oscillations in pentacene, reportedly witnessed by Bertram Batlogg.

6) No laboratory records (e.g., signed notebook, dated sheets of paper, or data/sample logs) were systematically maintained by Hendrik Schön in the course of the work in question, either with respect to samples, processing, characterization or measurement.

Hendrik Schön maintains that his record keeping practices were not unique for his Department within Bell Labs.

7) All primary electronic data files were deleted by Hendrik Schön. Current records, provided in response to the Committee's request for supporting information on six papers, comprise only secondary, processed data kept in numerous computer files and on loose sheets of paper – and these not systematically so.

Hendrik Schön claims that he had insufficient storage capacity on the old computer available to him and therefore deleted these files, although he acknowledges that other back-up storage options were available. Bertram Batlogg asserts that had this problem been brought to the attention of the management of Bell Labs, they would surely have provided a better computer.

Note that the current state of these data records makes it impossible for the committee to confirm or refute the scientific claims made in the papers in question.

8) No working devices with which one might confirm claimed results are presently available. In addition, no nonworking devices are available for structural or other types of characterization. All of the hundreds of devices that are claimed to have been studied were either damaged during measurement, damaged in transit from Konstanz or simply discarded.

It should be noted that some (but not all) of the measurements are prone to destroying samples for the purposes of additional physical measurement (e.g., when breakdown occurs at high gate voltages, or at the high current densities required for light emission in transistor structures).

It should also be noted that two experts in their fields who spoke with the Committee noted that they had seen data (unpublished) that in some cases showed subtle features that, these experts believed, were unlikely to be known by non-experts. In their minds such details lend credibility to the results.

Finally, it should be noted that in the course of its investigation the Committee heard of two reports by researchers outside of Bell Labs of some success in achieving conduction (but not, to date, superconductivity) in field-effect transistor structures incorporating C_{60}. The Committee also heard that attempts to reproduce the very high breakdown strength gate insulators at Konstanz, using the same equipment used by Hendrik Schön, have not been successful.

9) All figures in the papers in question were (with one exception) processed and prepared by Hendrik Schön alone, with no direct physical participation by any coauthor.

The one exception is Figure 3 in the paper by Schön and Bao mentioned above. In some cases coauthors did discuss the general form of the figures and which data should be included and which should not.

B. Findings Related to Possible Manipulation and Misrepresentation of Data

The most serious allegations regarding the work in question relate to possible manipulation and misrepresentation of data. These allegations speak directly to the question of scientific misconduct. The Committee carefully investigated each of these allegations. Specific findings for each allegation can be found in Appendix E. Here we focus on the most substantial findings.

1) Substitution of data in the papers in question did occur in multiple instances. Specific examples include:

- Substitution of whole figures, single curves and partial curves in different or the same paper to represent different materials, devices or conditions.

- Nontrivial alteration or removal of individual data points or groups of data points within a data file.

Hendrik Schön acknowledges this substitution, alteration, and selection took place, but states that their occurrence results from mistakes made either in extracting the intended data from his database or by accident while examining individual data points. In some instances the substitution of data has been noted *and challenged by other researchers. In light of these challenges, in some instances the appropriate journals have been notified and new figures provided. In no case was the substitution or alteration of data discussed with any coauthor prior to publication.*

2) Further examples of substitution and alteration of data include:

- Substitution of fitted or assumed mathematical functions (e.g., power laws, sine functions, exponentials, exact zeros) where measured data would be expected. In some cases, these surrogate data were spliced, using unspecified matching procedures, with other surrogates or with real measurements to create the overall curves that were presented.

- Selection of data for illustration of trends so as to match the expected trend to within a few percent, even though the original data varied by more than a factor of ten.

Hendrik Schön acknowledges these substitutions and alterations but states that these practices were used for the purpose of achieving a better and/or more convincing representation of the observed phenomena. In no case was such data substitution or alteration discussed with any coauthor.

3) Instances in which the data in figures have characteristics that are manifestly unreasonable also occurred. There are three types:

- Individual curves in different figures or even the same figure that are identical in shape (e.g., simply shifted vertically) over their entire extent or over only a portion of the curve.

- Statistical plots that are inconsistent with the unbiased sampling process implied in the associated paper.

- Perfect numerical symmetry in measured data values for continuous upward and downward sweeps in a control parameter.

The most serious example of the first type occurs in Fig. 2 of the paper on superconductivity in polythiophene (Paper XXV), which shows the behavior of the normal-state resistance as a function of temperature, for various field-effect induced doping levels. The data points in the lower pair of curves differ from each other only by an exactly constant scaling factor over the entire temperature range, with the exception of the single pair of data points forming the low-temperature ends of both curves. For the upper two curves, the portions below 60K differ from the lower curves only by a scaling factor.

Examples of the second type occur in two separate papers: i) an externally circulated preprint on the deposition procedures and properties of the critically *important Al_2O_3 insulating layers used in the field-effect doping experiments in question (Paper XXIV), and ii) in the paper on conductance quantization in SAMFET devices (Paper XIII).*

The histogram of breakdown strengths, in the gate insulator preprint, and the distribution in the quantized conductance, in the SAMFET paper, each fit a Gaussian distribution to a degree that is extremely improbable, given the number of samples. In both of these cases, the expected deviation from the ideal is determined by well known statistical principles, not from any details of the measurement apparatus.

An example of the third type also occurs in the preprint on Al_20_3 gate insulators. It shows the reversible onset of conduction and then superconductivity in a field-effect doped material (unlabeled) as the gate voltage was ramped up and then down continuously. Despite the continuous nature of the measurement, the resistance data on the up and down sweeps are numerically identical to an extremely high precision.

While acknowledging the problematic nature of these results, Hendrik Schön has no explanation for how such problems arose.

C. Responsiveness of the Authors of the Papers in Question

1) In the course of the investigation and before, Hendrik Schön provided the Committee and others with voluminous information regarding the questions at issue in this investigation. However, with only one exception, he did not volunteer information about questioned results or practices until confronted with documentary evidence. In addition, in at least four cases, his initial explanation was revised when presented with more detailed information.

The exception is that he volunteered that a Gaussian line shape was used to "extrapolate" the laser output as shown in Figure 2 of Paper XIV.

The most important cases of revision are:

i) For the statistics of conductance quantization, he stated that the original data were obscured by a (highly unusual) wide bar on the histogram plot. When it was found that the original plotting file contained no such data points to be obscured, he stated that the original file had accidentally omitted every other point. (As it turns out, even this omission does not resolve the problem of the improbable statistics.)

ii) When questioned in an email about the relative current drives of drive and load transistors in inverter circuits, he responded that the currents were matched. Such a selection procedure for transistors cannot result in inverter gain greater than one, whereas Hendrik Schön claimed *a gain of 6-10. In later discussions, he stated that the transistors were not matched, and were chosen unsystematically to give a large gain.*

iii) For the normal state resistance of field-effect doped superconducting thin films, several instances have been noted in which the data follows a simple analytical form. In his initial response to the Committee, Hendrik Schön described how the apparent smoothness of the data could result from smoothing of real, noisy data points. However, when faced with the reality that such smoothing could not explain the extraordinary precision with which the data fit the analytic form, Hendrik Schön acknowledged that the data were in fact spliced-in analytic functions.

iv) In his initial response to the committee's list of Allegations and Observations, Hendrik Schön described a theoretical fit to the temperature-dependent mobility of pentacene, in which, the data and the fit disagree by only 10-20%. However, when confronted during the interview with evidence that the agreement between different fields was as good as 0.1% for half of the data points, he admitted that the "experimental" data was actually a theoretical curve.

2) The responses of all other coauthors were direct and required no later modification.

VI. Conclusions

A. Scientific Misconduct and Failure to Follow Accepted Scientific Practices

Based on its examination of all relevant factors, the Committee concludes that, based on the preponderance of the evidence, Hendrik Schön committed scientific misconduct as defined by the falsification or fabrication of data, such that the research is not accurately represented in the research record. This occurred in 16 of the 24 cases (Final Allegations) that the Committee examined, some of which were interrelated. He did this intentionally or recklessly and without the knowledge of any of his coauthors. The remaining 8 cases, while troubling, do not on their own provide compelling evidence of scientific misconduct. (See Appendix E for details.)

The evidence that manipulation and misrepresentation of data occurred is compelling. In its mildest form, whole data sets were substituted to represent different materials or devices. Hendrik Schön acknowledges that the data are incorrect in many of these instances. He states that these substitutions could have occurred by honest mistake. The recurrent nature of such mistakes suggests a deeper problem. At a minimum, Hendrik Schön showed reckless disregard for the sanctity of data in the value system of science. His failure to retain primary data files compounds the problem.

More troublesome are the substitution of single curves, or even parts of single curves, in multiple figures representing different materials or devices, and the use of mathematical functions to represent real experimental data. Hendrik Schön acknowledges these practices in many instances, but states that they were done to achieve a more convincing representation of behavior that was nonetheless observed. Such practices are completely unacceptable and represent scientific misconduct.

One of the most troublesome cases is that of superconductivity in polythiophene. Here, identical curves appear multiple times, in whole or in part, in a single figure. Hendrik Schön acknowledges that these data are not valid but cannot explain how they arose. In the view of the Committee, it is not possible that this set of curves represent real data and therefore this is a clear, unambiguous case of scientific misconduct.

Similarly, the statistics of the breakdown strengths of Al_2O_3 gate insulators are so improbable that the results as a whole must be drawn into question. While it is true that these data appear only in a preprint, this preprint was widely available and was produced as a means of quelling the growing frustration of researchers in the field by providing details on how to obtain such large breakdown fields. The large breakdown fields were, in turn, indispensable for producing the many unprecedented, and unrepeated, results on field-induced superconductivity.

The Committee further concludes that Hendrik Schön did not follow generally accepted practice in his field with regard to the maintenance of traceable records (in particular for critical results) nor did he retain original data in a form with which critical physical claims could be verified, or even examined.

As a result it is not possible to confirm or to refute the fundamental physical claims in the papers in question -- claims that Hendrik Schön maintains are valid despite admitted manipulation and misrepresentation of data, which he acknowledges he should not have done.

In the end, the correctness of the fundamental physical claims in the work in question will come through the normal processes of science – specifically through the reproduction, or not, of the results. On the basis of the evidence at hand, the Committee cannot exclude the possibility that some of the specific results claimed in the papers in question will someday be shown to be true. At the same time, there is no basis to argue that all of the effects claimed are physically impossible. Indeed, these general effects (perhaps differing in specific details) may be demonstrated in the future by others in a fully independent way.

However, even if some of the claims in question turn out to be true, it would not invalidate the conclusion that scientific misconduct occurred. It is the persistent, intentional data manipulation and misrepresentation themselves, for whatever reason, in presenting the claimed discoveries, not the ultimate validity of any or all of those claims, that is at issue here. To apply a lesser standard would imply that "ends justify the means". This is unacceptable in reporting scientific results and is at odds with the fundamental tenet of science that results must be presented honestly, and in such a way that the reader can judge their validity on the merits.

The Committee finds all coauthors of Hendrik Schön in the work in question completely cleared of any scientific misconduct. The Committee also finds no evidence that the laboratory practices of any coauthor of Hendrik Schön, in the work in question, are outside the accepted practices of their fields.

B. Responsibilities of Coauthors

The question of whether the coauthors of Hendrik Schön exercised appropriate responsibility, in ensuring the validity of the data and physical claims in the papers in question, requires careful discussion. There is no implication here of scientific misconduct; the issue is one of professional responsibility.

However, the Committee chose to include this issue in the report because coauthors, through their explicit association with the papers, by implication endorse the validity of the work. Moreover, the coauthors often have access to technical details that other parties, such as management, referees, editors and award committees do not have, and thus the coauthors represent the first line of defense against misconduct. When that defense fails, as in this case, it emphatically raises the question of whether the community has a right to expect more from coauthors. The Committee hopes to stimulate a discussion of this question, but no definitive resolution will be found here.

This issue of the responsibilities of coauthors in collaborative work is of particular importance in the present era of increasing multidisciplinary research across fields of science. The U. S. *Federal Policy on Research Misconduct*, being concerned only with scientific misconduct in the most stringent sense, does not address this broader issue. The Committee has not found any authoritative document, prepared by an appropriate U.S. national body, that discusses comprehensively the responsibilities of coauthors in collaborative work. The most explicit expression found by the Committee has been given in guidelines issued by the Deutsche Forschungsgemeinschaft (DFG), the quasi-governmental German research agency (http://www.dfg.de/aktuell/download/self_regulation.htm). In its *Recommendation 11*, the DFG states flatly:

"Authors of scientific publications are always jointly responsible for their content. A so-called "honorary authorship" is inadmissible."

Joint responsibility could range from a hard-to-define *collective* responsibility all the way to considering every coauthor to be *fully* responsible for everything in the paper.

The Committee does not endorse the latter view that each coauthor is responsible for the *entirety* of a collaborative endeavor: the relative responsibility of researchers with very different expertise, seniority and levels of participation must be considered, particularly in view of the increasing importance of interdisciplinary research. The Committee has adopted, for working purposes, the following minimal principles that it feels should be honored in collaborative research:

• All collaborators share *some* degree of responsibility for the *entirety* of any paper of which they are a co-author.

• The *relative* responsibility among coauthors will vary. For example, the nature of expertise, the centrality of individual contributions, and evident leadership roles inevitably and appropriately play a role in determining both the degree of responsibility, and the relative responsibility for different aspects of a paper.

• Collaborative scientific research requires a high level of trust among the participants. However, such trust must be balanced with a responsibility to ensure the veracity of all results. Shared credit for the accomplishment must be matched with shared responsibility.

Two corollaries follow from these principles: 1) Researchers unwilling or unable to accept responsibility for a paper should not be coauthors and their contributions should be recognized through an appropriate acknowledgement; 2) Every coauthor should be given an opportunity to review the final draft of any manuscript before the latter is submitted for publication and, as a rule, coauthors should in turn insist on such an opportunity.

Based on these principles, the Committee assessed whether or not the individual coauthors in the work in question met their respective responsibilities. We begin with the principal coauthors.

Christian Kloc grew many single crystals that were absolutely essential to the research in question. This clearly qualifies him as a coauthor in the large number of papers on which he is listed. However, the field of physical measurements where data manipulation and misrepresentation took place is outside his specific expertise. It would be unreasonable to expect him to notice data misrepresentations that were for so long missed by even experts in the field. On balance the Committee concludes that Christian Kloc met reasonably his responsibilities as a coauthor.

Zhenan Bao participated in a relatively small number of the papers in question. In addition to synthesizing molecules for Hendrik Schön, she also prepared thin films of organic material on patterned electrodes. One of the papers combined quite reasonable electrical results that Zhenan Bao measured on her own apparatus, on structures she fabricated, with spectacular measurements by Hendrik Schön, on quite different structures he fabricated. The juxtaposition of these results in a single, short paper, of which she was the corresponding author, should perhaps have stimulated more critical attention on her part. Still, on balance, the Committee concludes that Zhenan Bao met reasonably her responsibilities as a coauthor, for reasons basically similar to those in the case of Christian Kloc.

Turning to Bertram Batlogg, the Committee agrees with his emphasis on the importance of trust in collaborative research, and it agrees that Bertram Batlogg took appropriate action once explicit concerns had been brought to his attention, beginning in the summer of 2001. To this extent, the Committee concludes that Bertram Batlogg met his responsibilities as a coauthor.

On the other hand, the Committee felt the need to question whether Bertram Batlogg, as the distinguished leader of the research, took a sufficiently critical stance with regard to the research in question, even in the absence of direct knowledge of the growing concerns. Should Batlogg have insisted on an *exceptional* degree of validation of the data in anticipation of the scrutiny that a senior scientist knows such *extraordinary* results would surely receive? Such attention need not violate the spirit of trust. To the contrary: Unprecedented and spectacular results are guaranteed to lead to serious critical inquiries from the scientific community at large. A senior coauthor who has paid close attention to the details of the work, who recognizes the fallibility of the experimental process and the human beings carrying it out, and who has asked searching questions is in a much better position to support his colleagues in defending the work.

In a similar spirit, but admittedly more difficult, should Batlogg have crossed the line of trust and questioned the integrity of the data? After all, during the period from 2000 to 2002, many condensed-matter physicists, with no specific vested interest in the work in question, were becoming seriously skeptical about the extraordinary rate of publication of spectacular results on extremely difficult material systems, independent of any specific evidence of problems with the data.

These are extraordinarily difficult questions, which go to the heart of what we as a community of scientists expect of one another professionally, in the real world within the context of a collaborative research endeavor. The Committee does not consider itself qualified to make a specific judgment in this case, in the absence of a broader consensus on the nature of the responsibilities of participants in collaborative research endeavors.

In the case of other coauthors not specifically discussed, the Committee finds that their role in the totality of the work in question was sufficiently limited, and in some cases of such a highly specialized nature, that they are judged as having met reasonably their responsibilities as coauthors.

C. A Closing Comment

The Committee is aware, through written and verbal communications, that there are expectations by some in the scientific community and beyond that it will pass judgment on questions that the Committee regards beyond its purview, given its charge, authority and expertise – not to mention the limits of time. The Committee was given considerable latitude to define the scope of its investigation. Indeed, many crucial questions naturally arise, now that it has been established that scientific misconduct occurred. Among these questions are: the validity of the central observations for the papers in question; the validity of the other groundbreaking papers by Hendrik Schön; the extent to which Bell Labs management, the journals, and award committees performed properly; and the evolving standards of scientific documentation in computerized laboratories.

As to the first issue, the Committee has said all that it feels can be said within the constraints of its charge and the available evidence. As to the remaining issues, these are matters appropriately left to the scientific community as a whole and to the relevant institutions. The Committee's task was to *establish the facts regarding scientific misconduct as quickly and as clearly as possible*. It is hoped that this report will provide a solid foundation on which to base any further considerations.

VII. Acknowledgements

The Committee would like to thank the many members of the scientific community who sent us thoughtful and detailed communications pertinent to the investigation. The Committee would also like to thank Jean Ainge and Suzanne Merten for their highly competent and always cheerful assistance throughout this endeavor.

Appendix A: Charge to the Investigation Committee

The Investigation Committee has been convened by Bell Labs management to investigate the possibility of scientific misconduct, the validity of the data and whether or not proper scientific methodology was used in papers by Hendrik Schön et al. that are being challenged in the scientific community. Bell Labs management takes these charges very seriously and would like to get the facts on the table as quickly as possible. We have asked for this objective and open review assuming that the authors of the papers in question are innocent of any wrongdoing until proven otherwise. It is the prerogative of the Investigation Committee to decide the scope of the investigation in terms of the body of scientific work of Hendrik Schön and his coauthors, based on the allegations it has received from Bell Labs and those which have been transmitted to it directly.

The Investigation Committee will report its findings in the form of a written report to Cherry Murray, Physical Sciences Sr. VP, Bell Labs and Jeff Jaffe, President of Research and Advanced Technologies, Bell Labs.   We would like to have a fair, thorough and objective report of the Committee's findings by September 1, 2002. If, however, the IC determines it needs more time to complete its report, we ask that the IC advise us.

In the interest of openness and scientific integrity, Bell Labs would like to make the findings of the Investigation Committee as public as possible.   As the report or its appendices may contain either proprietary or confidential information, Lucent Technologies reserves the right not to publicize those portions it deems either proprietary or highly confidential. The Investigation Committee may also wish to write an executive summary that does not contain proprietary or confidential information and therefore is suitable for more general audiences.

The Investigation Committee is asked to conduct an investigation of the scientific papers under question using appropriate guidelines such as those spelled out by the Office of Scientific Integrity of the NIH or such other usual and customary practices as may be used in research universities to respond to allegations of possible scientific misconduct. The Investigation Committee will be given complete freedom to conduct any interviews and to gather any evidence that it deems necessary in order to conduct a thorough and fair investigation of the misconduct allegations, of the scientific methods and of the scientific validity of the data under question as well as the soundness of the scientific findings derived from the data.

The Investigation Committee will be provided any evidence, including proprietary information that will be so labeled, that it deems relevant. The Investigation Committee may not reveal Lucent proprietary information. If the Investigation Committee decides to tape interviews or gather any material data or evidence, then at the conclusion of its work this material and the original interview tapes will be owned and archived by Lucent Bell Labs

Appendix A: Charge to the Investigation Committee

During the course of the investigation, the Investigation Committee will have the assistance from Bell Labs of Jean Ainge, a staff person to take notes, keep records, etc. as well as legal counsel on Lucent matters by two attorneys, Art Saiewitz and Bruce Schneider.

In addition the Bell Labs Research management is always at the service of the Investigation Committee should they require more information or access to data.

As an initial provision of materials to you, we will provide each committee member with a CD with the following information burned into it:

1. Executive summary of external and internal allegations known to John Rogers and Federico Capasso
2. List and copies of the papers mentioned in the allegations
3. Timeline of work on molecular materials by Hendrik Schön
4. Any external and internal allegations known to us as of May 24, 2002 involving Schön and his collaborators work
5. Hendrick Schön written responses to allegations and supporting letters
6. List of 'mistakes' by Hendrik Schön sent by email to his management
7. A pdf file of best practices and research integrity policies for Fordham University
8. a timeline of papers published by H. Schön et al.
9. a compilation of the emails sent between John Rogers and Federico Capasso relating to Schön and his work.
10. a compilation of John Rogers email to Hendrik Schön
11. a contact list of relevant people & phone numbers – coauthors, mentors, critics,
12. copies of the letters Bell Labs sent to the editors of Science, Nature, and Applied Physics Letters stating that we are convening an external review committee.
13. copies of selected email correspondence between Hendrik and collaborators.
14. CV's of Committee members
15. Bell Lab's code of conduct policy

Again, this is a preliminary deliverable and Bell Labs will provide such other material the Investigation Committee deems necessary for its work.

Formal Charge to the Committee:

1. Ascertain that the composition of the Committee will enable a fair, objective and thorough scientific review of the work under question.
    a. Reveal any conflicts of interest on the Committee that would impair a fair and objective investigation
    b. Assure that there is the correct mix of expertise on the committee to do a thorough scientific review of the work
    c. Add or remove committee members as needed, including for the addition of other scientific or technical expertise, in consultation with the agreement of Bell Labs management

2. Review as the Investigation Committee deems necessary evidence such as papers, lab practices, samples, notebooks, correspondence, etc. and conduct interviews of people the committee deems relevant to doing a thorough scientific review of the body of work.

3. Explore to the extent it deems necessary the allegations, examine the evidence in depth, determine whether there are instances of possible misconduct, whether there are additional instances that would broaden the scope beyond the initial allegations and determine whether there is evidence of, scientific misconduct and, if so to what extent (such as whether the preponderance of the evidence supports an allegation), who was responsible, and its seriousness.

4. Make a record of all Committee meetings and conference calls

5. Document the Committee's findings in a final report

Cherry Murray
Physical Sciences Research Sr. Vice President

Appendix B: Biographies

I.   Malcolm R. Beasley

Personal:
Born 4 January 1940, San Francisco, California.
Married to Jo Anne Horsfall Beasley; three children.

Education
Cornell University 1962, B.E. (Physics); Cornell University 1968, Ph.D. (Physics).

Professional Experience:
1962–67, Research Assistant, Cornell University;
1967–69, Research Fellow, Div. of Engineering and Applied Physics, Harvard University.
1969–72, Assistant Professor of Applied Physics, Harvard University.
1973–74, Associate Professor of Applied Physics, Harvard University.
1974–80, Associate Professor of Applied Physics and Electrical Engineering, Stanford University.
1980-present, Professor of Applied Physics and Electrical Engineering (by courtesy), Stanford University.
Sept. 1998-2001, Dean of School of Humanities & Sciences, Stanford University

Research Activities and Interests:
Condensed Matter and Materials Physics. Superconductivity and superconducting materials. Transport studies of novel materials. Applications of superconductivity. Nonlinear dynamics of coupled oscillators. Advanced approaches to thin film deposition of novel materials.

Membership in Professional Associations, etc.:
Fellow, American Physical Society
Member, IEEE, 1991
Member, Materials Research Society

Honors and Awards:
1961, Tau Beta Pi
1983, School of Humanities & Sciences Dean's Award for Superior Teaching.
1985, Fellow, American Physical Society.
1988, Morris Loeb Lecturer, Harvard University.
1990, Clerk Maxwell Lecturer, IEE, London, U.K.
1990, appointed Theodore and Sydney Rosenberg Professor of Applied Physics, Stanford University.
1991, Fellow, American Academy of Arts and Sciences.
1991, Fellow, American Association for the Advancement of Science
1993, elected to National Academy of Sciences

Administration:
1985–89, Department Chairman
1986–1988, 1998-, Member, University Senate.
1986–87, Member, Committee on Committees.
1986–88, Member, Policy Committee, School of Humanties & Sciences.
1992-98, Director, Center for Materials Research
1993-94, 1998, Member, H&S Appointments and Promotions Committee

Sept. 1998-2001, Dean of School of Humanities & Sciences, Stanford University

II. Supriyo Datta

1285 Electrical Engineering Building
School of Electrical and Computer Engineering
Purdue University; West Lafayette, IN 47907

Personal Born 2 February, 1954

Education

Indian Institute of Technology, Kharagpur, India	B.Tech.	1975
University of Illinois at Urbana-Champaign	M.S.	1977
University of Illinois at Urbana-Champaign	Ph.D.	1979

Professional Experience

9/02 -	Director, NASA Institute for Nanoelectronics and Computing
7/99 -	Thomas Duncan Distinguished Professor of Electrical & Computer Engineering, Purdue University, West Lafayette, IN
8/88 -	Professor, Purdue University, West Lafayette, IN
8/84 - 7/88	Associate Professor, Purdue University, West Lafayette, IN
7/83 - 7/84	Assistant Professor, Purdue University, West Lafayette, IN
7/81 - 6/83	Visiting Assistant Professor, Purdue University, West Lafayette, IN
8/79 - 6/81	Visiting Assistant Professor, U. of Illinois at Urbana – Champaign, IL

Honors and Awards

•Cledo Brunetti Award, 2002, with M.S. Lundstrom, from the
IEEE (Institute of Electrical and Electronics Engineers)
"For significant contributions to the understanding and innovative simulation of nanoscale electronic devices"
•Technical Excellence Award, 2001, with M.S. Lundstrom, from the
SRC (Semiconductor Research Corporation)
•Fellow of the IOP (Institute of Physics), UK
•Fellow of the APS (American Physical Society)
"For contributions to the theory of quantum transport and the interplay between quantum interference and dissipation in mesoscopic systems"
•Fellow of the IEEE
"For contributions to the understanding of electronic transport in ultrasmall devices"
•Frederick Emmons Terman Award from the
ASEE (American Society of Engineering Education), 1994
•Centennial Key to the Future Award from the IEEE, 1984
•Presidential Young Investigator Award from the National Science Foundation, 1984
•D.D.Ewing teaching award from the School of Electrical Engineering, Purdue University, 1983

Current research interests are centered around the physics of nanostructures and includes nanoscale device physics, molecular electronics, spin electronics and mesoscopic superconductivity. Has written three books:

1. S. Datta, *Electronic Transport in Mesoscopic Systems*
   (Cambridge University Press, 1995, Paperback Edition, 1997).
2. S. Datta, *Quantum Phenomena*
   (vol. VIII of Modular Series on Solid State Devices, Addison-Wesley, 1989).
3. S. Datta, *Surface Acoustic Wave Devices* (Prentice-Hall, 1986)

III. Herwig Kogelnik

Herwig Kogelnik was born in Graz, Austria in 1932. He received the Dipl. Ing. and Doctor of Technology Degrees, both from the Technische Hochschule Wien, Vienna, Austria, in 1955 and 1958, respectively, and the Ph.D. Degree from Oxford University, Oxford, England, in 1960.

From 1955 to 1958 he was Assistant Professor at the Institut fur Hochfrequenztechnik, Vienna, engaged in microwave research and teaching. He won a British Council Scholarship to Oxford from 1958 to 1960, where he did research on electromagnetic radiation in magnetoplasmas and anisotropic media. He joined Bell Laboratories (earlier owned by AT&T, currently by Lucent Technologies), Holmdel, New Jersey, in 1961, where he has been concerned with research in optics, electronics and communications, including work on lasers, holography, optical guided-wave devices, and integrated optics. He was Head of the Coherent Optics Research Department from 1967 to 1976, was Director of the Electronics Research Laboratory from 1976 to 1983, and Director of the Photonics Research Laboratory from 1983 to 1997. He is presently Adjunct Photonics Systems Research Vice President.

Dr. Kogelnik is a Fellow of the Institute of Electrical and Electronics Engineers and of the Optical Society of America. He was elected to the National Academy of Engineering in 1978 and to the National Academy of Sciences (NAS) in 1994, and served as chairman of the Engineering Sciences section of the NAS from 1999 to 2002. In the spring of 1982 he was a visiting McKay Lecturer at the University of California at Berkeley. He is the recipient of the 1984 Frederic Ives Medal of the Optical Society of America (OSA), the 1989 David Sarnoff Award of the Institute of Electronic and Electrical Engineers (IEEE), the 1990 Joseph Johann Ritter von Prechtl Medal from the Technical University of Vienna, Austria and the 1991 Quantum Electronics Award from the IEEE Lasers and Electro Optics Society. He was elected Vice President of the Optical Society of America for 1987 and served as President in 1989. He was elected as Honorary Fellow of St. Peter's College at Oxford University in 1992. He is the recipient of the 2001 IEEE Medal of Honor. He was inducted into the NJ Inventors Hall of Fame in 2002, and received the 2001 Marconi International Fellowship Award in Telecommunications

Herwig Kogelnik served as Program Chairman and Chairman of the IEEE/OSA sponsored conferences on Laser Applications and Engineering (CLEA), Integrated Optics, and the International Quantum Electronics Conference (IQEC). He was a member of the Scientific Advisory Council of the Max-Planck Institute for Solid State Physics in Stuttgart, Germany. He has also served as Vice-Chairman and Chairman of the Monmouth Arts Foundation, as Chairman of the Selection Committee for the Marconi International Fellowship Award, as a Trustee of the New York Museum of Holography, and as president of the Seabright Lawn Tennis and Cricket Club. He is currently a member of the International Jury for the Austrian Wittgenstein Prize, and a member of the National Research Council (NRC) Board on Assessment of NIST Programs.

Herwig Kogelnik and his wife Christa (nee Müller) live in Rumson, New Jersey. They have three children: Christoph, Florian and Andreas. Their favorite sports are tennis, swimming, paddle tennis and skiing.

IV. Herbert Kroemer

Dr. Herbert Kroemer is the *Donald W. Whittier Professor of Electrical Engineering* at the University of California at Santa Barbara (UCSB), where he has been since 1976. He also holds an appointment at the Materials Department at UCSB.

Dr. Kroemer was born (1928) and educated in Germany. He received a Ph.D. in Physics (Solid State Theory) in 1952 from the University of Göttingen, Germany, with a dissertation on the theory of what would now be called *hot-electron effects,* in the then-new transistor. Since then, he has worked on the physics and technology of semiconductors and semiconductor devices in a number of research laboratories in Germany and the U.S.:

1952/54	German Telecommunications Service Research Laboratory (Fernmeldetechnisches Zentralamt), Darmstadt, Germany;
1954/57	RCA Laboratories, Princeton, NJ;
1957/59	Philips Research Laboratory, Hamburg, Germany;
1959/66	Varian Associates Central Research Laboratory, Palo Alto, CA;
1966/68	Fairchild R&D Laboratory, Palo Alto, CA;
1958/76	University of Colorado, Boulder, CO.

Dr. Kroemer is the originator of several device concepts, such as the drift-transistor concept, the double-heterostructure injection laser, and other heterostructure concepts. While working on the drift transistor concept during the early-50's, he realized that the incorporation of controlled energy gap variations into a bipolar transistor has the potential of greatly expanding the performance limits of that device. In 1957, he generalized these ideas to the concept that energy gap variations represent "quasi-electric" fields and potentials, the use of which represents a powerful new design principle for semiconductor devices in general. This work was basically the start of the heterostructure device physics and technology of today, one of the central parts of modern semiconductor device physics and technology. He also analyzed in detail a first application of this principle, in the form of what has become known as the heterostructure bipolar transistor (HBT), an idea that was beyond technological realization at the time. His 1963 proposal of the double heterostructure laser, still seven years ahead of technological realization, was another direct outgrowth of the 1957 work, with vast repercussions on today's lightwave technology.

During the '60s, Kroemer worked on microwave device problems, and in 1964 he was the first to publish an explanation for the Gunn Effect. With the emergence of molecular beam epitaxy (MBE) in the mid-'70s, he returned to heterostructure devices, especially to HBTs, to the further conceptual development of which he made several contributions that continue to influence the experimental developments in that field. In addition to his previously dominantly theoretical work, he also started to take an active part in experimental heterostructure work by MBE, expanding quickly beyond HBTs into new kinds of quantum well and superlattice structures, and making several contributions to the development of MBE technology itself, especially for unconventional materials combinations, such as GaAs-on-Si growth, and InAs/AlSb heterostructures.

He is the author or a co-author of over 270 publications.

Dr. Kroemer has received numerous awards, honors, and recognitions:

1972 Fellow of the IEEE, and Fellow of the APS
1972 Chair, International Symposium on GaAs and Related Compounds
1973 *J. J. Ebers Award* of the IEEE *"for outstanding technical contributions to electron devices"*
1974 Chair, Device Research Conference
1981 Chair, International Workshop on Molecular Beam Epitaxy
1986 *Jack Morton Award* of the IEEE
1982 *Senior Research Award* of the ASEE
1982 *GaAs Symposium Award* and the *Heinrich Welker Medal* of the 10th International Symposium on GaAs and Related Compounds "*In recognition of his contributions to hot-electron effects, the Gunn Oscillator, and III-V heterojunction devices, including the heterojunction laser*"
1985 *Honorary Doctorate of Engineering* from the Technical University of Aachen, Germany *"in honor of his great merits in the understanding and the technical introduction of heterojunction devices"*
1994 *Alexander von Humboldt Research Award*
1997 Election to the National Academy of Engineering
1998 *Honorary Doctorate in Technology* from the University of Lund, Sweden
2000 *Nobel Prize* in Physics
2000 Fellow, Institute of Physics (London);
2001 *Golden Plate Award*, American Academy of Achievement;
2001 *Honorary Doctorate in Science*, University of Colorado.
2001 *Order of Merit* (Bundesverdienstkreuz) of the Federal Republic of Germany;
2002 Goff Smith Prize, University of Michigan
2002 IEEE Medal of Honor

Dr. Kroemer's current research interests continue to be in semiconductor heterostructures, ranging from their basic physics to their device utilization, especially in the form of new quantum-effect structures that require heterostructures as an essential structural element without which they could not be built.

V. Don Monroe

Agere Systems
Room 4E-707B
4 Connell Drive.
Berkeley Heights, NJ 07922

Experience

Following a doctorate in condensed-matter physics from MIT, became a member of technical staff at Bell Labs. After first exploring low temperature phenomena in GaAs heterostructures, evolved toward device physics, processing and design of modern technologies, including fiber devices, silicon MOSFETs and InGaAsP optolectronic devices:

- 1978 Designed tunable microwave filter using YIG.
- 1980-1985 Experimentally characterized optically-induced transients in Chalcogenide glasses.
- 1984-1985 Developed theoretical picture of hopping transients, introducing "transport energy."
- 1985-1987 Devised unique screening experiment to demonstrate electron glass in impurity bands at low temperatures.
- 1987-1989 Demonstrated thermal nature of optically induced electrical response in high-Tc superconductors.
- 1988 Devised electron beam-induced voltage experiment for characterizing junctions in high-Tc films.
- 1990 Theoretically described ordering phenomena and mobility in impurity bands and DX centers.
- 1991-1994 Performed mobility, Shubnikov-de Haas, quantum Hall measurements of 2D SiGe heterostructures.
- 1992-1993 Theoretically analyzed scattering mechanisms for SiGe heterostructures.
- 1993 Introduced a phenomenological model for reliability of UV-written Bragg gratings in fibers.
- 1993-1994 Led team exploring fabrication of MOSFETs using strained-layer SiGe.
- 1994-1995 Examined in device and circuit simulation the low-power potential of ultra-thin oxides.
- 1995-2001 Contributed physical insight and measurements to understanding of thin gate oxide reliability.
- 1993-2001 Electrically characterized mobility and capacitance of thin oxides.
- 1998-2000 Coordinated Si wafer processing in Orlando development fab and Murray Hill research fab.
- 1995-2000 Designed and tested electrical test structures for CMOS wafers.
- 1999-2001 Co-developed, coordinated, and characterized novel planar CMOS process sequences.
- 1997-2000 Helped re-introduce and evaluate Silicon-on-Insulator (SOI) MOSFETs in Murray Hill and Orlando
- 1997-2000 Framed the circuit issues surrounding SOI for possible adoption by Lucent Microelectronics
- 1997-2001 Co-invented the Vertical-Replacement Gate (VRG) MOSFET process.
- 1994-2000 Developed analytical model for short-channel effects in MOSFETs
- 1999-2000 Developed process flow, design rules and circuit layouts for side-by-side VRG CMOS.
- 2001 Designed waveguide and layer structure for integrated photodetector and Semiconductor Optical Amplifier for 40Gb/s operation in InGaAsP

Employment History

2001-present	Agere Systems Distinguished Member of Technical Staff High Performance Structures and Device Research Department	Murray Hill, NJ

1984 - 2001	Bell Labs Member of Technical Staff	Murray Hill, NJ
	1995 – 2001 ULSI Technology Research Department 1993 – 1995 Silicon Materials Research Department 1990 – 1993 Physical Chemistry Research Department 1984 – 1990 Condensed Matter Physics Research Department	
February-December, 1978	Raytheon Research Division	Waltham, MA

Education

1980 - 1985	Massachusetts Institute of Technology **Ph.D., Physics** Thesis Topic: "Transient Transport and Optical Studies of Chalcogenide Glasses" Thesis Advisor: Marc Kastner	Cambridge, MA
1976 – 1977, 1979-1980	Massachusetts Institute of Technology **B.S., Physics**	Cambridge, MA

Professional Memberships

- Optical Society of America
- Institute of Electrical and Electronic Engineers (Senior Member)
- Materials Research Society
- American Association for the Advancement of Science
- American Physical Society (Fellow)

Patents Awarded

- J. M. Hergenrother and D. P. Monroe "A CMOS Integrated Circuit having Vertical Transistors and a Process for Fabricating Same"
- 6,197,641: J. M. Hergenrother and D. P. Monroe, "Process for Fabricating Vertical Transistors"
- 6,027,975: J. M. Hergenrother and D. P. Monroe, "Process for Fabricating Vertical Transistors"
- 5,442,205: Brasen et al., "Semiconductor Heterostructure Devices with Strained Semiconductor Layers"
- 5,620,496 Erdogan et al., "Method for Making Stable Optical Devices Employing Radiation-Induced Index Changes"

Other Awards

Bell Lab President's Gold Award Winner 2000- Wavestar LambdaRouter Team

Appendix C: U.S. Federal Policy on Research Misconduct[1]

I. Research[2] Misconduct Defined

Research misconduct is defined as fabrication, falsification, or plagiarism in proposing, performing, or reviewing research, or in reporting research results.

- *Fabrication* is making up data or results and recording or reporting them.
- *Falsification* is manipulating research materials, equipment, or processes, or changing or omitting data or results such that the research is not accurately represented in the research record.[3]
- *Plagiarism* is the appropriation of another person's ideas, processes, results, or words without giving appropriate credit.
- Research misconduct does not include honest error or differences of opinion.

II. Findings of Research Misconduct

A finding of research misconduct requires that:

- There be a significant departure from accepted practices of the relevant research community; and
- The misconduct be committed intentionally, or knowingly, or recklessly; and
- The allegation be proven by a preponderance of evidence.

III. Responsibilities of Federal Agencies and Research Institutions[4]

Agencies and research institutions are partners who share responsibility for the research process. Federal agencies have ultimate oversight authority for Federally funded research, but research institutions bear primary responsibility for prevention and detection of research misconduct and for the inquiry, investigation, and adjudication of research misconduct alleged to have occurred in association with their own institution.

---

[1]*No rights, privileges, benefits or obligations are created or abridged by issuance of this policy alone. The creation or abridgment of rights, privileges, benefits or obligations, if any, shall occur only upon implementation of this policy by the Federal agencies.*

[2]*Research, as used herein, includes all basic, applied, and demonstration research in all fields of science, engineering, and mathematics. This includes, but is not limited to, research in economics, education, linguistics, medicine, psychology, social sciences, statistics, and research involving human subjects or animals.*

[3]*The research record is the record of data or results that embody the facts resulting from scientific inquiry, and includes, but is not limited to, research proposals, laboratory records, both physical and electronic, progress reports, abstracts, theses, oral presentations, internal reports, and journal articles.*

[4]*The term "research institutions" is defined to include all organizations using Federal funds for research, including, for example, colleges and universities, intramural Federal research laboratories, Federally funded research and development centers, national user facilities, industrial laboratories, or other research institutes. Independent researchers and small research institutions are covered by this policy.*

- Agency Policies and Procedures. Agency policies and procedures with regard to intramural as well as extramural programs must conform to the policy described in this document.
- Agency Referral to Research Institution. In most cases, agencies will rely on the researcher's home institution to make the initial response to allegations of research misconduct. Agencies will usually refer allegations of research misconduct made directly to them to the appropriate research institution. However, at any time, the Federal agency may proceed with its own inquiry or investigation. Circumstances in which agencies may elect not to defer to the research institution include, but are not limited to, the following: the agency determines the institution is not prepared to handle the allegation in a manner consistent with this policy; agency involvement is needed to protect the public interest, including public health and safety; the allegation involves an entity of sufficiently small size (or an individual) that it cannot reasonably conduct the investigation itself.
- Multiple Phases of the Response to an Allegation of Research Misconduct. A response to an allegation of research misconduct will usually consist of several phases, including: (1) an inquiry – the assessment of whether the allegation has substance and if an investigation is warranted; (2) an investigation – the formal development of a factual record, and the examination of that record leading to dismissal of the case or to a recommendation for a finding of research misconduct or other appropriate remedies; (3) adjudication – during which recommendations are reviewed and appropriate corrective actions determined.
- Agency Follow-up to Institutional Action. After reviewing the record of the investigation, the institution's recommendations to the institution's adjudicating official, and any corrective actions taken by the research institution, the agency will take additional oversight or investigative steps if necessary. Upon completion of its review, the agency will take appropriate administrative action in accordance with applicable laws, regulations, or policies. When the agency has made a final determination, it will notify the subject of the allegation of the outcome and inform the institution regarding its disposition of the case. The agency finding of research misconduct and agency administrative actions can be appealed pursuant to the agency's applicable procedures.
- Separation of Phases. Adjudication is separated organizationally from inquiry and investigation. Likewise, appeals are separated organizationally from inquiry and investigation.
- Institutional Notification of the Agency. Research institutions will notify the funding agency (or agencies in some cases) of an allegation of research misconduct if (1) the allegation involves Federally funded research (or an application for Federal funding) and meets the Federal definition of research misconduct given above, and (2) if the institution's inquiry into the allegation determines there is sufficient evidence to proceed to an investigation. When an investigation is complete, the research institution will forward to the agency a copy of the evidentiary record, the investigative report, recommendations made to the institution's adjudicating official, and the subject's written response to the recommendations (if any). When a research institution completes the adjudication phase, it will forward the adjudicating official's decision and notify the agency of any corrective actions taken or planned.

- Other Reasons to Notify the Agency. At any time during an inquiry or investigation, the institution will immediately notify the Federal agency if public health or safety is at risk; if agency resources or interests are threatened; if research activities should be suspended; if there is reasonable indication of possible violations of civil or criminal law; if Federal action is required to protect the interests of those involved in the investigation; if the research institution believes the inquiry or investigation may be made public prematurely so that appropriate steps can be taken to safeguard evidence and protect the rights of those involved; or if the research community or public should be informed.
- When More Than One Agency is Involved. A lead agency should be designated to coordinate responses to allegations of research misconduct when more than one agency is involved in funding activities relevant to the allegation. Each agency may implement administrative actions in accordance with applicable laws, regulations, policies, or contractual procedures.

IV. Guidelines for Fair and Timely Procedures

The following guidelines are provided to assist agencies and research institutions in developing fair and timely procedures for responding to allegations of research misconduct. They are designed to provide safeguards for subjects of allegations as well as for informants. Fair and timely procedures include the following:

- Safeguards for Informants. Safeguards for informants give individuals the confidence that they can bring allegations of research misconduct made in good faith to the attention of appropriate authorities or serve as informants to an inquiry or an investigation without suffering retribution retribution. Safeguards include protection against retaliation for informants who make good faith allegations, fair and objective procedures for the examination and resolution of allegations of research misconduct, and diligence in protecting the positions and reputations of those persons who make allegations of research misconduct in good faith.
- Safeguards for Subjects of Allegations. Safeguards for subjects give individuals the confidence that their rights are protected and that the mere filing of an allegation of research misconduct against them will not bring their research to a halt or be the basis for other disciplinary or adverse action absent other compelling reasons. Other safeguards include timely written notification of subjects regarding substantive allegations made against them; a description of all such allegations; reasonable access to the data and other evidence supporting the allegations; and the opportunity to respond to allegations, the supporting evidence and the proposed findings of research misconduct (if any).
- Objectivity and Expertise. The selection of individuals to review allegations and conduct investigations who have appropriate expertise and have no unresolved conflicts of interests help to ensure fairness throughout all phases of the process.
- Timeliness. Reasonable time limits for the conduct of the inquiry, investigation, adjudication, and appeal phases (if any), with allowances for extensions where appropriate, provide confidence that the process will be well managed.
- Confidentiality During the Inquiry, Investigation, and Decision-Making Processes. To the extent possible consistent with a fair and thorough investigation and as allowed by law, knowledge about the identity of subjects and informants is limited to

those who need to know. Records maintained by the agency during the course of responding to an allegation of research misconduct are exempt from disclosure under the Freedom of Information Act to the extent permitted by law and regulation.

V. Agency Administrative Actions

- Seriousness of the Misconduct. In deciding what administrative actions are appropriate, the agency should consider the seriousness of the misconduct, including, but not limited to, the degree to which the misconduct was knowing, intentional, or reckless; was an isolated event or part of a pattern; or had significant impact on the research record, research subjects, other researchers, institutions, or the public welfare.
- Possible Administrative Actions. Administrative actions available include, but are not limited to, appropriate steps to correct the research record; letters of reprimand; the imposition of special certification or assurance requirements to ensure compliance with applicable regulations or terms of an award; suspension or termination of an active award; or suspension and debarment in accordance with applicable government-wide rules on suspension and debarment. In the event of suspension or debarment, the information is made publicly available through the List of Parties Excluded from Federal Procurement and Nonprocurement Programs maintained by the U.S. General Services Administration. With respect to administrative actions imposed upon government employees, the agencies must comply with all relevant federal personnel policies and laws.
- In Case of Criminal or Civil Fraud Violations. If the funding agency believes that criminal or civil fraud violations may have occurred, the agency shall promptly refer the matter to the Department of Justice, the Inspector General for the agency, or other appropriate investigative body.

VI. Roles of Other Organizations

This Federal policy does not limit the authority of research institutions, or other entities, to promulgate additional research misconduct policies or guidelines or more specific ethical guidance.

Appendix D: Allegations and Observations

[The following is the list of allegations and observations (which may fall short of being allegations) maintained by the committee, as of June 20, 2002. The summaries listed were condensed from the full statements made by the sources of the allegations. The Committee has maintained records of these sources, as indicated by the letters, and the original statements. The identity of these sources, and the full statements, are not included in this report.]

Comments on the Allegations/Observation Document

This document is intended as a thorough, straightforward compilation of the allegations and observations received by the Investigation Committee prior to June 20, 2002 bearing on possible scientific misconduct by the authors indicated. It is based on the report transmitted to the Committee by Lucent Technologies of their initial inquiry into the allegations, written communications sent directly to the Committee, and verbal communications taken to be credible by the Committee.

It contains both entries that suggest directly scientific misconduct and entries that note scientific issues that can reasonably be taken to raise questions as to the validity of the data.

The document does not reflect any rank ordering or any other judgment by the Committee regarding the allegations.

I. Experimental data matching theory too well

Normal state resistance of C_{60} films

[From Source D; adopted as Allegations X, XI, and XII]

- Hole-doped C_{60} films[1] show perfect parabolic normal-state resistance
- $CaCuO_2$ normal state resistance[2] is too smooth
- C_{70} normal-state resistance[3] is too smooth

Transport in single-crystals of acenes

[From Source D; adopted as Allegations XIII and XIV]

[1] "Superconductivity at 52 K in hole-doped C-60," J.H. Schön, Ch. Kloc, and B. Batlogg, *Nature* **408**, 549 (30 November 2000). (Paper XIX)

[2] "Superconductivity in $CaCuO_2$ as a result of field-effect doping," J.H. Schön, M. Dorget, F.C. Beuran, X.Z. Zu, E. Arushanov, C.D. Cavellin, Lagues, *Nature* **414**, 434-436 (22 November 2001). (Paper XXI)

[3] "Superconductivity in single crystals of the fullerene C_{70}," J.H. Schön, C. Kloc, T. Siegrist, M. Steigerwald, C. Svensson, B. Batlogg, *Nature* **413**, 831 (25 October 2001).

- Pentacene mobility data[4] matches theory too well
- Ballistic transport peaks[5] match theory too well

Dilution series

[From Source A; adopted as Allegation XVI]
Dilution series in SAMFETs (Ref. 6, Inset of Fig. 1(B)) shows perfect agreement down N=1, when Poisson statistics would predict sometimes 0, sometimes 2. No indication of distribution of results.

Conductance quantization

[From Source D; adopted as Allegation XV]
Histograms of conductances in single-molecule[6] have much too little variance, and shapes of individual distributions are much too perfect ($\chi^2 \sim .08$). Explanation after this was challenged: bar width of histogram was much wider than spacing (about five bins) which distorted statistics. Original data may have been replaced, however.

Width series

[From Source D; adopted as allegation XVII]
Width series for SAMFETs (unpublished[7], produced after width dependence was questioned) implies a very small process bias (~0.01μm) for a presumably crude process.

II. Multiple instances of data

Triode characteristics I

[From Source B; adopted as Allegation II]
Substantially the same data (transistor triode characteristic), represented as different materials, and with polarities changed.

- Ref. 8, Fig 2: perylene
- Ref. 9, Fig. 1: α-6T
- Ref. 10, Fig. 2: pentacene

---

[4] "Hole transport in pentacene single crystals," J. H. Schön, Ch. Kloc, and B. Batlogg, *Phys. Rev.* B **63,** 245201 (2001).
[5] "Ballistic hole transport in pentacene with a mean free path exceeding 30 μm," Schön JH, Kloc C, Batlogg B, *J. Appl. Phys.* **90** 3419 (October 1 2001).
[6] "Field-Effect Modulation of the Conductance of Single Molecules," Jan Hendrik Schön, Hong Meng, Zhenan Bao, *Science* **294**, 2140 (December 7, 2001). (Paper XIII)
[7] PowerPoint file of Bell Labs Seminar by Hendrik Schön, January 2002.
[8] "Perylene: A promising organic field-effect transistor material," J. H. Schön Ch. Kloc, and B. Batlogg, *Appl. Phys. Lett*. **77** (December 4, 2000). (VI)
[9] "A Light-Emitting Field-Effect Transistor," J. H. Schön, A. Dodabalapur, Ch. Kloc, and B. Batlogg, *Science* **290** 963 (November 3, 2000). (V)

Triode characteristics II

[From Source B; adopted as Allegation I]
Substantially the same data (transistor triode characteristics) represented as different materials

- Ref. 13, Fig. 2 pentacene
- Ref. 11, Fig. 1 C_{60}
- Ref. 12, Fig. 2 lower: C_{60} (same data as preceding)
- Ref. 14, Fig. 2, SAMFET (compare with lower curve of others) molecule 2.
- Ref 14, Fig. 3: molecule 6 (represented as a different molecule in the *same* paper, represented as two different molecules, scale and some of the data changed

Inverter characteristics

[From Source B; adopted as Allegation III]
Substantially the same data (inverter characteristics) represented as different materials, temperatures (scales partially changed).

- Ref. 13, Fig. 4: pentacene (complementary)
- Ref. 14, Fig. 4: SAMFET (unipolar)
- Ref. 15, Fig 4: single molecules (unipolar)

Ring oscillators

[From Source B; adopted as Allegation IV]
Substantially the same data (ring oscillator time dependence) in different papers, with time scale changed, represented as different materials

- Ref. 10, Fig. 3: pentacene
- Ref. 16, Fig 2: pentacene (scale changed)
- Ref. 17, Fig. 5: CdS

---

[10] "Ambipolar organic devices for complementary logic," J. H. Schön, Ch. Kloc, and B. Batlogg, *Synthetic Metals* **122,** 195 (2001). (VIII)
[11] "A Superconducting Field-Effect Switch," J. H. Schön, Ch. Kloc, R. C. Haddon, B. Batlogg, *Science* **288**, 656 (April 28, 2000).(Paper III)
[12] "Band-Like Charge Transport in C_{60} Single Crystals," J.H. Schön, Ch. Kloc, and B. Batlogg, *phys. stat. sol.* (b) **225**, 209 (2001). (Paper XX)
[13] "Ambipolar pentacene field-effect transistors and inverters," J.H. Schön, S. Berg, Ch. Kloc and B. Batlogg, *Science* **287** 1022-1023 (February 11, 2000). (Paper II)
[14] "Self-assembled monolayer organic field-effect transistors," Jan Hendrik Schön, Hong Meng, and Zhenan Bao, *Nature* **413,** 713 (October 18, 2001). (Paper XII)
[15] "Field-Effect Modulation of the Conductance of Single Molecules," Jan Hendrik Schön, Hong Meng, Zhenan Bao, *Science* **294**, 2140 (December 7, 2001). (Paper XIII)
[16] "Fast organic electronic circuits based on ambipolar pentacene field-effect transistors," Jan Hendrik Schön and Christian Kloc, *Appl. Phys. Lett.* **79**, 4043 (10 December 2001). (Paper XI)
[17] "Solution processed CdS thin film transistors," J.H. Schön, O. Schenker, and B. Batlogg, *Thin Solid Films* **385**, 271 (2001). (VII)

Space-charge limited I-V

[From Source B; adopted as Allegation VI]
Substantially the same data (space-charge-limited current I-V) in two papers, represented as different materials:

- Ref. 18, Fig. 2, top graph, top curve, α-6T
- Ref. 19, Fig. 2: pentacene

Laser emission spectrum

[From Source C; adopted as Allegation VII]
Substantially the same data (emission spectra) represented as two different temperatures (peak wavelength should also have shifted significantly):

- Ref. 20, Fig. 2
- Ref. 20, Fig. 5

Superconducting T_c versus charge

[From Source R; adopted as Allegation VIII]

- Ref. 21, Fig. 3: curves of T_c for different intercalants as a function of hole concentration all have the same abscissa, and seem to be simple multiples of one another.
- Ref. 2, Fig. 3

Shubnikov de Haas

[From Sources B and E; adopted as Allegation IX]
Data represented as the same (Shubnikov-de Haas data) but rigidly shifted in a completely non-physical way

- Ref. 22, Fig. 2
- Ref. 23, Fig. 4

Normal-state resistance of polythiophene

[From Source F; adopted as Allegation V]

---

[18] "Electrical properties of single crystals of rigid rodlike conjugated molecules," J. H. Schön, Ch. Kloc, R. A. Laudise, and B. Batlogg, *Phys. Rev.* B **58**, 12952 (1998). (Paper I)
[19] "Hole transport in pentacene single crystals," J. H. Schön, Ch. Kloc, and B. Batlogg, *Phys. Rev.* B **63,** 245201 (2001). (Paper IX)
[20] "An Organic Solid State Injection Laser," J. H. Schön, Ch. Kloc, A. Dodabalapur, and B. Batlogg, *Science* 289, 599-601 (28 July, 2000). (Paper XIV)
[21] "High-Temperature Superconductivity in Lattice-Expanded C_{60}," J. H. Schön, Ch. Kloc, B. Batlogg, *Science* **293**, 2432 (28 September, 2001). (Paper XV)
[22] "Fractional Quantum Hall Effect in Organic Molecular Semiconductors", J. H. Schön, Ch. Kloc, B. Batlogg, *Science* **288**, p 2338 (June 30, 2000). (Paper IV)
[23] "New Phenomena in High Mobility Organic Semiconductors," J.H. Schön, *Phys. Stat. Sol.* **226,** 257 (2001).(Paper X)

Curves of resistance versus temperature for different gate-induced charge densities are very similar, up to a multiplicative factor, at low temperatures. For the two metallic densities, the resistance is the same, up to a multiplicative factor for all temperatures, except where one sample is superconducting.

- Ref. 24, Fig. 2

III. Results in conflict with known physics

SAMFET subthreshold swing

[From Sources, A, D, M, N, and Q; adopted as Allegation XX]
Subthreshold swing of ~30mV/decade is not physically consistent with MOSFET physics, which should not be capable of being steeper than 60mV/decade. For the nominal structure, with a 2nm channel and a 30nm gate oxide, the effect of the gate voltage on the channel potential should be reduced by a more than an order of magnitude, but the device turns off as it should and has a high transconductance.

Gate coupling of single molecules

[From Source B; partially incorporated into Allegation XX]
Curves are said to represent contributions from molecules at different positions, but they manifest the same gate voltage. Transconductance larger than could be expected from an individual molecule, even perfectly coupled to the gate.

Gating of resonant tunneling current

[From Source N; not adopted since it was related to unpublished work]
Gating[25] of resonant tunneling current (unpublished?) makes no sense, since the current is represented as a phenomenon of the whole film.

Unipolar inverter characteristics

[From Sources P, Q, and S; adopted as Allegation XIX]
The width ratio of the inverters is not specified, although private communications indicate "matched" transistors were used. If this were true, there is no way to get a gain greater than one (required for cascading) using the same transistor for load and drive. The inverter characteristics represented as coming from single transistor polarity are much more consistent with complimentary transistors.

---

[24] "Gate-induced superconductivity in a solution-processed organic polymer film," J.H. Schön, A. Dodabalapur, Z. Bao, C. Kloc, O. Schenker, and B. Batlogg, *Nature*, **410** 189 (8 March 2001). (Paper XXV)

[25] "Nanoelectronic Devices Based on Molecular Heterostructures," J. H. Schön,*, Günther Götz, and P. Bäuerle, unpublished.

Kondo temperature

[From Source G; not adopted since it relates to unpublished work]
The known energy scales lead to the conclusion that the Kondo temperature should be tens of orders of magnitude too small to be measured, in contrast to the unpublished claim of tens of Kelvin.

Laser threshold

[From Source C; not adopted since it may be a legitimate scientific question]
Claimed threshold of laser is too low to be consistent with constraints relating spontaneous and stimulated emission.

Hysteretic planar Josephson junctions

[From Source H; adopted as Allegation XXI]
Josephson junctions[26] are supposed to be SNS type, but look like textbook tunnel junctions. Hysteresis appears inconsistent with capacitance of structure.

Sub-gap conductance

[From Sources H and I; adopted as Allegation XXII]
Low sub-gap quasiparticle conductance[27] reported even at a temperature that is a significant fraction of T_c of polythiophene. Other aspects remarkably good as well. Peaks in d^2I/dV^2 should be dips if they represent phonon modes as claimed.

Squid results

[From Sources H and I; adopted as part of allegation XXIII]
Periodicity of oscillations[27] does not, in fact, match the stated area of $10um^2$, and extends over more periods than would be expected given the sketch of the structure.

IV. Unusual fabrication and procedures

SAMFET structure

[From Source D; relevant to Allegation XX but not specifically pursued]
Figure 1 of Ref. 14 describes MOSFET formed on sidewall of trench. Detailed questions reveal that the angled deposition of the first gold film should result in a MOSFET on the bottom of the trench.

---

[26] "Josephson Junctions with Tunable Weak Links," Jan Hendrik Schön, Christian Kloc, Harold Y. Hwang, Bertram Batlogg, *Science* **292**, 252 (13 April 2001). (Paper XVII)
[27] "Plastic Josephson junctions," Jan Hendrik Schön, *Appl. Phys. Lett.* **14**, 2208 (11 October 2001). (Paper XVIII)

Shadowing effects of angled evaporation of second gold film due to first gold film thickness (not specified in paper) should lead to a channel length determined by geometry, not the molecularly defined channel length which is the central point of the entire body of work.
No microscopy or other evidence that the SAMFET structure is as described in the schematic drawing.

Gate dielectric

[From Sources J, K, O, and S; adopted as part of Allegation XVIII]
Subsequent analysis indicates that Al_2O_3 films are an order of magnitude thicker than claimed. Possible lack of proper calibration procedures for film thicknesses suggested.

Self-assembled monolayers

[From Source L; not adopted since it may be a legitimate scientific question]
Ordering of self-assembled monolayers is usually poor for fewer than 18-carbon alkyl groups.
Molecules with a thiol group on each end are often found to bond both ends to a gold surface.

Adding conductances

[From Source D; included in Allegation XV]
Histograms of conductances in single molecule work (Ref. 15, Fig. 3) were sometimes computed by adding peak values for multiple peaks.

Discarding data

[From Source M; included in Allegation XV]
The bar graph of conductances has no tail in what otherwise might look like a Poisson distribution. When asked, Schön said that he threw out conductances in those bins.

Inferred mobility

[From Source N, included in Allegation XX]
Horizontal SAMFET results[28] are said to be similar in mobility to vertical ones, but current is three times smaller and width is said to be 25µm instead of 0.8µm. Total difference in current density should be more like two orders of magnitude, so how can the mobility similar? In the apparently duplicated figures, the data are exactly the same, but the reported mobilities for the different materials are all different.

Low yield

[From Source D; not specifically included in allegations]

[28] "Nanoscale organic transistors based on self-assembled monolayers," J. H. Schön and Z. Bao, *Appl. Phys. Lett.* **80**, 847 (4 February 2002). (Paper XVI)

Low yield in SAMFETs could allow for personal bias in choice of results. No description of protocols used for what was included or excluded.

Unusual operating voltages

[From Source Q; included in Allegation XIX]
If the transistors used in the inverter can be operated at 2V[14], why weren't they characterized at that voltage in the triode data?

Unusual data acquisition

[From Source D; not specifically included in allegations]
SdH data (Ref. 22) are sampled very coarsely, unusual because of eddy-current heating.Almost all plots (versus temperature, carrier density per C_{60}, etc) have the same abscissa for all curves, with all points at very round numbers.

V. Unusually good results

Conductance quantization

[From Sources D, Q; relevant to Allegation XV]
Quantization of conductance (unpublished?) is surprisingly good (a few percent?)

Gate dielectric films

[From Sources D, J; relevant to Allegation XVIII]
Al_2O_3 breakdown strength is twice that of other workers. Pulled paper called "sputtering.doc"[29] shows detailed justification of this, including a dense 12x12 matrix study as a function of deposition rate and pressure (144 depositions!). The signal to noise is totally out of character for processing studies, and can even be plotted on a contour plot.

On characteristics of SAMFETs

[From Source D; relevant to Allegation XX]
Transconductance of SAMFETs[14] implies extraordinary velocity, ballpark $2\text{x}10^9$cm/s [=(17mA/V)/0.8μm) x(30nm)/(3.9)/8.85x10^{-14}F/cm)], for a cutoff frequency f_T of 10,000 GHz.

Leakage current of organic films

[From Sources A, B; included in Allegation XX]

[29] "Sputtering of alumina thin films for field-effect doping," J. H. Schön

Off-current (leakage) of SAMFETs[14] is 2-3 orders of lower than careful scanning probe measurements on similar systems

Uniformity of electrical properties

[From Source D; relevant to several Allegations but not specifically included]
Resolving the number of molecules in the diluted SAMFETs[14] requires uniform conductance per molecule of a few percent, and threshold to about 20mV, both extraordinary.

Fractional Quantum Hall Effect

[No specific Allegations were identified]
Fractional QHE 22 and especially the unpublished data.

Superconducting junctions

[Relevant to Allegations XXI, XXII, and XXIII]
Weak link and squid results[26,27].

Superconductivity in gated fullerenes

[Relevant to Allegations VIII, X, and XI]
Superconducting T_c in both pure[1] and expanded fullerenes[21]

Laser action

[Relevant to Allegation VII]
Light emission and lasing[20.]

Mobility of organic crystals

[Relevant to Allegations XIII and XIV]
The very high mobility[4] of the acene crystals (attributed to the high crystal quality, which is not without precedent).

Conductance quantization

[Relevant to Allegation XV]
Since the conductance peaks[15] are shown as not flat-top, there is no reason why they should be quantized, especially to the accuracy claimed.

Similarity of different molecules

[Not pursued as possibly a legitimate scientific issue]
Surprisingly consistent behavior of different molecules in SAMFETs.

Threshold voltages

[Not pursued as possibly a legitimate scientific issue]
Threshold voltages are always exactly where one would like them to be, although no obvious thought has been given to how to adjust them.

Scatter of conductance quantization

[Relevant to Allegation XV]
Width of conductance peaks does not grow as the number of molecules contributing increases.

Squid results

[From source I; included in Allegation XXIII]
Perfect oscillations over many periods, although the schematic device structure would suggest single-junction interference at a few periods.

VI. Data similar to that of other workers

Inverter data

[Not pursued since the similarities were not compelling]
Inverter data mentioned above are similar in threshold and overall gain to work of Lin et al. (Ref. 30). (Gain of all of the inverters is 6.6).

VII. Plagiarism

Vertical MOSFETs

[From Source D; not pursued as not being particularly egregious]
Whole sentence in Ref. 14 lifted from Hergenrother et al.[31]

VIII. Overall discomfort issues

Number of papers

[From many sources; not considered in final allegations]

---

[30] "Organic complementary ring oscillators," Y.-Y. Lin, A. Dodabalapur, R. Sarpeshkar, Z. Bao, W. Li, K. Baldwin, V. R. Raju, and H. E. Katz, *Appl. Phys. Lett*. **74**, 2714 (May 3, 1999).
[31] "The Vertical Replacement-Gate (VRG) MOSFET: A 50-nm Vertical MOSFET with Lithography-Independent Gate Length," J.M. Hergenrother, D. Monroe, et al., *Proceedings of the International Electron Device Meeting*, 1999.

Overall volume of output is phenomenal.

Number of samples

[From Sources D, Q; relevant to Allegations XV, XVI, XVII, and XVIII]
The statistical studies of the diluted SAMFETs[15] involve hundreds of samples, probed at 4K. The yield is said to be less than 10% for the normal SAM layers, even lower for the diluted films. How were the required thousands of low-temperature measurements performed?
Number of experiments done[29] to characterize the Al_2O_3 films is huge.

Isolation

[From Source S; relevant to many allegations, but none specifically]
In the majority of papers, Hendrik is the first author and the only one doing measurements. In many cases, he is also doing the device fabrication as well.
Much of the work was done in Germany, not seen by the collaborators.

Reproducibility

[From Source S; relevant to many allegations, but none specifically]
Attempts to reproduce the samples in Murray Hill have not been successful, in particular the crucial deposition of the dielectric for gating carrier concentration.
Outside workers appear to have been unable to reproduce results.
Samples are said not to survive long enough in air to be remeasured, or are subjected to destructive experiments.

Poor record keeping

[From Source S; relevant to many allegations, but none specifically]
Reportedly, no lab notebooks are kept.

Too lucky

[From Source D; relevant to many allegations, but none specifically]
A large fraction of the reports include results that are either much better than previously published, reveal or require new physics, or both.
Many enabling aspects of the devices (dielectric breakdown strength, gold morphology, film morphology and ordering, purity of samples, scattering rates, non-radiative lifetimes, parasitic leakages, etc.) are much better than obtained by other workers. There is no indication of special effort being expended to achieve these advances, nor does there appear to be time to optimize them.
New structures and experiments appear to work as expected the first time.

Disregard for context

[From Source D; relevant to many allegations, but none specifically]

High level of comfort by authors with results that violate physical constraints or are inconsistent with other work. Even after serious errors or distortions are revealed, errata or corrections are not sent to journals. Little follow-up, in the sense of exploring the reproducibility or systematics of experiments. Next paper is usually a totally new breakthrough.

Availability of equipment and supplies

[From Source T; not pursued as too difficult to determine]
Some of the specialized apparatus for making the measurements may not have been available to Hendrik. Liquid Helium consumption may not have been adequate.

Appendix E: Elaborated Final List of Allegations

Appendix E: Elaborated Final List of Allegations

In this Appendix, we present and discuss the Final List of Allegations that the Committee distilled from the full set of Allegations and Observations (Appendix D). The allegations are grouped into the broad categories described in the main body of the text of this report: data substitution, unreasonable precision, and contradictory physics. In each case, we detail the allegation and present a summary of the evidence that the Committee has established relevant to the allegation. We also summarize the responses obtained in the interviews (primarily those of Hendrik Schön) and state a conclusion with regard to each allegation.

The evidence was acquired from various sources. These include the report of the inquiry carried out by the Bell Laboratories management, related electronic files such as PowerPoint™ presentations provided by Lucent, the supporting documentation provided by those raising the allegations and the Committee's own examination of the materials it was provided. Critical, in many cases, was the availability of drafts of the various journal publications under question, in electronic form (Microsoft Word™). The published figures were often identical to those in the drafts, in which case it was possible to extract the precise, numerical data underlying the published figures. These data, referred to in this Appendix as "original plotting data", were included as embedded files associated with the Origin™ data processing and plotting program used by Hendrik Schön. In a few cases, the electronic draft was not available, but a clearly related figure was found embedded in a PowerPoint file, or in a freestanding Origin file; these cases are noted in the text. Note that the Committee established as part of its investigation that all the figures in the papers under question were (with one exception) created by Hendrik Schön alone, with no active participation by any of the coauthors. Most of the figures based on original plotting data extracted from electronic documents were shown to Hendrik Schön during the interviews. Only in the case of Allegation XI (C_{70}) did he raise an objection to the use of these embedded data as proxies for the published data.

The allegations raise suspicions about various aspects of the work in question. Although the evidence suggesting a problem differs in the various cases, the underlying scientific misconduct that is being alleged is essentially the same: *knowingly or recklessly publishing data that is not what it is represented to be*.

Appendix E: Elaborated Final List of Allegations

Evaluating these allegations involves three questions:

> *a) Is there clear evidence that the data do not come from the measurements described?*

This evidence takes different forms: Data Substitution, in which data sets for distinct experimental conditions show unreasonable similarity to each other, in some cases after multiplying one data set by a constant factor; Unreasonable Precision, in which a data set agrees better with a simple analytic expression than would be expected from the measurement accuracy; and Contradictory Physics, in which the data appear to be inconsistent with prevailing scientific understanding and the description of the measurement. Many great discoveries in science would at first have been included in the Contradictory Physics category, so the Committee has set aside all but a few especially problematic examples. However, extraordinary results demand extraordinary proof. Unless special diligence is demonstrated, results that contradict known physics are just as likely to suggest simple error, self-deception or misrepresentation of data. For final judgement of the validity of the observations, however, the Committee defers to the scientific community.

Other types of evidence, while important, are difficult to decide definitively and have not been considered in detail. These include failure of others to reproduce the work, results that are much better than others have achieved, and a pace of breakthroughs and a success rate that far surpass other workers.

The Committee has limited its investigation to data for which concrete, objective evidence to doubt the validity was brought to its attention prior to June 20, 2002.

> *b) If the data are not valid, are there mitigating circumstances that explain how the data came to be misrepresented?*

For example, a clerical error in including the wrong data in a figure represents poor procedures, but not misconduct. Unfortunately, such innocent explanations tend to require an understanding of the state of mind of the authors at the time the data were prepared, and this cannot be determined definitively. It must be noted that it is natural and appropriate that the credibility of a particular innocent explanation depends on the overall credibility of the scientist in question. This in turn depends on whether there is an unreasonable number of problems or a pattern of questionable practices. This is *not* a case of many poorly founded allegations being accepted as proof that "something must be wrong." Rather, the problems with the data are already established, and the question is whether many improbable, innocent explanations should be accepted.

c) Can the data presented be traced back to primary data, free of any data processing or other manipulation?

It is a well-established tenet of science that clear records should be kept. At the end of the day, only credible, primary data can provide unambiguous corroborating evidence for published data. An understanding of the procedures of data acquisition and analysis also provides a context within which possibly mitigating circumstances can be assessed. It is worth emphasizing that the retention of primary data, together with adequate record keeping, are necessary to the ordinary conduct of science, not simply for the examination of possible wrongdoing. Frequently, in the conduct of research, new questions arise that require a revision of the original analysis, and thus require a return to the primary data. Failure to keep primary data and records for a reasonable time is, by itself, a threat to the health of the scientific enterprise. This remains as true in the computer age as it has been in the past.

I. Data Substitution: Triode characteristics

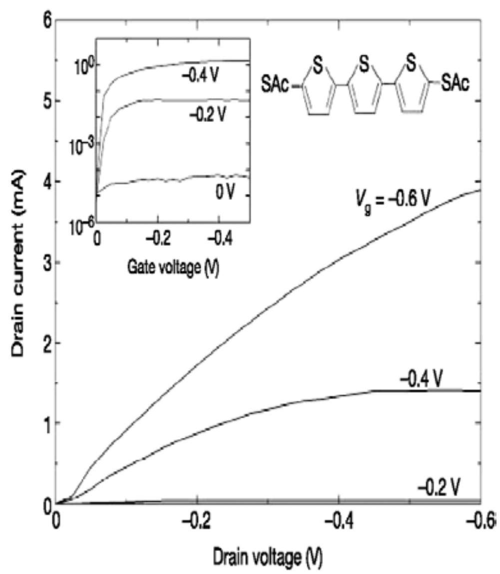

Figure 2. Triode data from "SAMFET" Paper (XII), Fig. 3: "molecule 6". The figure has been compressed laterally for comparison.

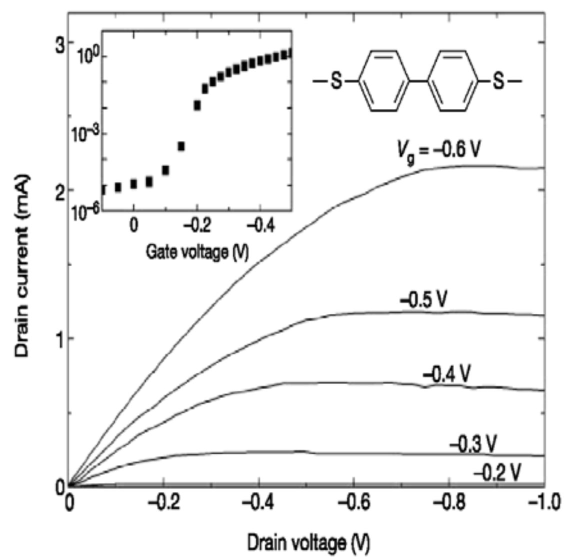

Figure 1. Triode data from "SAMFET" Paper (XII), Fig. 2: "molecule 2"

Allegation

Very similar data (transistor triode curves), including detailed "noise," appear in two different figures in the *same* paper, represented as two different molecules making up the Self-Assembled Monolayer Field Effect Transistor (SAMFET). The vertical scale differs by a factor of two, and some curves are present in only one figure.

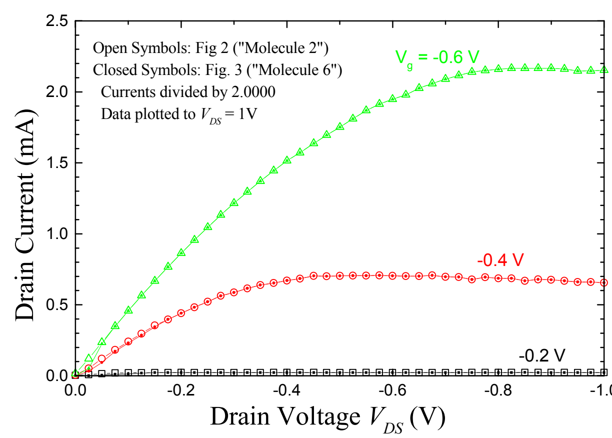

Figure 3. Original plotting data from Figure 1 and Figure 2 (extracted from an electronic draft), replotted to illustrate that the data present in both are exactly *the same, after dividing the latter by 2. All but a few of the solid symbols are within the open symbols, and agree with each other to five significant figures, although they represent distinct data sets.*

- "SAMFET" Paper (XII), Fig. 3: "molecule 6" (see Figure 2)
- "SAMFET" Paper (XII), Fig. 2: "molecule 2" (see Figure 1)

Appendix E: Elaborated Final List of Allegations

The Committee obtained the original plotting data for the two graphs. Those data, for gate voltages of –0.2 V, –0.4 V , and 0.6 V are replotted on the same scale in Figure 3. To make this plot, the data from Fig. 3 of the paper have been divided by *exactly* a factor of 2. In addition, the data are plotted out to a drain voltage of –1.0 V (the data were present in the file but were only displayed to –0.6 V in the original figure). A few points near the origin are different, but the remainder of the data for all three gate voltages are in perfect agreement. Examination of the underlying data shows that the agreement extends to *five significant figures*, well beyond any reasonable instrumental precision.

The presence of an identical figure in a context representing it as different data is troubling, since the purpose of figures in journals is to show what the measurements objectively reveal. It is possible to imagine that a clerical error could cause an entire identical figure to be placed in a manuscript in the wrong position; even one such occurrence would indicate a level of sloppiness that would begin to undermine the credibility of other data. However, it is difficult to understand how the data could be *accidentally* manipulated to: (1) remove some curves (2) scale the data by a factor of two (3) change the range of the plot to obscure some real data, and (4) alter some data points.

The same triode data for the SAMFET also appears to match other, much older data, represented as different materials:

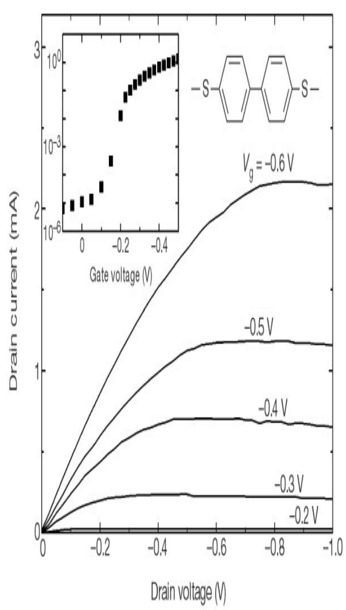

Figure 4. Triode characteristics from "SAMFET" Paper (XII). The figure has been compressed horizontally for comparison. Fig. 2: "SAMFET."

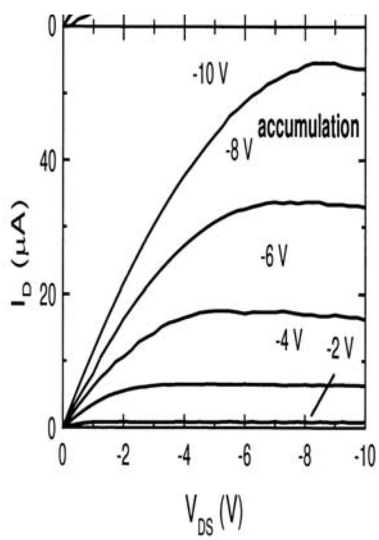

Figure 6. Triode characteristics from "AmbipolarPentacene" (II) Fig. 2, lower part:."Pentacene."

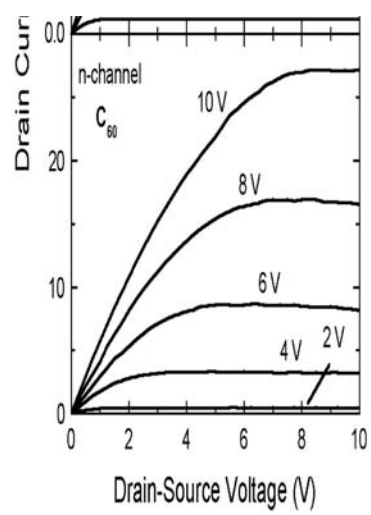

Figure 5. Triode characteristic from "SuperFETswitch" Paper (III). Fig. 1 lower part: "C_{60}."

- “SAMFET” Paper (XII), Fig. 2, SAMFET (see Figure 4).
- “AmbipolarPentacene” Paper (II), Fig. 2 lower: pentacene (see Figure 6).
- “SuperFETswitch” Paper (III), Fig. 1 lower, and “BandlikeC60” Paper (XX), Fig. 2 lower: C_{60} (see Figure 5).

Comparing these figures shows that: the vertical scales are different by integer factors; the horizontal scale is different by an integer factor for the SAMFET paper; the sign of the voltage has been changed; the labels have been changed; some of the noise details on the data are different, while others appear to be the same.

Response

Hendrik Schön’s states that “AmbipolarPentacene” and “SuperFETswitch” data are *not* identical. No primary data for any of these curves, nor the electronic versions of the last two figures, could be found. Hendrik Schön acknowledged that multiplication of curves by a factor of two was occasionally employed for comparing SAMFETs of different nominal width (the overall current should be proportional to the width; it is common to plot the drive current of transistors per micron of device width). Hendrik Schön acknowledged the alteration of individual data points as an accidental consequence of using the “move” function to interrogate points in the Origin plotting program, instead of the more straightforward “read” function.

Conclusion

It is undeniable that the two figures in the SAMFET paper contain the same data. The scale change, multiplication by an integer, missing curves, and limited plotting range make an innocent explanation not credible.

For the other set of three figures, in the absence of the underlying data, the similarity of the data, including the “noise,” is compelling, but not definitive. This substitution was done either intentionally or recklessly.

The preponderance of evidence indicates that Hendrik Schön committed scientific misconduct, specifically data falsification, in this case.

II. Data Substitution: Ambipolar triode characteristics

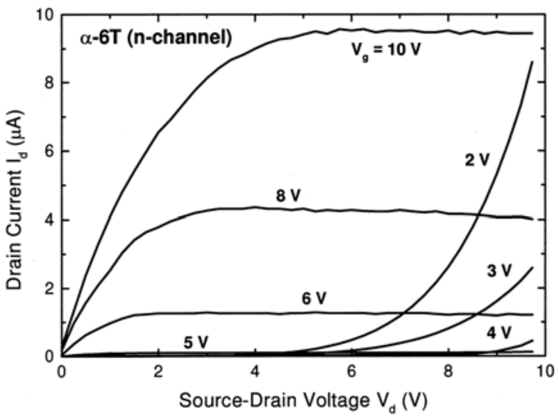

Figure 7. Triode characteristic from "LightEmitting" Paper (V), Fig. 1.: "alpha-sexithiophene (α-6T)"

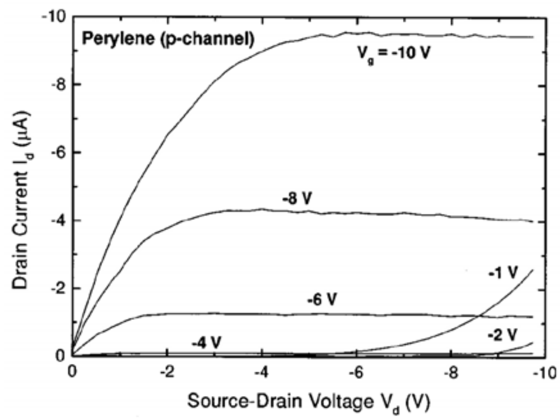

Figure 8. Triode characteristic from "Perylene" (VI), Fig. 2: "perylene". Note the sign change from Figure 7. One curve is missing.

Allegation

Very similar data (ambipolar transistor triode characteristics), including similar details of the "noise," are represented as different materials, and with voltages changed, in three papers.

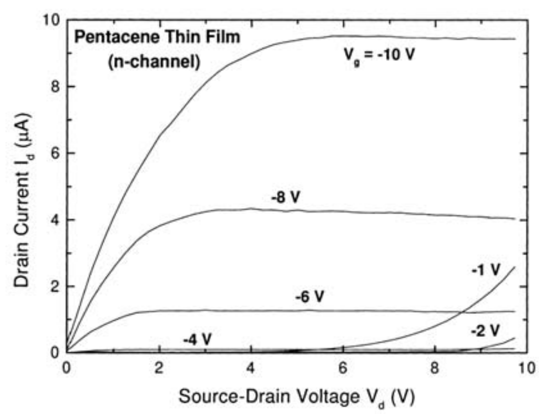

Figure 9. Triode characteristic from Paper (VIII), "AmbipolarOrganic", Fig. 2: "pentacene."

- "LightEmitting" Paper (V), Fig. 1: α-6T (see Figure 7). The positive polarities of gate and drain voltage are appropriate for an n-channel device. For gate voltage below 4 V, and large drain voltages, extra conduction attributed to electrons is observed.
- "Perylene" Paper (VI), Fig 2: perylene (see Figure 8). The gate and drain voltage and the drain current are listed with the opposite polarity, appropriate for a p-channel device. The positions of the labels are the same. In addition, the gate voltage labels have been modified, from 5V to –4V, 4V to –2V, and 3V to –1V; the 2V curve is missing altogether.

- “AmbipolarOrganic” Paper (VIII), Fig. 2: pentacene (see Figure 9). This figure is identical to the preceding one, except that the sign of the current is now listed as positive (potentially a question of definition), and the material is different.

As discussed in the previous allegation, the clear repetition of data in different materials over an extended period, by itself, calls into question the record-keeping process, and the credibility of this and other data. However, the figures evince detailed modifications of the plot, including changes in the sign of gate and drain voltage and drain current, as well as the changed labels on the plots and the removal of a data set. The polarity of the carriers is of central importance in organic conductors, for which it is common that only one polarity is mobile. Such manipulation appears to be inconsistent with even the sloppiest “clerical” error.

Response

Hendrik Schön has acknowledged data substitution between “Perylene” and “LightEmitting” papers. He acknowledged a procedure in which he selected data that looked appropriate for the device and material in question. The figures would then be relabeled, without due diligence to determine if the data were really taken from that device and material. He stated in the interview, “I know that I had an Origin file which is called I think ‘ambipolar’ where I put in transistor characteristics of ambipolar devices and in most of the cases when I write a paper or prepare a manuscript, I normally have an idea what kind of figures I want to put in those papers and I would take those figures…. Most of the figures that I have in those manuscripts are for me more as an example for the physics, or test the physics, rather than being that there is a detail analysis in those figures.”

Conclusion

The evidence strongly suggests that all three figures contain identical data, in spite of the omitted curves and changes in scale. This substitution was done either intentionally or recklessly.

The preponderance of evidence indicates that Hendrik Schön committed scientific misconduct, specifically data falsification, in this case.

III. Data Substitution: Inverter characteristics

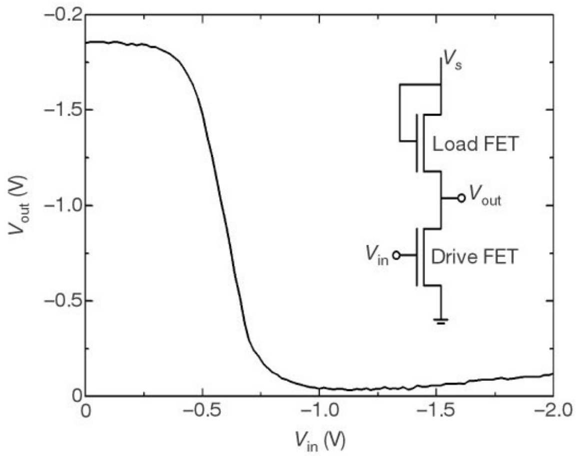

Figure 11. Inverter characteristic from "SAMFET" (XII), Fig. 4: "self-assembled monolayer transistor." Note the inconsistency in labeling the vertical axis.

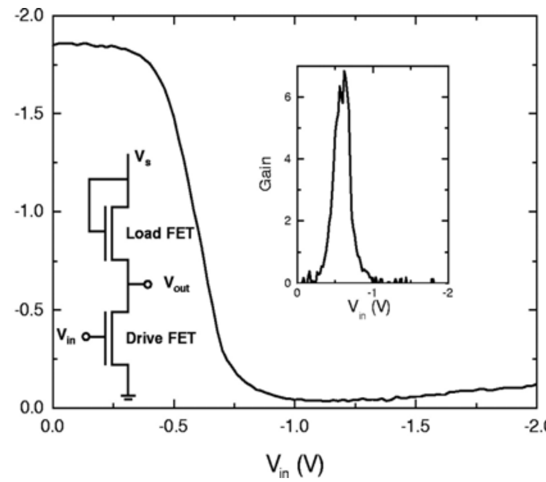

Figure 10. Inverter characteristic from "SingleMolecule" (XIII), Fig. 4: SAMFET with diluted active ingredient, at T= 4 K.

Allegation

Very similar data (inverter characteristics), were represented as different materials, circuit topologies, and temperatures (scales partially changed).

- "SAMFET" Paper (XII), Fig. 4: SAMFET transistors in a unipolar inverter (see Figure 11)
- "SingleMolecule" Paper (XIII), Fig 4: single molecules in a unipolar inverter at 4 K (see Figure 10)
- "AmbipolarPentacene" Paper (II), Fig. 4: Ambipolar (p- and n-type) pentacene transistors, in a complementary inverter (see Figure 12)

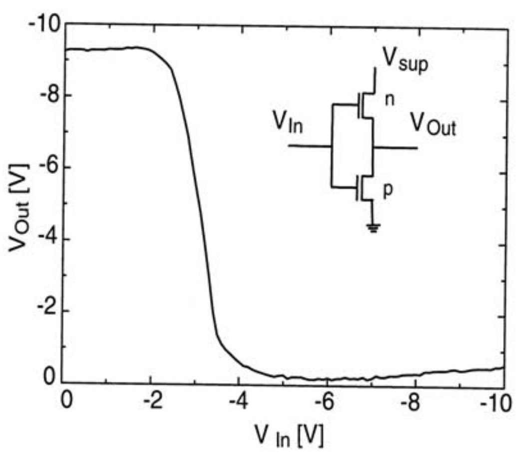

Figure 12. Inverter characteristic from "AmbipolarPentacene" Paper (II), Fig. 4: "pentacene."

The rise of the output voltage V_{OUT} at high V_{IN} is highly unusual for inverters, but is seen in all three cases. The similarity of the "noise" in this region is particularly striking. In addition, as discussed in Allegation XIX, the data shown do not appear to be consistent with the circuit configuration described.

Response

Hendrik Schön acknowledges substitution of data between the “SAMFET” and “SingleMolecule” paper, indicating that the data were correct for the SAMFET, and that there were real data for the “SingleMolecule” case with a gain of 10, not 6.6. He acknowledged that the latter data were taken at room temperature, although the caption in the paper said it was taken at 4 K.

Hendrik Schön has characterized some of the data acquisition equipment, and demonstrated some systematic distortions introduced by that equipment. This was offered as a possible explanation for the similarities in the “noise.” However, he acknowledged that the distortions he measured are not large enough to explain those features. The actual equipment used might conceivably have shown larger distortions, but those instruments are no longer available.

Conclusion

The evidence strongly suggests that all three figures contain identical data, except for modification of some regions. This substitution was done either intentionally or recklessly.

The preponderance of evidence indicates that Hendrik Schön committed scientific misconduct, specifically data falsification, in this case.

IV. Data Substitution: Ring oscillator time dependence

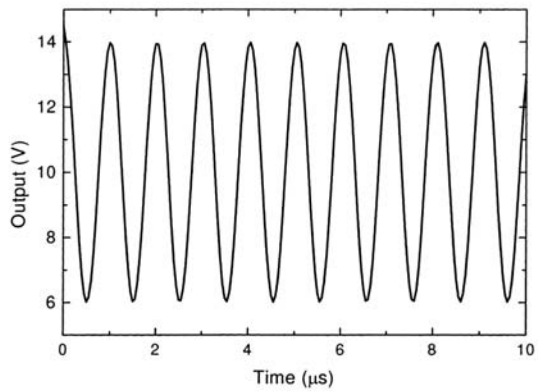

Figure 14. Time dependence of ring oscillator output from "AmbipolarOrganic" Paper (VIII), Fig. 3: pentacene.

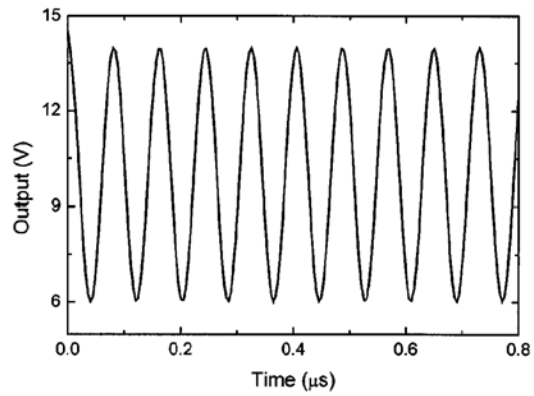

Figure 13. Time dependence of ring oscillator output from "FastOrganic" Paper (XI), Fig. 2: pentacene. The time axis differs by exactly a factor 12.5. from that for the same material in Figure 14

Allegation

Very similar data (ring oscillator time dependence) were presented in different papers, with time scale changed, but represented as different materials.

- "AmbipolarOrganic" Paper (VIII), Fig. 3: pentacene (see Figure 13).
- "FastOrganic" Paper (XI), Fig 2: pentacene (see Figure 14).
- "CdS" Paper (VII), Fig. 5: Cadmium Sulfide (see Figure 15).

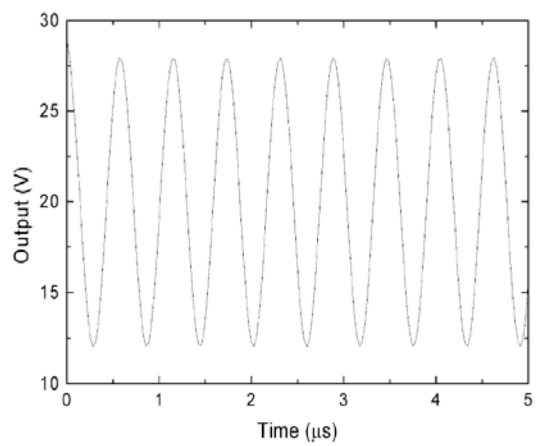

Figure 15. Time dependence of ring oscillator output from "CdS" Paper (VII), Fig. 5: (Cadmium Sulfide). Vertical axis is changed by exactly a factor of 2 from Figure 14.

Note that in these cases the curves differ in scale on both time and voltage axis. In each case, the transient near zero time is very much the same. The waveform is rather sinusoidal, characteristic for a ring oscillator with a small number of stages.

Response

Hendrik Schön has acknowledged a procedure for presenting ring oscillator data collected on an oscilloscope, in which a few points are collected and fit to a sinusoid (although the general time dependence of a ring oscillator need not be sinusoidal): "…the ring oscillator measurements were mainly that I read off some numbers from the oscilloscope and then I use a fit for representing those data…these are not directly measured data." He stated that the oscillator was allowed to reach steady-state before data collection, although all three figures clearly show a transient (identical in each case) near zero time. (Note that the procedure for capturing such a transient on a standard oscilloscope would require repeatedly removing and reapplying the supply voltage, a very tedious procedure.) He stated that he had noted some similarity in the maximum and minimum voltage levels for his ring oscillators that he thought might reflect some imperfections in the measurement system, but asserted that the observed oscillation frequency should be a lower bound on the true result. No primary data for any of the figures was available.

Conclusion

Hendrik Schön has acknowledged procedures that constitute intentional fabrication of data: representing fitted data as actual measurements. The existence and approximate frequency of the oscillations would nonetheless be valid, and he did not acknowledge copying the measurements. However, for the "FastOrganic" Paper (XI) and "CdS" Paper (VII), original plotting data for the figures was found after the interview. Figure 16 shows that, after scaling vertically by 1.5, and horizontally by a different factor, these data are

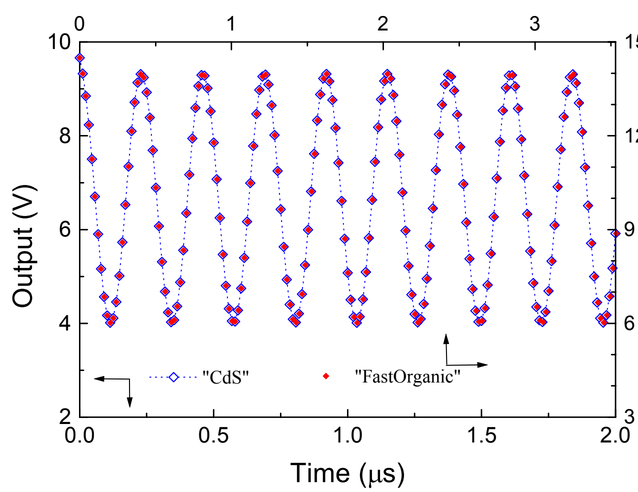

Figure 16. Combination of original plotting data (extracted from electronic drafts) for "FastOrganic" Paper (XI) (Figure 13, top time axis and right voltage axis) and "CdS" Paper (VII) (Figure 15, read bottom time axis and left voltage axis). Every point in the curves is the same, including the transient near zero time, on the scaled axes.

identical, point by point, including the initial transient. While no electronic data were found for the "AmbipolarOrganic" Paper (VIII) the similarity is too great to be accidental. The relabeling of the axes for the different systems constitutes clear, intentional falsification of data.

The preponderance of evidence indicates that Hendrik Schön committed scientific misconduct, specifically data fabrication and falsification, in this case.

V. Data Substitution: Normal-state resistivity of polythiophene

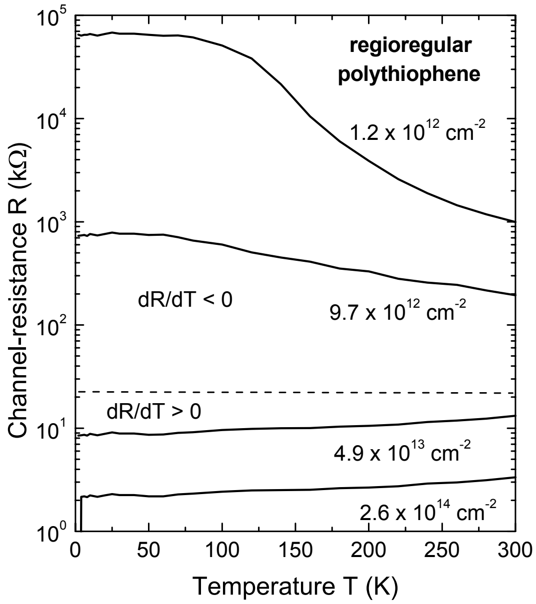

Figure 17. Plot from "Gate Induced Super" Paper (XXV) showing gate-induced reduction of resistivity as carrier density is increased, and eventual superconductivity.

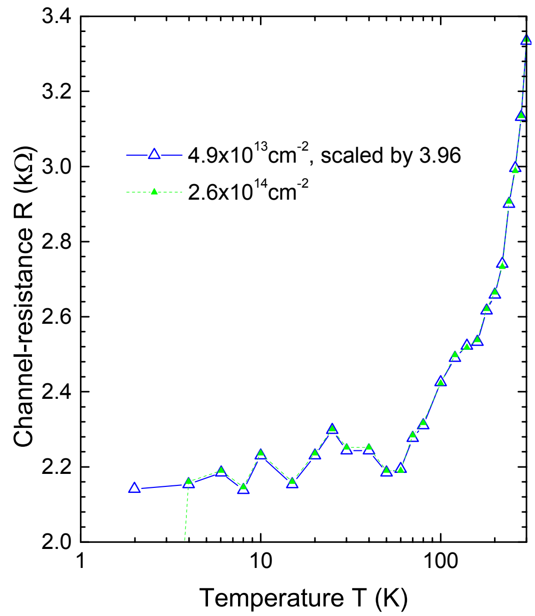

Figure 18. Original plotting data from an early draft, containing the same figure as "Gate Induced Super" Paper (XXV) (Figure 17), replotted with the $4.9x10^{13}cm^{-2}$ data set divided by 3.96 to show that data are the same.

Allegation

The "Gate Induced Super" paper (XXV) shows resistivity versus temperature for different gate-induced carrier densities (see Figure 17). Original plotting data were extracted from an earlier draft of the paper containing the same figure. With one exception, the data points in the curves for a density of $2.6x10^{14}$ cm^{-2} and $4.9x10^{13}$ cm^{-2} are identical, differing only by a scale factor of precisely 3.96 (see Figure 18). The only place where the scaled curves are not identical is the single point indicating a superconducting transition in the most conductive sample. Superconductivity is the central issue of the paper. Below 60K, the curves labeled $9.7x10^{12}$ cm^{-2} and $1.2x10^{12}$ cm^{-2} are also proportional to the other two as well (see Figure 19), to an accuracy of about 1%.

Response

Schön had no explanation for these observations. He showed a fifth curve lying between the others that showed insulating behavior only at low temperatures. This data was omitted from the paper, apparently because it did not fit with the expectations of the authors.

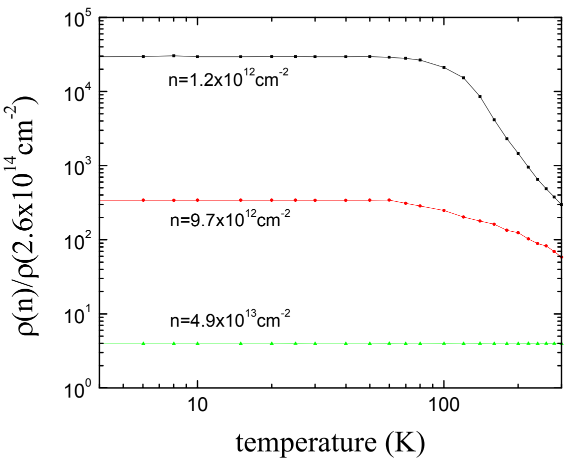

Figure 19. Original plotting data from an early draft of "Gate Induced Super" Paper (XXV). The ratio of each curve to the fourth curve (not shown) demonstrates that all of the data in Figure 17 below 60K are the same, within a constant factor.

Conclusion

It is clear that data were substituted and scaled between the two lower curves and spliced together with an apparent superconducting transition. In the upper two curves, the same data, below 60 K, were scaled and spliced together with other data. This substitution was done either intentionally or recklessly.

The preponderance of evidence indicates that Hendrik Schön committed scientific misconduct, specifically data falsification, in this case.

VI. Data Substitution: Space-charge limited I-V

Allegation

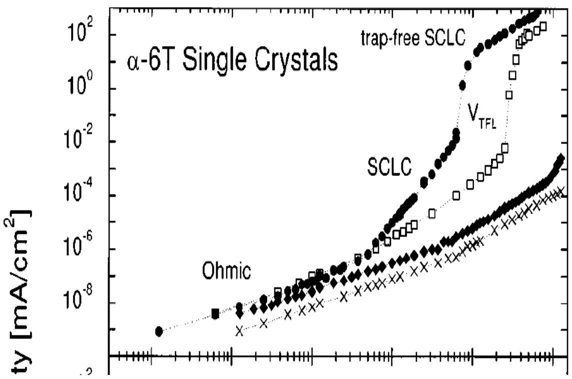

Figure 20. Current density versus voltage illustrating space-charge-limited current, from "Rodlike" Paper (I), Fig. 2.

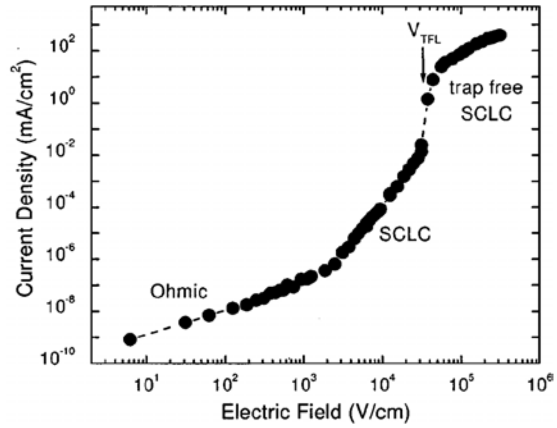

Figure 21. I-V characteristic for space-charge-limited current, from "HolePentacene" Paper (IX), Fig. 2.

Very similar current-voltage ("I-V") data in a space-charge-limited current measurement appeared in two papers, represented as different materials:

- "Rodlike" Paper (I), Fig. 2, top graph, top curve: "α-6T" (see Figure 20)
- "HolePentacene" Paper (IX), Fig. 2: "pentacene" (see Figure 21)

Response

Hendrik Schön acknowledges that the "HolePentacene" data were not correct, and were probably the α-6T data from the "Rodlike" paper (which contained data on both materials). No primary data were available.

Conclusion

It has been acknowledged that the data were duplicated. It is conceivable that this reflects very poor record keeping practices.

While troubling, this instance on its own does not provide compelling evidence of scientific misconduct.

VII. Data Substitution: Laser emission spectrum

Allegation

Very similar data (emission spectra under complex pulsed bias conditions) were represented as corresponding to two different temperatures:

- "Laser" Paper (XIV), Fig. 2: 5K
- "Laser" Paper (XIV), Fig. 5: 300K

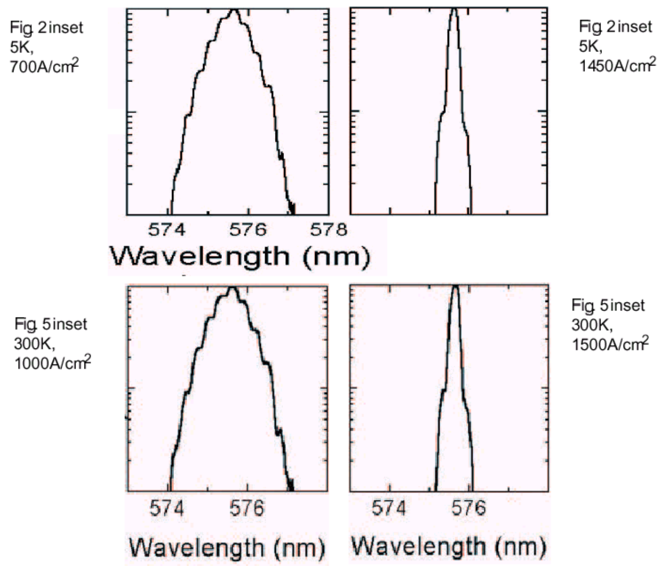

Figure 22. Emission spectrum at temperature of 5K (top) and 300K (bottom) for two injection current levels, from "Laser" Paper (XIV), Figs. 2 and 5.

In particular, the structure on the emission line, attributed to Fabry-Perot modes in the laser cavity, are virtually identical. Also notable is that the peak emission wavelength is essentially unchanged, while a shift with temperature is expected. (However, the shift is much smaller for organics than for ordinary inorganic semiconductor lasers).

Response

Hendrik Schön acknowledged that the room temperature data were in error, and were actually the 5K data. Some replacement data were offered for the 300K spectra taken on a different sample. The replacement data were surprisingly similar to the original plotting data in shape, although shifted and scaled.

Hendrik Schön also volunteered that in another case the measured spectrum was "extrapolated" using a theoretical, Gaussian line shape.

Conclusion

Hendrik Schön acknowledges substitution of data. It is conceivable that this occurred as a result of very poor record keeping. He also acknowledged representing a simple extrapolation as experimental data. After the interviews, the data in Figure 23 was extracted from the original plotting data. It shows that indeed the highest drive-current spectrum in the papers was a Gaussian extending over more than 100 orders of magnitude. However, rather than being an "extrapolation" of measured data as claimed, the very regular structure in the second derivative (see Figure 23) shows that all data in the plot were calculated from the analytical expression. (The fact that the second derivative hops between various discrete values, differing by about 1.5%, may result from unknown procedures such as interpolation.)

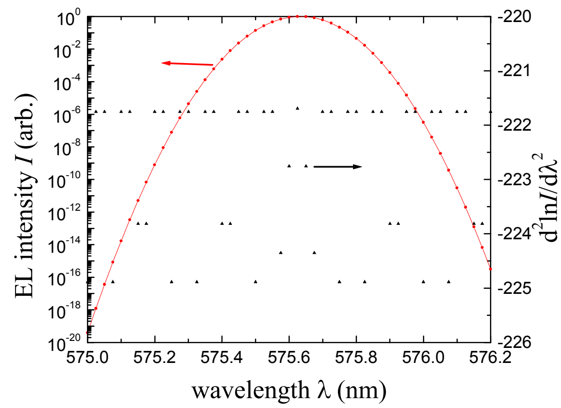

Figure 23. Original plotting data for the highest intensities for the "Laser" Paper (XIV) (extracted from an identical plot in a PowerPoint presentation). The data extend over more than 100 orders of magnitude. However, even the data near the peak show the same details of the second derivative, indicating that all *of the data comes from the Gaussian expression.*

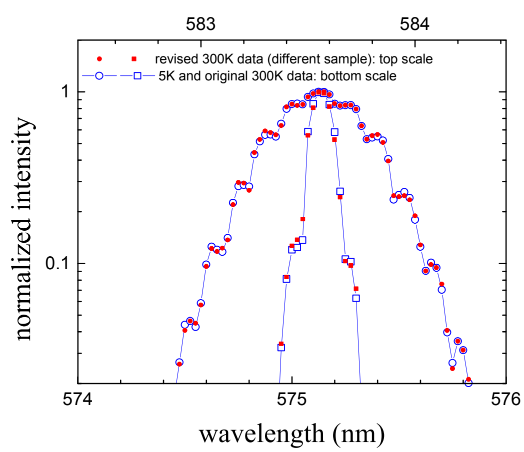

Figure 24. Emission spectra supplied directly by Hendrik Schön. The original plotting data (open symbols) for 300K were actually the 5K data for the same sample. Revised 300K data were for a different sample. However, they differ from the original primarily by a wavelength shift (note the different horizontal scales). Other details of the spectra are very similar.

Scientific discussion of these results has included significant attention to whether the observations reflect true lasing or only superluminescence. This controversial issue is a legitimate scientific question, and we will not discuss it further here.

The observation of *either* laser action or superluminescence was unprecedented, and has not been reproduced in these material systems. Indeed, no one except Hendrik Schön ever observed any of the visible light from these structures at all.

The preponderance of evidence indicates that Hendrik Schön committed scientific misconduct, specifically data fabrication, in this case.

VIII. Data Substitution: Superconducting T_c versus charge

Allegation

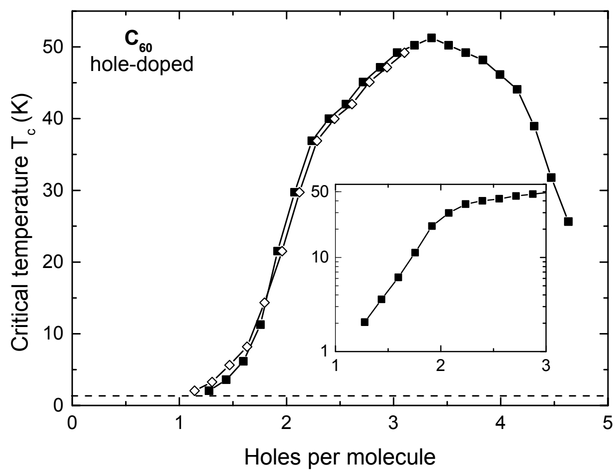

Figure 26. Fig. 2 of "Super C60" Paper (XIX) showing data on superconducting transition temperature for two different samples. The number of holes per molecule is calculated from the applied gate voltage using the measured gate capacitance, which is different for the two samples.

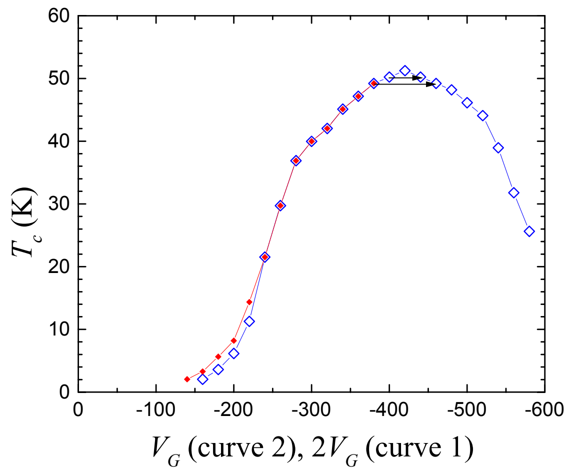

Figure 25. Original plotting data for Figure 26 against the original gate voltage (extracted from an electronic draft). Multiplying the gate voltage for one sample by exactly two results in perfect agreement in T_c for eight points. In addition, two pairs of points on either side of the peak are exactly equal (see arrows).

The "Super C60" paper (XIX) shows data for two separate samples. However, the transition temperatures for the two sets are largely in exact agreement (see Figure 26). The original plotting data were extracted from an electronic draft. These showed that the points at which the transition temperatures were the same for the two "samples" also had gate voltages that differed by exactly a factor of two for many of the points. The different hole densities in the original plot arose because the capacitances used to calculate hole density were not exactly a factor of two different.

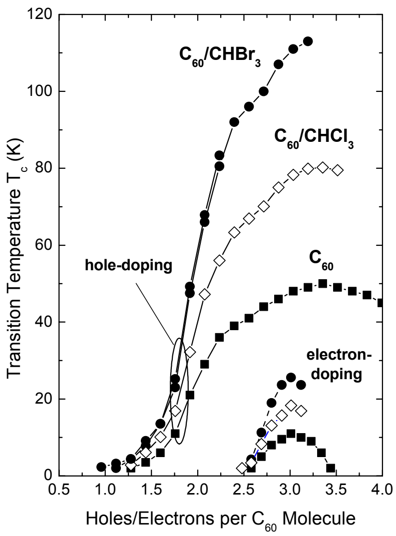

Figure 29. Figure 3 from "Expanded C60" Paper (XV) illustrating enhanced superconducting T_c of C_{60} upon intercalation with haloforms.

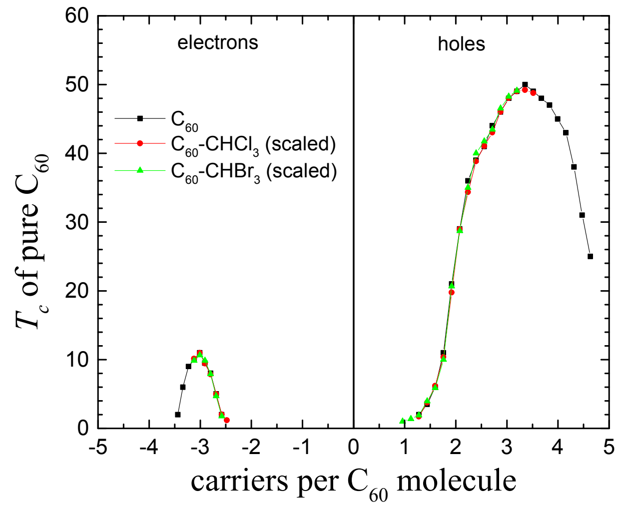

Figure 28. Original plotting data (taken from early draft containing Figure 29) showing the great similarity in the dependence of T_C on doping.

"Expanded C60" Paper (XV), Fig. 3: curves of T_c for different intercalants as a function of hole concentration all have the same abscissa, and are surprisingly close to being simple multiples of one another. (See Figure 28). The concept underlying the intercalation is that pushing the molecules apart (increasing the lattice constant) decreases the density of states and thereby enhances superconductivity. While to the casual observer this may seem unsurprising, the complex physics underlying superconductivity rarely results in such simple results.

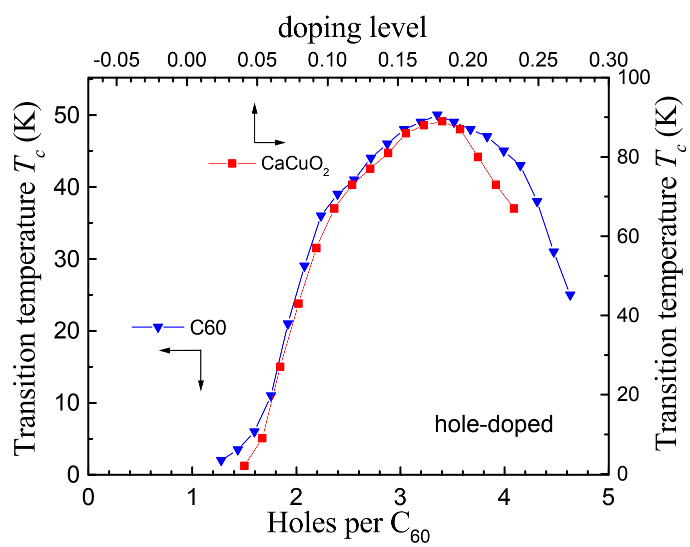

Figure 27. Comparison of original plotting data (from electronic drafts) of superconducting T_c vs. doping for C_{60} (from "Super C60", XIX) and $CaCuO_2$ (from "FETCaCuO2", XXI) on different axes.

"FETCaCuO2" Paper (XXI), Fig. 3 shows great similarity, after scaling the axes. In this case, no clear relationship between the doping axes for the two materials has been found, but the similarity is still quite high.

Response

Hendrik Schön describes the procedure for obtaining T_c as follows: Gate voltage was set, and a temperature sweep was performed. The transition temperature was then determined by hand from the data plot, using one of several inconsistent procedures; it was not known which procedure was used for this data. It is to be expected that such a procedure would yield integer values for the temperature, which then might be the same between different curves. After this procedure, all the temperatures were multiplied by 1.025, ostensibly to mimic using a slightly higher point on the resistive transition to define T_c. No primary data for the resistive transitions was offered, and no one except Hendrik Schön ever saw any of the transitions.

For C_{60}, Bertram Batlogg reports that the first data stopped before reaching the peak in the transition temperature with doping, and there was active speculation among the collaborators as to the form that the curve would take thereafter.

Hendrik Schön reported that all of the haloform-intercalated samples were prepared by him, dissolving and regrowing Christian Kloc's single crystals of C_{60}. No structural characterization of the surface layer where superconductivity occurs was performed. (There is evidence in the literature that the Bromoform-intercalated crystals are unstable at temperatures above about 90°C, and the Chloroform intercalates above 82°C, which are temperatures that are likely to be reached during deposition of the Al_2O_3 dielectrics.)

The similarity in shape, after scaling, for the intercalated materials and the $CaCuO_2$ had been noted in the papers.

Conclusion

For the two "different" samples of C_{60}, it is unlikely that the procedure described would result in such great similarities in transition temperatures at closely related voltages (not hole densities). For the subsequent papers, the high degree of similarity suggests that the data may have been fabricated as well. The physics underlying the transition temperature is very complicated, and it is not to be expected that it would exhibit such simple scaling. The very similar behavior of electron and hole doping in all of these materials is also surprising from a physical point of view.

The T_c data from $CaCuO_2$ represent the least convincing evidence of similarity of the three cases. Allegation XII discusses the much clearer evidence that some of the resistivity-versus-temperature data for that paper are fabricated.

The high charge densities required for these results cannot be achieved without a very high breakdown strength of the dielectric. Allegation XVIII discusses the problematic evidence that these properties have been achieved.

For all of the materials discussed here, the field-induced superconducting transitions would have been expected to be two-dimensional. Allegation XXIV discusses the surprising sharpness of the observed transitions, which casts doubt on the observations for all of the materials in this section.

While extremely troubling, this instance on its own does not provide compelling evidence of scientific misconduct.

IX. Data Substitution: Magnetotransport

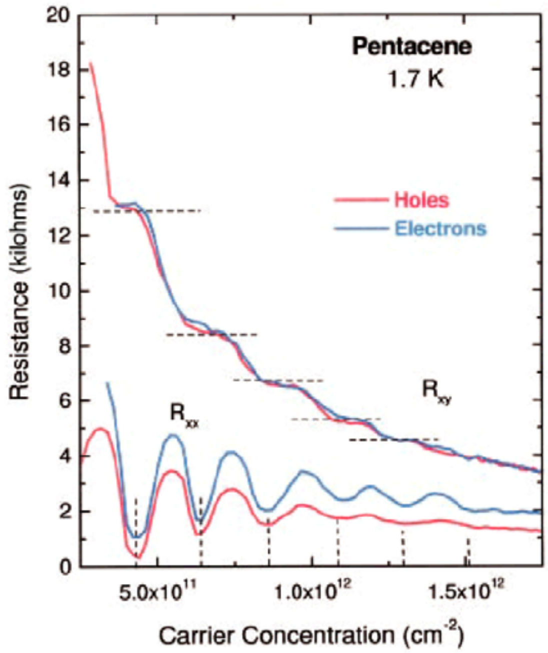

Figure 30. From "FQHE" Paper (IV), Fig.2.

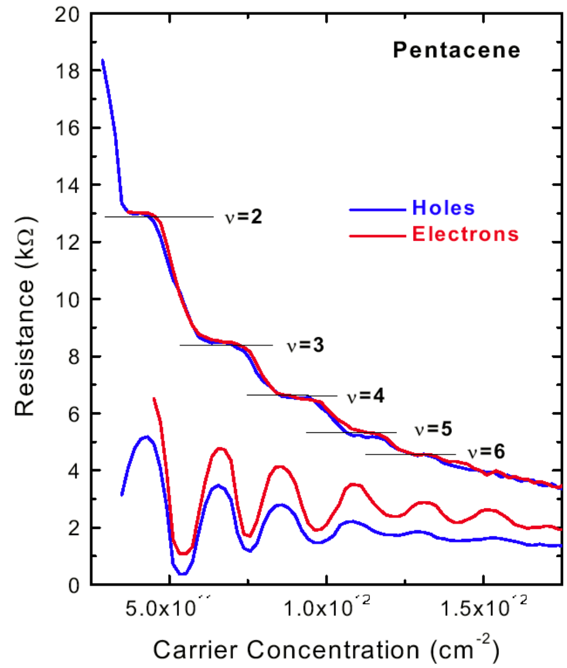

Figure 31. From "NewPhenomena" Paper (X), Fig. 4.

Allegation

Shubnikov-de Haas data were represented as the same, but the longitudinal (R_{xx}) and transverse (R_{xy}) magnetoresistance were shifted relative to one another.

- "FQHE" Paper (IV), Fig. 2 (see Figure 30).
- "NewPhenomena" Paper (X) Fig. 4 (see Figure 31).

The significance of the result is that, in the usual quantum Hall effect, the plateaus in the Hall resistance R_{xy} correspond to *minima* in the longitudinal resistance R_{xx}, not to maxima as seen in Figure 31.

Response

Hendrik Schön acknowledges the shift, which is stated to result from failure to correct the carrier concentration axis for the threshold voltage. The correction was applied in the earlier paper "FQHE" but was forgotten when the data were prepared for the later review paper. Hendrik Schön stated that, in these early measurements, separate magnetic field sweeps were required for R_{xx} and R_{xy} .

Conclusion

Hendrik Schön admitted presenting the same data twice, in inconsistent ways. This error could conceivably reflect sloppiness in data processing. However, after the interview, the original plotting data for Figure 30 were obtained. In the file, R_{xx} and R_{xy} are listed as separate columns in the same table, with a single density column, as would be expected if they were measured simultaneously. However, a secondary density, not measured, but explicitly calculated from the first, was used for R_{xy} in the figure, while the uncorrected density was used for R_{xx}. The correction shifts the data by one half-period with respect to each other, so that the plateaus in R_{xy} correspond to minima in R_{xx}. In the original plotting data, the plateaus correspond to maxima in R_{xx}. This is true for both the "electron" data and the "hole" data. The complexity of the required corrections and their unsystematic nature provides little confidence in the robustness of the procedures for data acquisition and presentation.

While troubling, this instance on its own does not provide compelling evidence of scientific misconduct.

X. Unrealistic Precision: Normal-state resistance of gated C_{60}

Allegation

Figure 32, from Paper XIX ("Super C60") shows an amazing systematic variation of the resistance versus temperature as the gate voltage is varied, which in turn varies the induced hole concentration in this FET-like structure. Figure 33 shows the derivative of original plotting data, dR/dT. The linearity is truly striking, as is the reproduction of the wiggles near 50 K. (It is possible that there could be a calibration problem with the thermometer there). Normally, taking a derivative increases the relative noise, but these data remain highly linear over most of the range. The linearity is demonstrated by taking the second derivative, as shown in Figure 34.

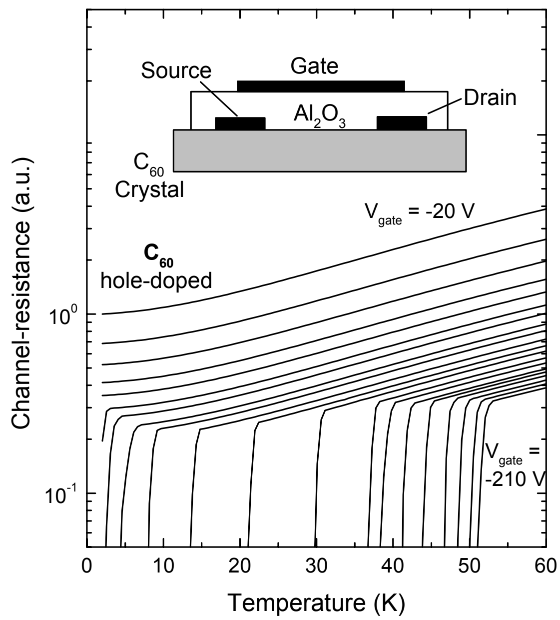

Figure 32. Reported superconductive transition for C_{60} for various gate voltages, Figure 1 of the "Super C60" Paper (XIX).

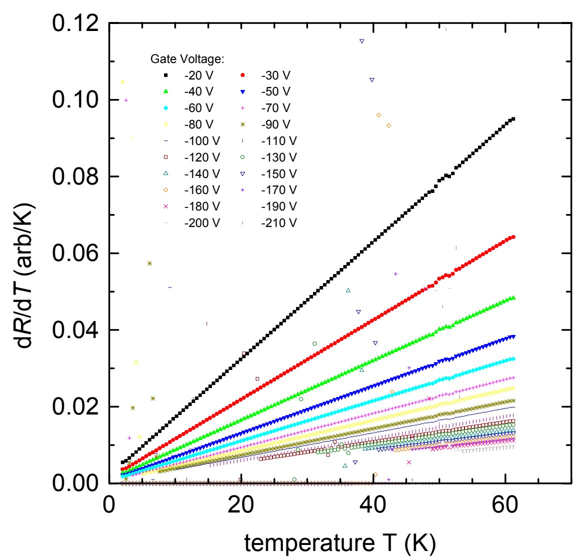

Figure 33. First derivative of the original plotting data in Figure 32 (extracted from an electronic draft).

The second derivative of this curve is constant to more than *eight significant digits*, except in the region of "T_c", and in the range 5-10K and around 50K. Even the deviations are reproduced with high precision between the various curves, in direct proportion to the constant value of the second derivative. It is clear that these are not real data: they have been generated using a mathematical function. Even the curves for different gate voltage are the same data, multiplied by a constant factor.

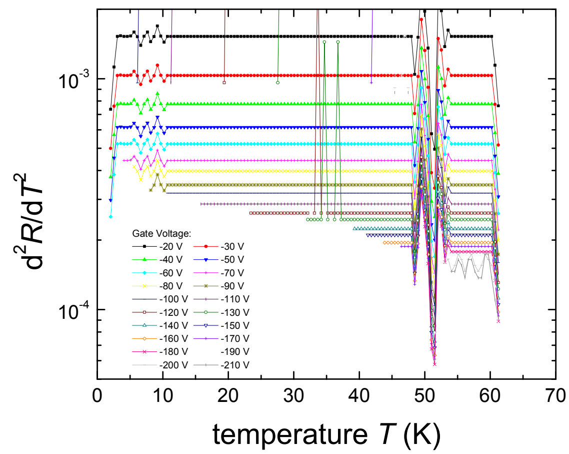

Figure 34. Second derivative of the resistance, from the data of Figure 33.

Response

Hendrik Schön has acknowledged that the data in question were generated analytically (using a functional form motivated by the observed temperature dependence), and then spliced together with the measured transitions and with zeros for the low-temperature resistance. This was done because it seemed to make a more compelling presentation. He stated in the interview: "I thought that a smoother curve would look much better…. In some cases there is less doubts if there is…not that much noise on the curves." No primary electronic data were offered, although a data plot was provided that represented very systematic but realistically noisy, normal-state resistance data for all of these curves. He maintains that the superconducting transitions were measured. He stated that the sheet resistances were of the order of several KΩ, so there should have been significant reductions in the resistance above the transition associated with fluctuations (see Allegation XXIV). Any information on this phenomenon would have been destroyed by the splicing procedure. Any smoothing or interpolation procedures applied to the spliced data would have further polluted the measured points with the fabricated data.

Conclusion

Hendrik Schön has acknowledged intentionally fabricating data for these figures.

The preponderance of evidence indicates that Hendrik Schön committed scientific misconduct, specifically data fabrication, in this case.

XI. Unrealistic Precision: Normal-state resistance of gated C_{70}

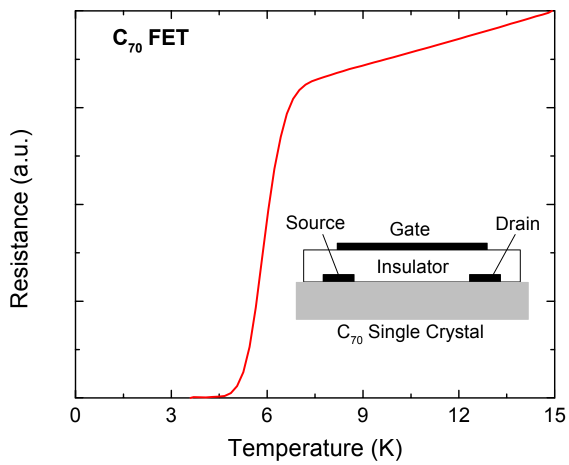

Figure 35. Figure 1 of "C70" Paper (XXII), showing superconducting transition in C_{70}.

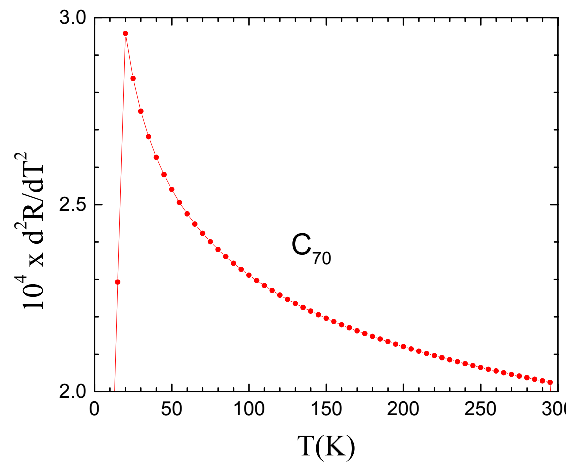

Figure 36. Second derivative of original plotting data resistance for C_{70} from an original plot.

Allegation

A similar situation arises for the field-induced superconductivity in C_{70} reported in Paper XXII ("C70"**)**, except that the functional form is not a parabola (see Figure 36). (The data shown come from an Origin file, included in C. Kloc's files, as supplied by Lucent.) The smoothness of the second derivative clearly indicates that this data also does not come from experiment.

Response

Hendrik Schön initially responded that the observed smoothness resulted from a smoothing algorithm, for the data in the paper. When presented with the above curve from unpublished material, he acknowledged that it was generated analytically. He maintains that the superconductive transitions were measured. No primary data were available.

Conclusion

Hendrik Schön has acknowledged intentionally fabricating data for this plot. However, the relationship between this curve and the published data is not established. His volunteered response that the data might be have been created by smoothing real data appears intentionally misleading, since he did not admit to substituting mathematically generated data until presented with incontrovertible evidence.

The preponderance of evidence indicates that Hendrik Schön fabricated data in this case. However, since the relationship between the fabricated data and the published data has not been clearly established, no finding of scientific misconduct is warranted.

XII. Unrealistic Precision: Resistance of $CaCuO_2$

Allegation

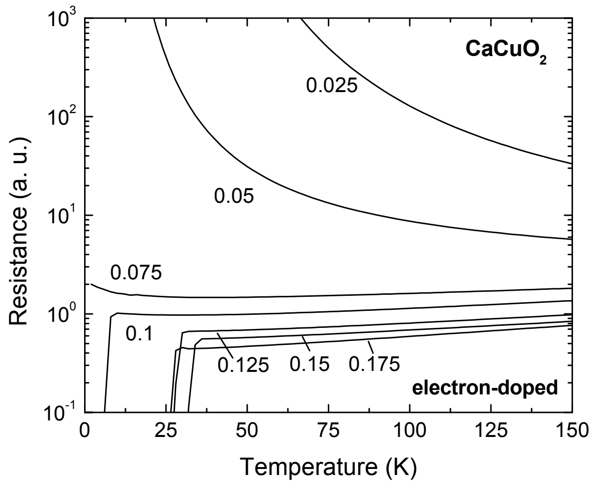

Figure 37. Resistivity data for electron-doped $CaCuO_2$ for various "electron doping levels," from Figure 3 of Paper XXI ("FETCaCuO2").

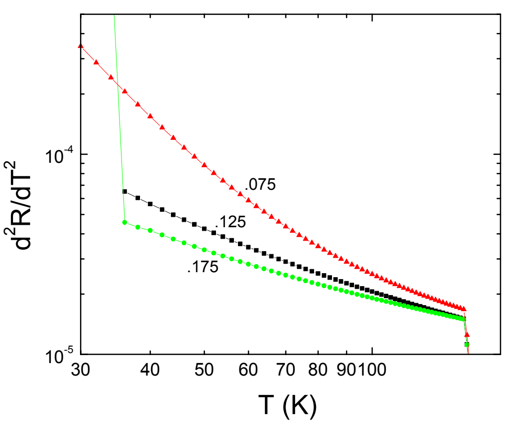

Figure 38. Second derivative of resistance for original plotting data from Figure 37, (extracted from electronic draft) for three metallic doping levels.

For $CaCuO_2$, the samples are tuned between insulating and metallic states with applied field in Paper XXI ("FETCaCuO2") (see Figure 37). As shown in Figure 38, for the electron-doped case, the normal-state resistivity on the metallic side shows the same smoothness in second derivative that the C_{60} data did, indicating a non-experimental source.

On the insulating side, the original plotting data embedded in a draft of the paper indicate an activated resistivity covering more than 70 orders of magnitude. ("Only" 30 orders are shown in Figure 39). There is no way these very high resistance values could represent real data; measurement apparatus covering more than

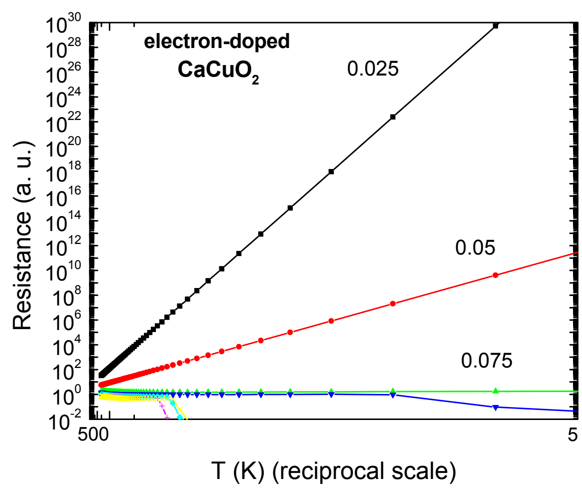

Figure 39. Resistivity data from Figure 37 (extracted from electronic draft), replotted on an Arrhenius plot to emphasize the insulating regime of gate voltage The reported resistivity follows an activated behavior over more than 25 decades.

10-12 orders of magnitude is very unusual. This data clearly comes from an analytical expression (Arrhenius' law), not experiment. Of course, the very high resistance points did not fit within the range of the plot in the original paper, but they were contained in the original plotting data.

Response

Hendrik Schön acknowledged using analytically generated data for both the metallic and insulating states. He maintains that the superconducting transitions were measured. No primary data on the resistive transitions were available.

Conclusion

Hendrik Schön has acknowledged intentionally fabricating data for this paper, in both the superconducting and insulating states.

The preponderance of evidence indicates that Hendrik Schön committed scientific misconduct, specifically data fabrication, in this case.

XIII. Unrealistic Precision: Pentacene mobility

Allegation

The "HolePentacene" Paper (IX) contains mobility extracted from the space-charge-limited current. One of the exciting things about the data, taken on high-quality single crystal samples, was the observation of very high band-like mobilities, placing transport in organics in a whole new light. Figure 40 the mobilities as originally presented, and a comparison with a theoretical value, derived at each temperature T from the $\mu_o(T)$ value in the same figure and the stated electric field. Two fitting parameters are used to match one of the curves, they are then used for the whole set. Of the 140 data points in the five curves, 72 of the points are within 0.1% of the theory. The only larger deviations occur near the crossover to low-temperature mobility, where the wrong crossover form may have been surmised. The precise form of the μ_o plot is not known. According to the paper, it is extrapolated from the measurement data, so there *should* be some agreement with one of the five curves. However, the extraordinary agreement suggests that most of the data curves are generated from one another.

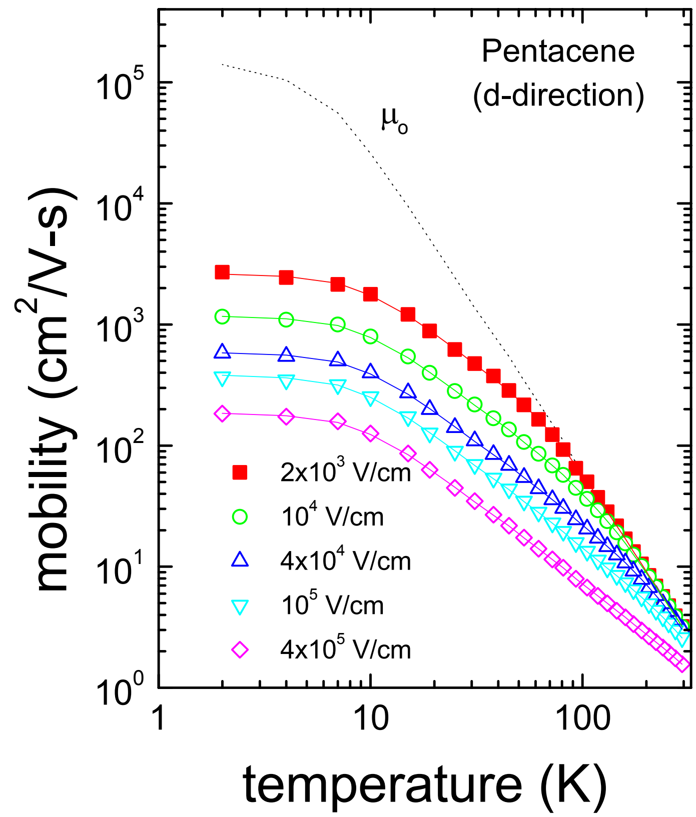

Figure 40. Mobility (symbols) deduced from space-charge limited current at various fields from Fig. 4 of "HolePentacene" Paper (IX), replotted from original plotting data (from an electronic draft). The μ_o curve is the original plotting data for the zero-field mobility extrapolated from the other measurements. Also shown, as lines, is the mobility calculated at each temperature from μ_o and two global fitting parameters.

The "HolePentacene" Paper (IX) also contains a summary of the historical improvement in mobility of pentacene crystals. The same data are presented in Figure 41, taken from a presentation on the distribution materials.

The data above 100K are replotted in Figure 42. The various curves show very much the same variations. This is illustrated at the bottom of the plot, where the ratios of various curves are shown. The data are proportional to better than 1%, although the internal variations from the power-law trends are much larger. These data sets cannot represent characterization of different samples, as claimed.

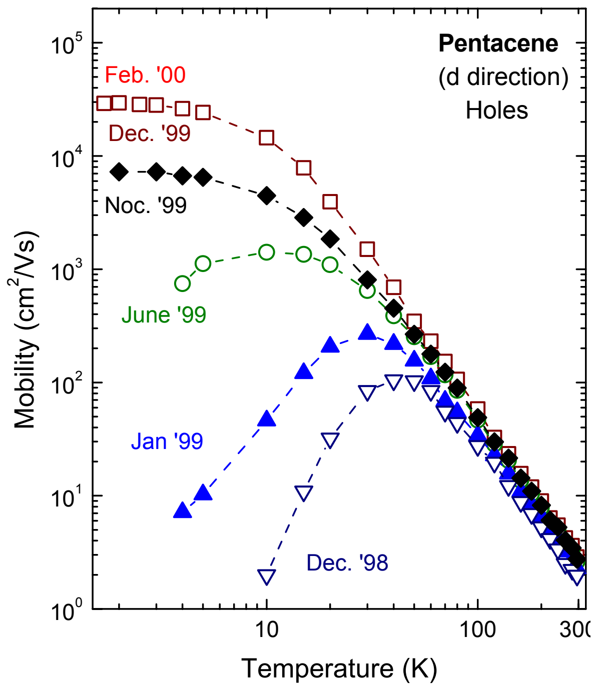

Figure 41. Data from Figure 5 of the "HolePentacene" Paper (IX), showing improvement in mobility over time as crystal quality is improved. The original plotting data and the dates are taken from an internal Bell Labs PowerPoint presentation where an almost identical figure appeared.

Response

Hendrik Schön's initial response claimed that the fit to a global theory for the mobility showed deviations of tens of percent. When presented with the precise fits during the interview, Hendrik Schön admitted that analytical fits to the data were published in the paper in place of the actual measurements. He stated that this was a clerical error, in which the fits were accidentally used instead of measured data. No primary data were available. Hendrik Schön had no explanation for the close relationship between what should

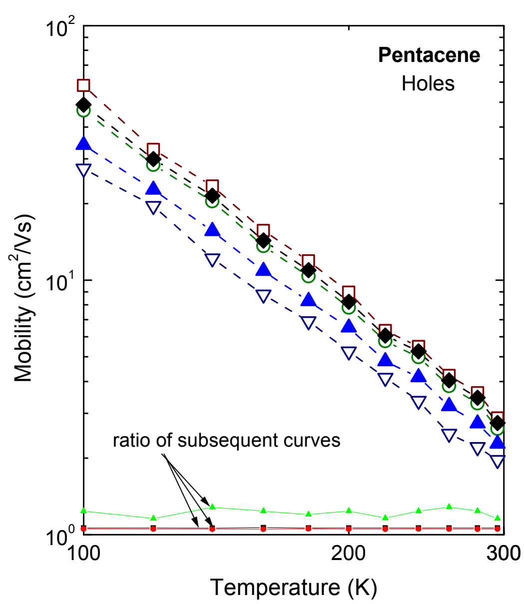

Figure 42. Data from Figure 41 replotted from 100 to 300K showing that at least two separate pairs of curves are simply multiples.

have been measurements made on different samples at different times.

Conclusion

Hendrik Schön has acknowledged that calculations were represented as actual data in this paper. This was done either intentionally or recklessly. Unfortunately, there is no convincing evidence available that the spectacular mobilities reported in this paper were ever measured. Other indications of high mobility would be ballistic transport (see Allegation XIV) and Fractional Quantum Hall Effect (see Allegation IX). There is a distinguished history in condensed matter physics of higher-quality crystals enabling improved transport properties, and the Committee does not question the high quality of the crystals grown by Christian Kloc. However, a host of serious questions surrounds the indications of spectacularly high mobilities and other transport properties reported by Hendrik Schön.

The preponderance of evidence indicates that Hendrik Schön committed scientific misconduct, specifically data fabrication and falsification, in this case.

XIV. Unrealistic Precision: Ballistic transport

Allegation

Paper XXIII ("Ballistic") shows focussing effects in the magnetoresistance of single crystals of Pentacene, as illustrated in Figure 43. This phenomenon has been observed in more traditional semiconductor systems, and it requires specular reflection at the boundaries of the crystal. It also requires a collimated beam to emerge from the contact. In the earlier demonstrations, specular reflection and collimation were achieved by using gates to form smooth "walls" and point contacts. No such effort was made here. (The crystals often grow as platelets with a faceted top and bottom face, but the lateral edges are not generally so well defined. The shadow-mask-defined contacts are certainly not.) Naturally, the transport mean free path (corresponding to the momentum relaxation time) must be at least comparable to the electrode spacing, several tens of microns.

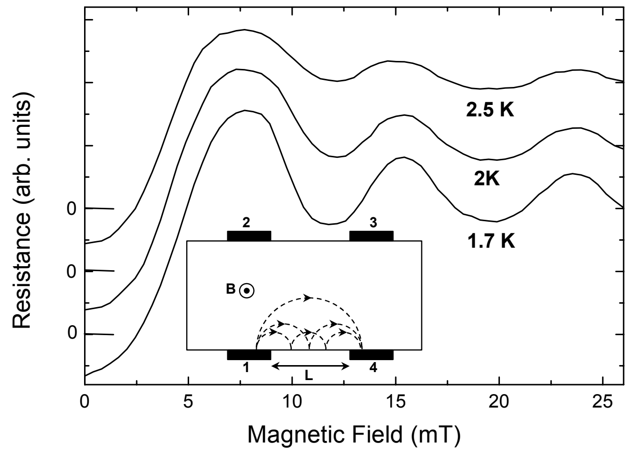

Figure 43. Fig. 1 of Paper XXIII ("Ballistic"), showing oscillations in magnetotransport for the sample geometry shown schematically in the inset.

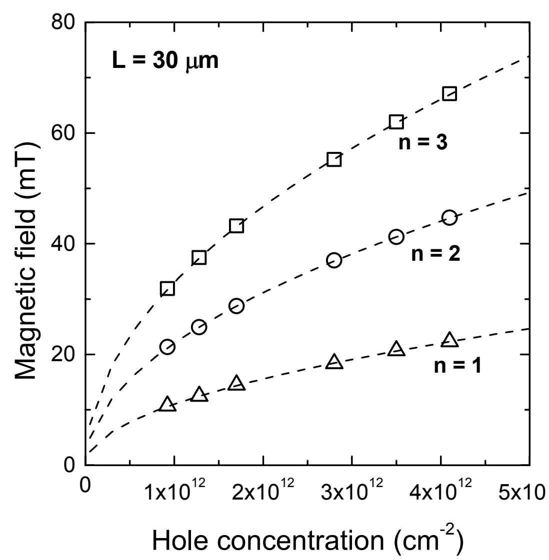

Figure 44. Figure 3 from "Ballistic" Paper (XXIII), showing positions of peaks in resistance from data like that in Figure 43 for various hole concentrations. Dashed line shows theoretical expectation. Original plotting data extracted from electronic draft.

The reported data include broad oscillations in the four-point resistance as the magnetic field (and thus the cyclotron radius) is varied. It is true that in some experimental situations, involving symmetrical peaks with well-defined baselines, peak positions can be determined with a precision much better than their width. Those conditions do not apply to the data shown, and one would expect the precision of peak determination to be no better than several percent. Various imperfections in the sample geometry would presumably degrade that precision further. Nonetheless, the data are shown in Figure 44 to agree very well with the predicted square-root dependence on magnetic field. By extracting the original plotting data, the high-quality agreement shown in Figure 45 is obtained. The peak positions scale with resonance number and the square root of field with an rms deviation of only 0.4%. This appears highly unlikely to result from an objective measurement process.

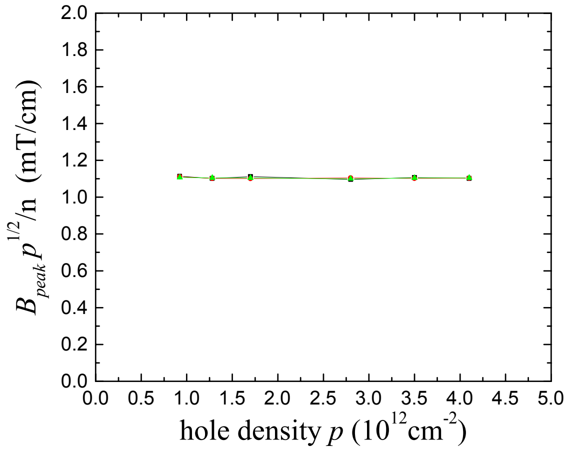

Figure 45. Original plotting data from Figure 44, normalized for magnetic field and number. Theoretical expectation is that all peaks would give the same value, which they do, with an rms variation of 0.4%.

Response

Hendrik Schön acknowledged a procedure in which the three magnetoresistance peaks were fit simultaneously (subject to the constraint that they be at integral multiples of one another). The carrier density (represented as an independent variable) was used as a fitting parameter to match the peak positions, rather than being calculated from the known capacitance and threshold. None of this was described in the paper. This procedure renders the figure completely meaningless, since it is impossible for the points to do anything other than agree with theory.

Hendrik Schön said that other measurements did not fit as well. No primary data were available.

Conclusion

Hendrik Schön acknowledged representing theoretical expectations as measured data. The paper describes no special attention to the many aspects of the sample geometry to achieve the spectacular results. The existence of acknowledged fabrication in an experiment that would be unlikely to succeed so easily is highly troubling.

The preponderance of the evidence indicates that Hendrik Schön committed scientific misconduct, specifically data falsification, in this case.

XV. Unrealistic Precision: Conductance quantization statistics

Allegation

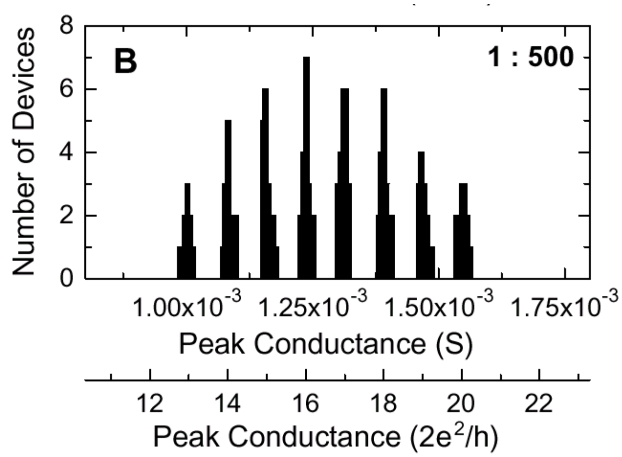

Figure 46. Figure 3(B) from "SingleMolecule" Paper (XIII), showing a histogram of conductances from diluted SAMFETs,

Paper XIII ("SingleMolecule") describes SAMFETs in which the active molecules are diluted with nonconducting molecules, so that conduction is controlled by only a few molecules– sometimes only one. One piece of evidence for this is shown in Figure 46: a histogram of the conductance for various devices, clustering around integral multiples of the quantum of conductance, $2e^2/h$.

Several questions arise about this plot. For one, the procedure for determining the conductance of a device is not clearly specified. Hendrik Schön has acknowledged a highly unusual procedure– not described in the paper– in which the conductances at several peaks are added to obtain the value in the plot. The peaks may occur at different gate *and* different drain voltages, and are acquired in a measurement with both parameters varied. The number of samples is also amazing: the plot shows 130 devices measured at low temperatures. Since the yield of these devices is said to be under 10%, this implies that at least 1300 devices were characterized to create this plot.

The distribution resembles a Gaussian, but the "tails" are missing. Hendrik Schön has acknowledged, with no justification, that devices with such values were ignored. If the distribution results from the independent contributions of spatially separated molecules, the number of molecules should vary around the average <N>, with an rms width of roughly $\langle N\rangle^{1/2}$. The observed distribution is narrower (rms width about 3 rather than 4), which is the opposite ofwhat would be expected if clustering were important. The widths of the individual peaks also do not increase as expected with the square root of the number of molecules contributing.

The most troubling aspect of the data is that, other than the truncated tails, they match a Gaussian distribution far *too* well. This is illustrated in Figure 47, where the reported data are compared with a Gaussian. For this plot, the small variations of conductance around the quantized value are ignored, and the devices are binned according to the closest number of conductance quanta. With relatively few samples N_i for each bin i, one should have seen large variations in the actual observations, typically $N_i^{1/2}$. Indeed, roughly 1/3 of the points would be expected to be outside of the 1σ error bars shown. For random data, the chance of all of the points being in such agreement with any functional form is very small.

Quantitatively, this statement can be evaluated by calculating the square of the ratio of the observed variation to the expected, known as χ^2. For real data this number should be near 1, but in this case *all* of the points are closer to the prediction than expected. For one bin, this could easily happen by chance, but for all of them it is quite unlikely. For the whole distribution, the average $\langle\chi^2\rangle$, (which is normalized to 8-3=5 instead of 8 to reflect the fact that the fit has three degrees of freedom), is 0.122. The probability of such high agreement occurring by chance is estimated at about 1.2%.

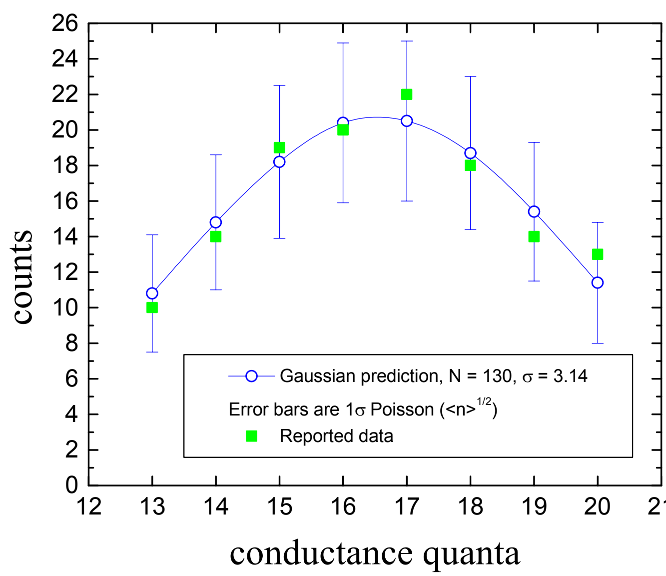

Figure 47. Comparison of reported number of devices in each conductance quantum bin with a fit to a Gaussian distribution. The reported data are extracted from original plotting data for Figure 46 from an electronic draft. The agreement exceeds the expected variation for such a small number of devices.

The low yield of the SAMFET devices, and their possibly unusual behavior, could allow for unintentional bias in selecting samples to skew the results. However, such bias cannot explain these observations, because the quality of the overall distribution is only apparent *after* all devices have been accepted or rejected. The only explanation is that points are included or discarded *solely to improve the agreement with the distribution*.

Response

These observations were noted by Sources M and D in October 2001, and discussed with Hendrik Schön and others at Bell Labs beginning that same month. In mid-December 2001, Hendrik Schön responded in detail, including numerical data for Figure 46, together with an explanation: the original figure had been constructed with a bar width on the histogram several times wider than the spacing of the bins, which obscured some of the points. This bizarre procedure seemed to resolve the problem: the above analysis applied to the new data yielded a $<\chi^2>$ of about 0.9, well within reason. However, it was discovered in May 2002 that the original plotting data were still embedded in an original electronic draft. These original plotting data show the disturbing characteristics described previously, and illustrated in Figure 46.

Prior to the interview, Hendrik Schön was made aware that the original plotting data was available. In the interview, he presented a new explanation: by accident, some of the original data (every other point) had been omitted from the plot in the paper. However, systematically removing every other point in the distribution without prejudice as to the overall form should still have produced data constrained by Poisson statistics, so even this mistake would not resolve the fundamental problem. Hendrik Schön still had no explanation for the original observation.

No body of primary data for the current, as a function of gate and drain voltage, was available.

Conclusion

The data indicating conductance quantization did not arise from an objective measurement process. At a minimum, the assignment of conductance values was colored by the expected shape of the final distribution. Such a biased process cannot provide convincing evidence for quantization. The response to this concern appears to be deliberately deceptive, suggesting that this misrepresentation was intentional.

The preponderance of evidence indicates that Hendrik Schön committed scientific misconduct, specifically data fabrication, in this case.

XVI. Unrealistic Precision: SAMFET Dilution series

Allegation

The inset of Fig. 1(B) of the "SingleMolecule" paper (XIII) shows perfect scaling of the drain current down a dilution ratio of 5000. In this experiment, the number of electrically active molecules expected in the active area of the SAMFET is reduced by dilution with electrically inactive alkanethiol molecules. At this dilution, it is claimed that one would expect on average about one molecule in the device, but Poisson statistics would predict sometimes 0, sometimes 2 (see Figure 48). Note that, if two molecules were present, as would be expected to happen quite frequently from Poisson statistics, the result would be noticeably off the line (zero molecules would not conduct, and might be eliminated as defective). No description of the sample selection procedure or the variability of these highly diluted samples is given in the paper.

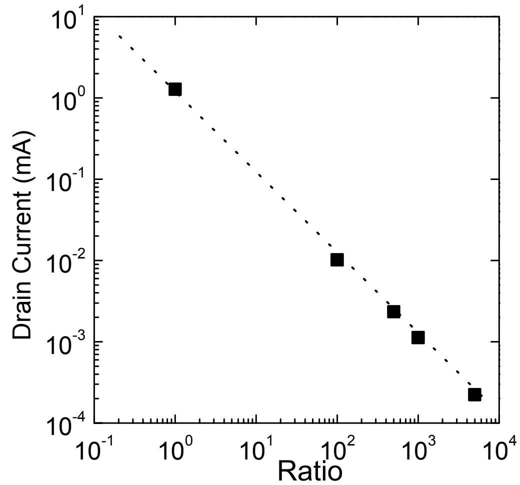

Figure 48. Inset of Fig. 1(B) of "SingleMolecule" paper (XIII), showing variation of drain current with dilution. Replotted from original plotting data extracted from electronic draft.

Figure 49 shows the scaled conductance relative to the expected number of molecules, computed as the drain current times the dilution ratio. The maximum deviation from the highest to lowest value is 25%, and the 1000 and 5000x diluted samples show a drain current that scales with nominal dilution to an amazing 0.7%.

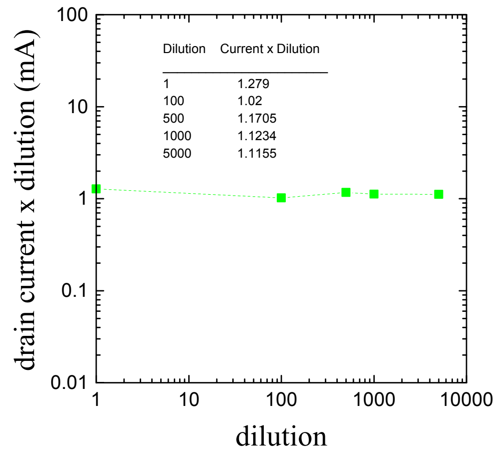

Figure 49. Apparent current as a normalized by a constant times the expected number of molecules (1/dilution), taken from original plotting data in Figure 48.

Response

In interviews and data provided, Hendrik Schön acknowledged that the drive currents for the SAMFETs varied by a factor of ten. He acknowledged that in constructing this plot he selected devices that matched his theoretical expectations. In the interview, he stated "I did not correctly average for all the devices that I had, did not include an error bar. I put in current numbers that would reasonably agree with this line…. I chose data that would agree with it….I thought this nice agreement would be a better way to show it."

Conclusion

Selective use of data to support a point is a judgement call, and poor judgement does not inherently constitute misconduct. However, in this case the selection process is so prejudiced as to constitute falsification, even if, as Hendrik Schön claims, the "trend" is the same.

Moreover, if the devices intrinsically vary by a factor of ten, one would have needed about eighteen devices to select from at each dilution (ninety total), to have a reasonable chance of finding this degree of agreement[1]. It is likely that more than simple selection of unbiased results was involved.

The preponderance of evidence indicates that Hendrik Schön committed scientific misconduct, specifically data falsification, in this case.

[1] We thank Michael Weissman for pointing out a logical flaw in an earlier estimate that hundreds of devices would be required.

XVII. Unrealistic Precision: SAMFET width series

Allegation

The ability of the SAMFETs to turn off with gate voltage is totally in contradiction to the electrostatics of the stated structure, with a 30nm oxide over a 2nm channel (see Allegation XX). One explanation would be that the actual device measured was a parasitic MOSFET, for example at the trench edge, which might have a long channel more consistent with the electrical behavior. However, this parasitic device would be formed in the regions of the trench that are not intentionally part of the device, and so should not scale with the intended width of the nominal transistor. Showing that the observed current scales with the width of the area where the claimed transistor action was happening is an essential cross-check that the device is where it was intended.

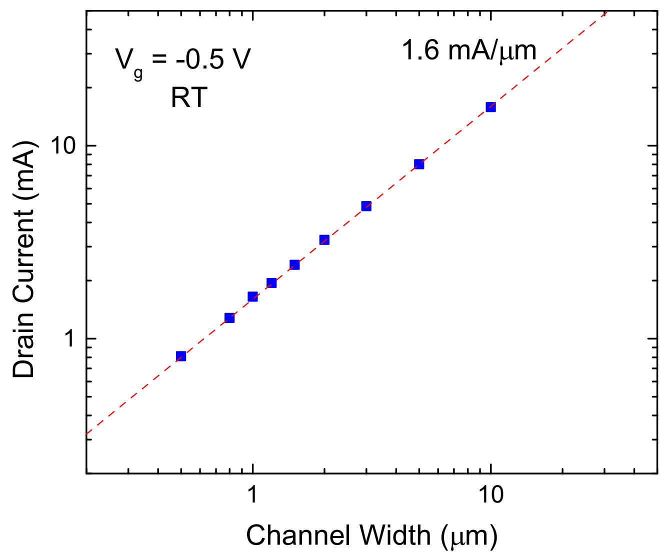

Figure 50. Reported variation of drain current with device width for the SAMFETs. Original plotting data were extracted from a PowerPoint presentation given at Bell Labs in 2002 and included in the material distributed to the Committee by Lucent.

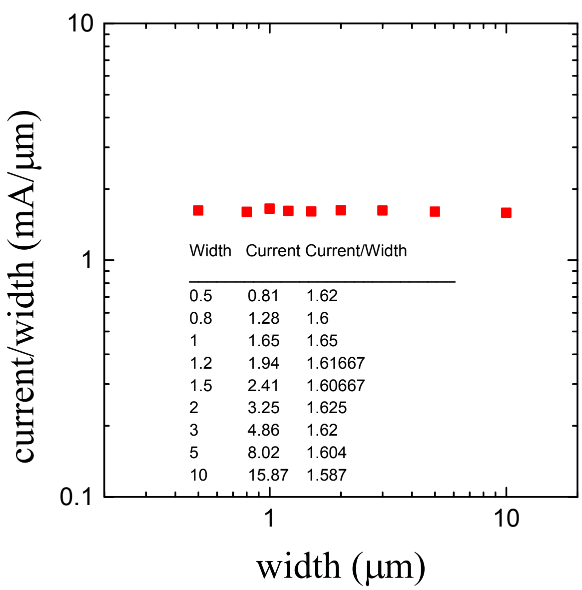

Figure 51. Normalized current drive per unit width, derived from data in Figure 50, is astonishingly constant.

When Hendrik Schön was asked in October 2001 whether the current scaled with the device width, he said that it did, but he did not support that statement with produce any data to support the statement. However, in January of 2002 the data of Figure 50 were presented to a Bell Labs audience. The plot shows the scaling of the drain current with channel width, as stated. The scaling is extraordinarily good. Figure 51 shows the same data, replotted normalized to width. The deviation between highest and lowest normalized current densities is 4%. This type of systematic behavior is much better than is typically observed even in Si manufacturing, let alone in an ad hoc research process. For example, suppose there were a process bias ΔW resulting from imperfections in mask generation, lithography, trench etching, evaporation, or metal etching of 1000Å (0.1 μm) per side. (This would require *very* precise process control on all of those steps or extraordinary luck for large numbers to add to something small. Hendrik Schön acknowledged that the lithography in Konstanz had a 10-15 μm resolution.) One would then expect a deviation of 2 ΔW/W in the apparent current density, which would be 40% for the 0.5μm width, ten times the reported variation.

Figure 52 (from the same PowerPoint presentation) represents the linear dependence on gate width and the independence of the current on the overlapping part of the structure, and is similarly astounding in its precision.

Hendrik Schön acknowledged the mask as having only two trench widths available. Some variation in device widths could be obtained by varying the deposition angle, but avoiding unintended parasitics places complex constraints on this process, and the resulting device sizes would need to be measured individually by, for example, scanning electron microscopy. Such measurements could not give devices with such well-defined round numbers for widths and lengths (and thus area) as illustrated in

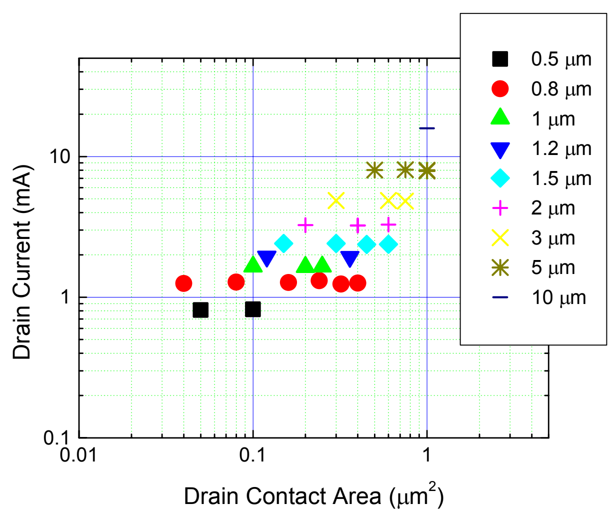

Figure 52. Variation of drain current with both width and length of overlap area. Replotted from the same PowerPoint presentation from which Figure 50 was taken.

Figure 52. For example, the leftmost points have areas of *exactly* 0.04, 0.05, 0.08, and 1.0 μm^2.

Response

Hendrik Schön acknowledged that data had been selected to illustrate the intended trend. No primary data on either the device characteristics or the device width and length characterization were offered.

Conclusion

Hendrik Schön has acknowledged selecting data to match expectations. As in Allegation XVI, such selection would have required sifting through a huge number of devices– *thousands* in this case— to obtain the precise results for more than thirty geometries in Figure 52. Moreover, he has acknowledged an intrinsic variability of the fabrication process that results in widths varying by a factor of two. Two widths were included on the mask; others could be obtained by carefully varying deposition angles in separate runs. Figure 51 and Figure 52 both imply widths that are precise round numbers, in microns. All of this evidence suggests that the data are not just selected, but fabricated.

The preponderance of evidence indicates that Hendrik Schön fabricated data in this case. However, since no relationship between the fabricated data and any published data has been established, no finding of scientific misconduct is warranted. Nonetheless, since these data were invoked as evidence that the assumed mechanism for SAMFET operation was correct, that mechanism must be regarded as highly suspect.

XVIII. Unrealistic Precision: Characterization of sputtering process

Allegation

Many questions have been raised about why the breakdown strength of Hendrik Schön's sputtered Al_2O_3 was so much greater than others have been able to achieve. Values up to 70-80 MV/cm (at low temperatures) are implicit in some of the field-induced superconductivity data; for the "Sputtering" Paper a mean of 23 MV/cm was indicated at room temperature. As reported to the Committee, various recent attempts to reproduce Hendrik Schön's results have so far been limited at 12 – 15 MV/cm, including work at the University of Konstanz using the same sputtering system used by Hendrik Schön in most of the work in question. In the "Sputtering" Paper Hendrik Schön provides evidence that the mean breakdown strength increases from 23 MV/cm at room temperature to 32 MV/cm at 220 K.

Reportedly, Hendrik Schön was strongly encouraged by Bertram Batlogg, his management, and external scientists to document the processing conditions and optimization of his Al_2O_3 gate insulators, to enable the reproduction of these results. The result is the unpublished "Sputtering" Paper (XXIV), included in the materials provided to the Committee by Bell Labs. This document was distributed in preprint form, and also submitted for publication. It has received wide circulation in the community, and for this reason it was judged appropriate for consideration by the Committee along with published papers. This document shows a level of statistical precision that is virtually unheard of in processing experiments, and in any event inconsistent with the reported size of the data set.

Figure 2 of the "Sputtering" Paper (XXIV) is a histogram of breakdown fields for a particular set of processing conditions within the "sweet spot" claimed by Hendrik Schön (see below). The line shows a best-fit Gaussian model. This Gaussian fit yields a mean breakdown field of 23.8 MV/cm and a standard deviation of 6.04 MV/cm. The data set includes over 600 samples, reportedly deposited and measured episodically over several years.

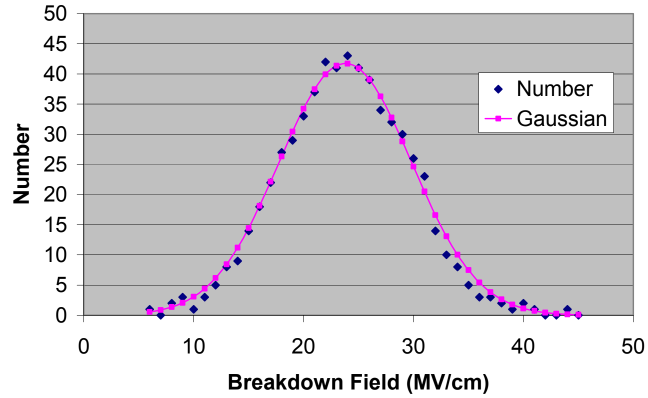

Figure 53. Distribution of breakdown fields from Figure 2 of "Sputtering" Paper (XXIV) (original plotting data from electronic draft) compared to a Gaussian fit.

There are several problems with these data. First, a Gaussian distribution is not expected. More typical breakdown data show many points clustered at the true, intrinsic breakdown and a tail at lower breakdown fields, described by a Weibull distribution. Nonetheless, the agreement with the Gaussian distribution is excellent. Indeed, the χ^2 for these data is about 0.41; a simple estimate of the probability of such good agreement arising from chance for the reported sample size of 600 is about 0.02%.

According to the histogram, one can get the very highest fields implied by the experiments only by operating at the extreme high end of the breakdown distribution, accepting the resultantly low yield. If the distribution were tighter, or skewed to low breakdowns, or there were no increase at low temperatures, these high breakdown fields would not be available. Hendrik Schön stated that if he did not observe superconductivity after a few tries, he would move on to something else.

Figure 54 shows a contour plot of the breakdown field as a function of two process variables: deposition rate and pressure. For those familiar with process studies and contour plots, it is extraordinary to see such a plot. Such smooth contours are not possible unless the "z axis" data are very precisely specified, and process studies are usually difficult to reproduce with precision, especially on typical research equipment. (In this case, Hendrik Schön claims that this was "not a systematic study," but simply a compilation of data taken over a period of several years; this makes the extraordinary reproducibility even more surprising.) One purpose of this plot is to illustrate the small "sweet spot" of the deposition near 0.02 nm/s deposition rate and 5 mbar pressure.

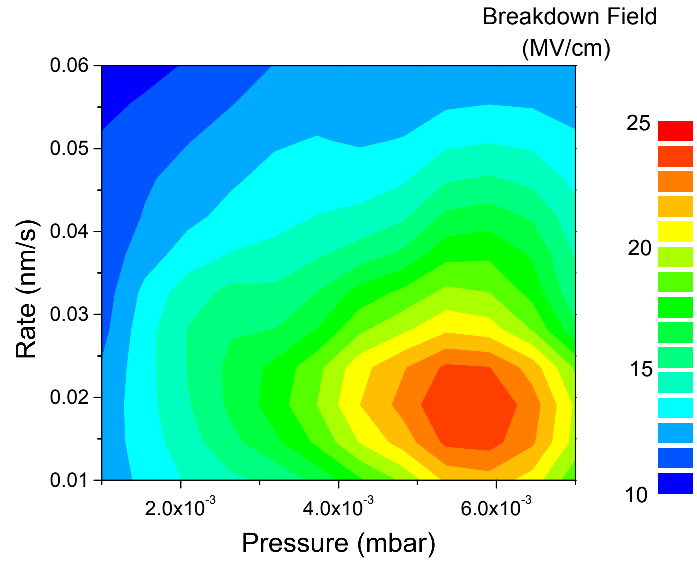

Figure 54 Contour plot of breakdown field from "Sputtering" Paper (XXIV), extracted from an electronic draft.

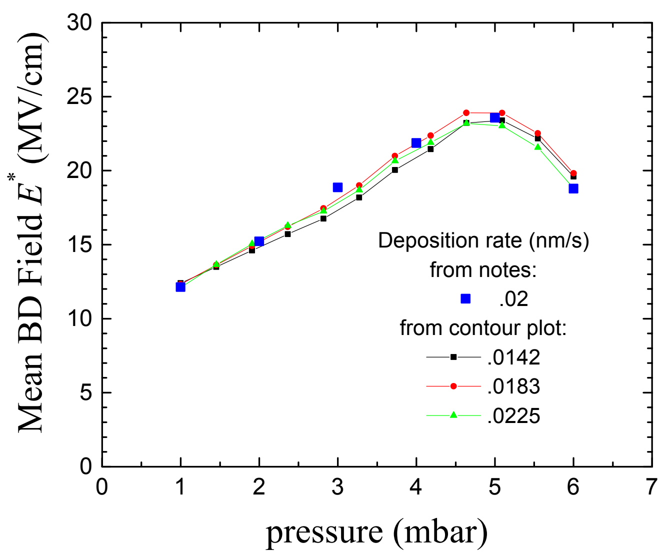

Figure 55 Constant-deposition-rate slices of the data underlying Figure 54. Also shown (blue squares) are some of the average data provided directly by Hendrik Schön.

This plot contains a dense array of points at twelve deposition rates and twelve pressures, including a large section of parameter space where the films are not very good. Consequently, there are 144 different deposition conditions specified. In each case, the signal-to-noise of the breakdown is very high. As illustrated in the Figure 55 (a slice of the above contour plot), the scatter appears to be less than 1MV/cm. Thus this figure requires a total of 36x144=5,184 breakdown measurements to be made. (To obtain the mean breakdown field to a precision of 1MV/cm requires roughly 36 measurements $(6\text{MV/cm} / 1\text{MV/cm})^2$, because of the 6 MV/cm standard deviation of the breakdown field).

The paper says that 150 samples were made at each of 36 conditions, also more than 5000 measurements. Most of them contribute little to the information about the process optimum. The phenomenal effort required to create this data, together with the fact that deposition systems do not as a rule behave this reproducibly, is the reason most process studies have just a few points.

For completeness, some caveats in the paper include the possibility that the breakdown criteria used here are more tolerant than in traditional breakdown studies, and the possibility of some history effect in the chamber.

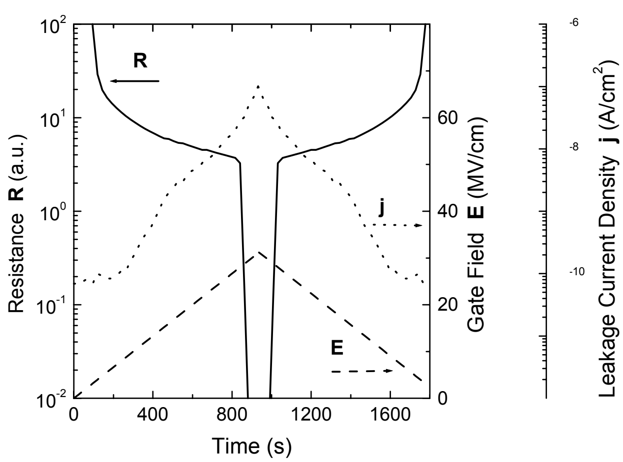

Figure 56. Data from "Sputtering" Paper (XXIV) showing field-induced superconductivity as the gate voltage is swept up and then down. Numerical examination shows that the data are the same to six significant figures on the up and down sweeps.

Finally, this preprint also contains an illustration of field-induced superconductivity involving sweeping the gate voltage up and then down (see Figure 56). Detailed examination (from the original plotting data in the electronic draft) shows that the sweep up and down are the same data to six significant figures, precisely reflected around the maximum field.

Response

Hendrik Schön supplied voluminous documentation describing the results of the breakdown studies. He was not able to explain the statistical anomalies. The description of some of the aspects of the breakdown measurement have changed during revision. For example, it was noted by Bertram Batlogg (in email to Hendrik Schön) that the breakdown measurements in Figure 54 would have taken 2.4 years, using the sweep rates stated in an early version of the preprint. The sweep rate in the paper was subsequently modified from 0.001 V/s to 1 V/s. According to Hendrik Schön and the documentation provided, the actual process matrix was 6x6, and the 12x12 points in the contour plot were created by smoothing and interpolation. No justification was offered for this information-destroying procedure, except “to give a nicer contour plot.” Surprisingly, this smoothing and interpolation procedure did not reduce the excellent breakdown field at the “sweet spot” (compare the blue squares in Figure 55 to the other symbols).

Included in the documentation Hendrik Schön provided to the Committee was a tabulation of the breakdown fields of all 150 samples for each of the 36 deposition conditions represented in the contour plot. Not one of the 5400 measurements indicated a breakdown field less than 3.7 MV/cm.

When presented with the details of symmetry of the field sweep demonstration of superconductivity, Hendrik Schön acknowledged that the data had been artificially symmetrized.

Conclusion

The data presented in this preprint are so statistically improbable that it seems impossible that they represent real data, free of some selection process or some other misrepresentation.

The wide distribution of this preprint among scientists in this field is considered by the Committee to be tantamount to publication. The preponderance of evidence indicates that Hendrik Schön committed scientific misconduct, specifically data fabrication, in this case.

XIX. Contradictory Physics: Unipolar inverter characteristics

Allegation

The "SAMFET" and "SingleMolecule" Papers (XII and XIII) report measurements of inverters wired in a "unipolar" configuration, with the gate of the pull-up, "load" transistor tied to the upper supply voltage (see the inset of Figure 11). This circuit topology behaves very differently than a "complementary" inverter that uses both p- and n-channel transistors. In particular, the two configurations differ markedly in their dependence on the ratio m of the drive current of the pull-down to that of the pull-up transistor. These differences are described in conjunction with Figure 57.

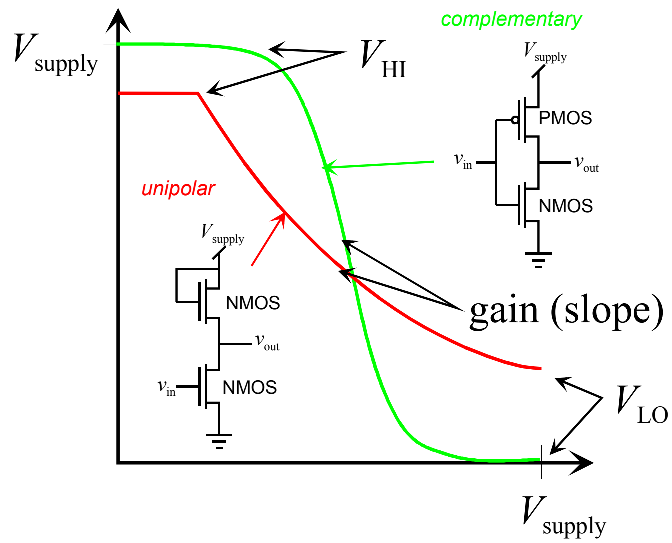

Figure 57. Comparison of general features of complementary (green) inverters and unipolar (red) inverters, as elaborated in the text.

The maximum slope of the transfer characteristic, the gain, must be greater than one if inverters are to drive one another without degrading the logic levels. For a complementary inverter, the gain is largest when the transistors are matched, $m = 1$. For a unipolar inverter, the gain can be large only if the "load" transistor (with gate tied to the supply) is much weaker than the "drive" transistor; the gain is roughly the square root of m. Thus the reported gain of 6-10 would require m of 36-100.

For the unipolar inverter, the output voltage is only gradually pulled down, eventually reaching a minimum value of $V_{supply}/2(1+m)$. Thus the observed outputs of .05 V for a 2 V supply suggest $m = 20$. For a complementary inverter, the pull-up (pull-down) turns off as the input voltage approaches within its threshold voltage of the lower (upper) supply, so the output can easily go "rail-to-rail," reaching very close to zero (supply voltage). For the unipolar inverter, the maximum output voltage V_{HI} is lower than the supply voltage by the threshold voltage of the load transistor. The observed characteristics get very close to the respective rails, as in a complementary inverter.

The unipolar inverter typically shows a “kink” when the load transistor turns on, The rounded characteristic observed is much more similar to a complementary inverter characteristic.

The methodology for selecting transistors for the inverters and ring oscillators, in particular the drive current ratio, was not described in the paper. Hendrik Schön indicated in private email: “…in the inverter circuits I try to match the drive and load transistor to get a good switching behavior. Since I wire them externally the FET characteristics of the individual device is known before.”

It is also surprising that, if the transistors used in the inverter can be operated at 2V, they were characterized only at much lower voltage in the triode data.

Response

Hendrik Schön expressed doubt as to whether the “kink” in the inverter characteristic is a robust feature of a unipolar circuit. He also presented sketches indicating that a kink was sometimes observed (but not published).

Hendrik Schön described the very unusual rise of the output voltage at high input voltages, seen in all of the transfer characteristics, as possibly being an instrumental artifact.

In the interview, Hendrik Schön recanted the email indicating matched currents were used. Instead, he described a highly unsystematic and time-consuming procedure for choosing the transistors to obtain a good inverter characteristic. Hendrik Schön raised the possibility that unspecified changes induced in the transistors during the measurement process might have altered the inverter characteristics. In no case were the primary triode characteristics for the transistors comprising the inverters retained.

Conclusion

The evidence indicates that the unipolar inverter data were not taken as described, since the actual data are consistent with a complementary circuit. In Allegation III, these unipolar inverters are both alleged to be identical to earlier data on a true complementary inverter, which would explain their properties. The presentation of these data in this context therefore constitutes falsification, either intentional or reckless.

The preponderance of evidence indicates that Hendrik Schön committed scientific misconduct, specifically data falsification, in this case. The specific evidence supporting this conclusion is that discussed in connection with Allegation III.

XX. Contradictory Physics: SAMFET subthreshold swing

Allegation

Papers XII ("SAMFET"), XIII ("SingleMolecule") and XVI ("NanoSAMFET") reported transistor characteristics for molecular devices that were superior to the best commercial Field Effect Transistors (FET's). For example, there is well-known constraint that a gate voltage change of at least (kT/e) ln 10 (which is around 60 mV) is required to turn off the current by a factor of ten. This constraint should apply to any device using the FET principle. The SAMFET's reported in these papers took far less gate voltage to turn off than this ideal minimum. What made these observations even more surprising was the fact that the devices as described had a very poor aspect ratio: the oxide thickness (~30 nm) was over ten times the reported channel length. Standard FET's usually have these dimensions reversed: the channel length is ten times the oxide thickness. This is necessary so that the gate, rather than the drain, controls the electrostatic potential.

Another surprising observation was the reported transconductance ~ 10 mS/μm ~ 10,000 mS/mm which is in excess of the values reported for state-of-the-art FET's (~ 1,000 mS/mm), achieved after thousands of man-years of development.

The background leakage of the SAMFETs is several orders of magnitude lower than would have been expected, based on the stated geometry and scanning probe measurements of leakage current on similar systems.

Response

Hendrik Schön acknowledged the surprising nature of these results, but maintains that a new physical mechanism may be at work.

Conclusion

These observations are clearly inconsistent with known physical mechanisms for MOSFET operation. It is possible that new, unspecified mechanisms are important. However, since much of the published data associated with this work were substituted from other sources or fabricated (see Allegations I, III, XIX, XV, XVI) the committee has serious doubts about the integrity of the data and finds it difficult to take it at face value.

The preponderance of the evidence indicates that Hendrik Schön committed scientific misconduct, specifically data falsification, in this case. The specific evidence supporting this conclusion is that discussed in connection with Allegations I and XVII.

The data presented by Zhenan Bao, on structures that she fabricated (in Fig. 3 of paper XVI ("NanoSAMFET"), do not exhibit the inexplicably high gate coupling discussed here. That subset of the paper therefore does not contradict prevailing scientific understanding.

XXI. Contradictory Physics: Hysteretic planar Josephson weak links

Allegation

Fig. 1 in "TunableWeakLinks" Paper (XVII) shows a standard planar SNS weak-link geometry (see Figure 58). Devices with this geometry have a low capacitance between the superconducting "banks," and their *I-V* characteristics should be non-hysteretic, exhibiting a very steep rise in current, followed by a leveling-out, eventually merging into an asymptotic normal resistance characteristic. Instead, Fig. 2 of the paper shows a hysteretic characteristic that looks like a textbook representation of a conventional tunnel junction of sandwich geometry, with its high, hysteresis-inducing capacitance (see Figure 59 below). However, the nominal separation between superconducting banks is far too large (>50nm) for any tunnel junction to form having currents on the order of microamperes. This inconsistency was pointed out by a referee, but was not addressed in the paper.

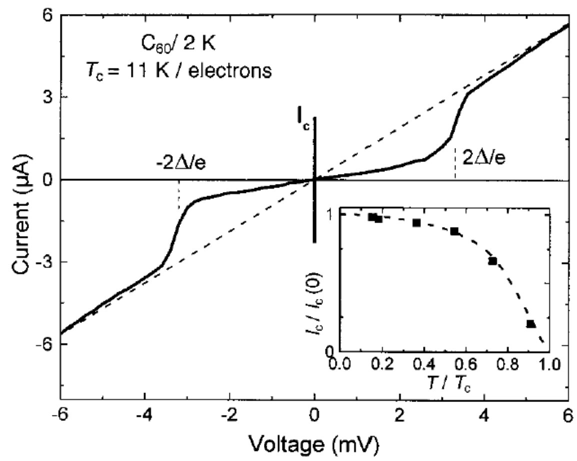

Figure 58. Fig. 2 from "TunableWeakLinks" Paper (XVII), showing hysteretic I-V characteristic for a planar weak link.

Response

Hendrik Schön suggested that the actual junctions were formed at geometrical irregularities that arose due to the use of shadow masks during deposition, for example where the metal pads accidentally formed unusually narrow gaps. He showed a sketch of such a structure to represent what he had seen in a scanning electron microscope. However, he could provide no scanning electron micrographs or optical photographs of any of the related structures. While such accidental geometries could conceivably change the microscopic parameters, no detailed explanation of the hysteretic junctions was given.

Hendrik Schön also acknowledged that some of the junctions that he studied looked non-hysteretic, but he did not explain why that fact was not included in the original paper. Indeed, the Committee learned that a referee for this paper asked very pointed questions about this issue, but apparently he or she was not informed that both types of junction existed.

Conclusion

The assertion that non-hysteretic *I-V* characteristics had, in fact, been seen, combined with the explicit raising of this issue by a referee, makes it extremely puzzling why the authors did not use (or even mention) those characteristics in their paper. It appears evident that the authors had only a very rudimentary understanding of superconducting weak links and of the differences between their properties and those of the more-widely studied tunnel junctions. The committee can only speculate that, as a result, the authors *expected* tunnel-like characteristics, and selected for presentation those data that met this expectation.

This still does not explain how the tunnel-like characteristics actually arose. The most that can be said is that they are not consequences of the simple geometrical model of Fig. 1, if the latter is taken at face value, but must be due to extraneous effects.

While extremely troubling, this instance on its own does not provide compelling evidence of scientific misconduct.

.

XXII. Contradictory Physics: Low sub-gap conductance

Allegation

Figure 59 shows a "typical" I-V characteristic of the planar junctions reported in "PlasticSquid" Paper (XVIII). This I-V curve shows a hysteretic tunnel-junction-like characteristic that appears to be inconsistent with the very low capacitance expected in such a planar geometry and with the nominal length of the barrier (50nm), which is much too long to achieve ideal tunneling. A weak-link-type I-V would seem more likely for such long junctions (see the related discussion for Allegation XXI). Also, the tunneling-like I-V curve shows a very low sub-gap conductance. Such low conductance would only be expected at very low temperatures, well below those in which the data were taken, assuming a transition temperature as seen in other papers on polythiophene. Finally, peaks in the second derivative of the I-V characteristic are reported and interpreted as so-called "phonon peaks", which suggest the electron-phonon interaction as the mechanism for the superconductivity in polythiophene. The problem is that this mechanism leads to dips, not peaks, in the second derivative. These various problems have caused some to doubt the validity of the data.

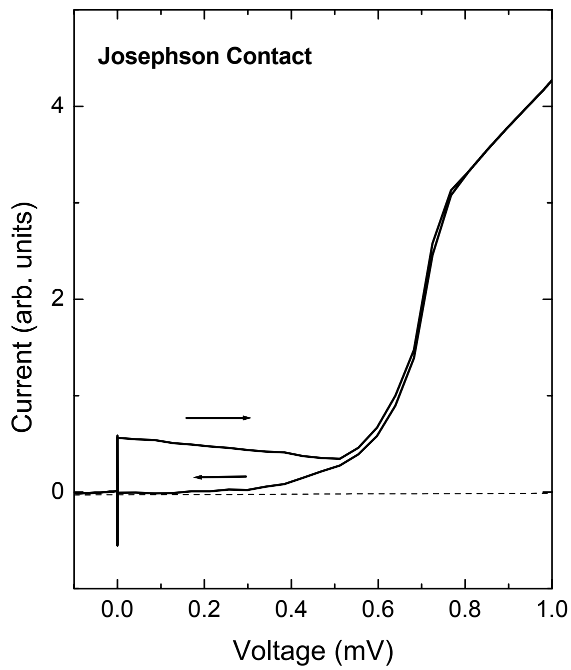

Figure 59. Figure 2 from "PlasticSquid" Paper (XVIII) showing surprising, hysteretic characteristic for a planar junction.

Response

In his response to allegations regarding tunable Josephson Junctions (Allegation XX), Hendrik Schön described how he used a shadow mask to define the barrier length in these planar junctions and claimed that the actual length of the junctions could be much less than the nominal value. He described how he selected junctions for test based on their finite (as opposed to zero) conductance. Therefore, the actual length of the barriers is not known. He also acknowledged that weak-link-like characteristics were sometimes seen. No explanation was offered for the low sub-gap conductance, which is the principle issue here. Schön acknowledged that the inversion of the peaks resulted from negative “arbitrary units.”

Conclusion

Given that the exact length of the barrier in these junctions is not known, but arguably much less than 50nm, it is hard to make a judgment. It seems very unlikely that true tunnel junctions could be achieved this way, but these are very unusual material systems whose barrier properties are not known independently. The low sub-gap conductance is clearly problematic. The problem with the second derivative of the I-V curve could be a simple plotting error.

While troubling, this instance on its own does not provide compelling evidence of scientific misconduct.

XXIII. Contradictory Physics: Squid results

Allegation

In the same "PlasticSquid" Paper (XVIII) discussed in the allegation above, magnetic diffraction data for the critical current of a SQUID device were also presented. The data are shown in Figure 60. By the usual convention, one assumes that the open circles are measured data and the solid line is either a theoretical calculation or some fit to the data, although the paper makes no statement about the meaning of the different symbols. Under the assumption that the solid line is a theoretical calculation, some critics have argued that the agreement is well beyond what is normally seen, causing them to question the data. Another problem is that the magnetic periodicity seen in the data are not compatible with the measured 10um^2 area of the device.

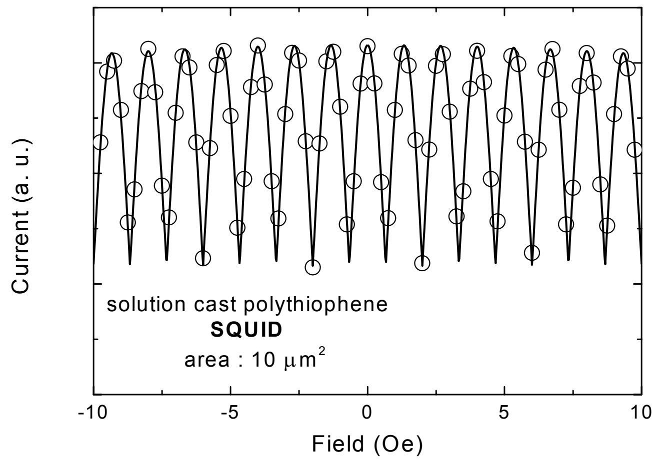

Figure 60. Plot of modulation of critical current by magnetic field, Figure 4 of "PlasticSquid" Paper (XVIII).

Response

In response to questioning, Hendrik Schön stated that he was not certain whether the open symbols in the figure represent real data or not. No original (raw) data files exist with which to check this point. He also explained that the solid curve is not a calculation based on theory, but rather a simple mathematical function (the absolute value of the sine function, offset from zero). He stood by the value of the area determined by the magnetic periodicity.

Conclusion

Clearly, the data in the figure have no verifiable basis. The meaning of the solid line is confusing, at best, and should have been explained in the paper. The disagreement between the measured area and that inferred from the data does not necessarily represent a serious discrepancy, given the planar nature of this SQUID and uncertainties of the strong field perturbations due to demagnetization effects in this geometry.

It is very disturbing that there is ambiguity in the meaning of the open symbols in Figure 4 of the paper, given that the solid line is an analytical construct. This suggests an irresponsible attitude toward data.

While troubling, this instance on its own does not provide compelling evidence of scientific misconduct.

XXIV. Contradictory Physics: Sharp 2-D superconducting transitions

Allegation

The field-effect doping induced superconductivity should almost certainly be two-dimensional. 2-D superconductivity is subject to well-established fluctuation phenomena that cause rounding (i.e. broadening) of the superconducting transition, both above and below the mean-field BCS transition.

Above the mean-field transition, fluctuations toward the superconducting state enhance the conductivity, causing lower resistivity than the extrapolated normal state resistivity. The relative importance of this effect becomes significant as the normal-state sheet resistance approaches the inverse of quantum of conductance $h/4e^2$, or about 6.5 KΩ. As a rule, Hendrik Schön plotted resistances in "arbitrary units," making it impossible to evaluate whether this fundamental effect should be evident. However, in the plots of the superconducting transition (see Figure 61, below), the normal state resistivity data show no deviation from parabolic behavior right down to the transition.

Below the mean-field superconducting transition, the well-known Kosterlitz-Thouless (KT) vortex-antivortex unbinding transition expected in 2D superconductors produces a nonzero resistance above the KT transition temperature. For high sheet-resistance superconductors, this leads to a significant broadening of the transition. Unfortunately, in many plots, such as Figure 32, the transitions are plotted on scale that suppresses information about the resistive tail, other than that it is extraordinarily small for films with T_c of tens of Kelvin.

Response

No detailed physical explanation for the sharpness of the transition was offered by any coauthor. Bertram Batlogg recalled that he tried very hard to get Hendrik Schön to include an absolute sheet resistance in the published data, although in the end that was not generally done. During the interviews, Hendrik Schön acknowledged typical sheet resistances of 1-10 KΩ per square, so that fluctuation effects should have been evident.

Conclusion

The Committee finds the reported sharpness of the superconducting transitions for these films to be contradictory to prevailing physics and the stated sample structure.

It is highly relevant that the resistance versus temperature curves discussed here are precisely the curves for which Hendrik Schön has admitted splicing together the actual transition with an analytic form above the transition and zeros below the transition (see Allegation X, for example). If there had been measured data exhibiting fluctuation resistance and resistive tails, those procedures would have obliterated them. Moreover, a normal state resistance spliced in the fluctuation regime would not have agreed with the actual resistivity at higher temperatures. As shown in Figure 61 for one of the curves, very little data remains after these procedures.

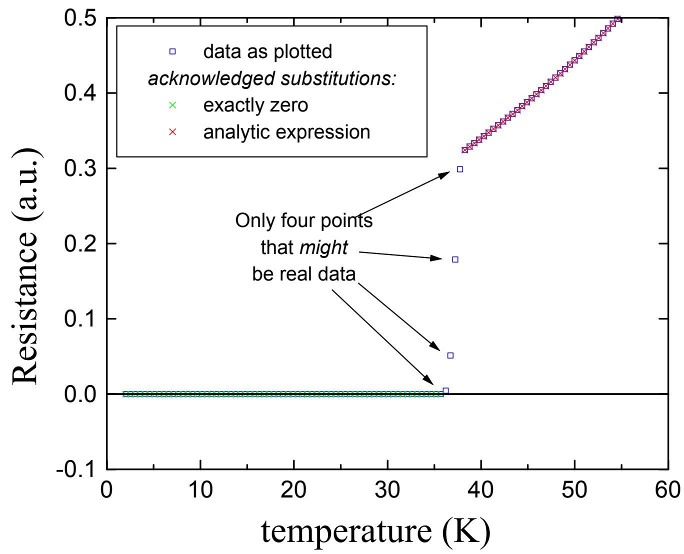

Figure 61.Data from the "Super C60"Paper (XIX) for one gate voltage, showing that only four points of the original 117 remain after acknowledged spliced points are removed. Any rounding of the transition would be obscured by this procedure.

The absence of fluctuation effects in the resistive transitions of C_{60} appears to be inconsistent with prevailing scientific understanding, and thus would, if true, demand radical new explanations. On the other hand, as determined in Allegation X, the data in question here are now known not to be real. Hence, the physical question posed cannot be adjudicated. No conclusion is possible and any judgment on the existence or not of fluctuations in any superconducting transition in C_{60} is deferred to the appropriate scientific community.

The preponderance of the evidence suggests that Hendrik Schön committed scientific misconduct in this case. The specific evidence supporting this conclusion is that discussed in connection with Allegation X.

Appendix F: Papers in Question

I. “Rodlike”

“Electrical properties of single crystals of rigid rodlike conjugated molecules,” J. H. Schön, Ch. Kloc, R. A. Laudise, and B. Batlogg, *Phys. Rev.* **B 58**, 12952 (1998).
Allegation VI: Data Substitution: Space-charge limited I-V

II. “AmbipolarPentacene”

“Ambipolar pentacene field-effect transistors and inverters,” J.H. Schön, S. Berg, Ch. Kloc and B. Batlogg, *Science* **287,** 1022 (February 11, 2000).

- Allegation I: Data Substitution: Triode characteristics
- Allegation III: Data Substitution: Inverter characteristics

III. “SuperFETswitch”

“A Superconducting Field-Effect Switch,” J. H. Schön, Ch. Kloc, R. C. Haddon, B. Batlogg, *Science* **288**, 656 (April 28, 2000).

- Allegation I: Data Substitution: Triode characteristics
- Allegation XXIV: Contradictory Physics: Sharp 2-D superconducting transitions

IV. “FQHE”

“Fractional Quantum Hall Effect in Organic Molecular Semiconductors”, J. H. Schön, Ch. Kloc, B. Batlogg, *Science* **288**, p 2338 (June 30, 2000).

- Allegation IX: Data Substitution: Magnetotransport

V. “LightEmitting”

“A Light-Emitting Field-Effect Transistor,” J. H. Schön, A. Dodabalapur, Ch. Kloc, and B. Batlogg, *Science* **290,** 963 (November 3, 2000)

- Allegation II: Data Substitution: Ambipolar triode characteristics

VI. “Perylene”

“Perylene: A promising organic field-effect transistor material,” J. H. Schön Ch. Kloc, and B. Batlogg, *Appl. Phys. Lett*. **77,** 3776 (December 4, 2000).

- Allegation II: Data Substitution: Ambipolar triode characteristics

VII. "CdS"

"Solution processed CdS thin film transistors," J.H. Schön, O. Schenker, and B. Batlogg, *Thin Solid Films* **385**, 271 (2001).

- Allegation IV: Data Substitution: Ring oscillator

VIII. "AmbipolarOrganic"

"Ambipolar organic devices for complementary logic," J. H. Schön, Ch. Kloc, and B. Batlogg, *Synthetic Metals* **122,** 195 (2001).

- Allegation II: Data Substitution: Ambipolar triode characteristics
- Allegation IV: Data Substitution: Ring oscillator

IX. "HolePentacene"

"Hole transport in pentacene single crystals," J. H. Schön, Ch. Kloc, and B. Batlogg, *Phys. Rev.* B **63,** 245201 (2001).

- Allegation VI: Data Substitution: Space-charge limited I-V
- Allegation XIII: Unrealistic Precision: Pentacene mobility

X. "NewPhenomena"

"New Phenomena in High Mobility Organic Semiconductors," J.H. Schön, *Phys. Stat. Sol.* **226,** 257 (2001).

- Allegation IX: Data Substitution: Magnetotransport

XI. "FastOrganic"

"Fast organic electronic circuits based on ambipolar pentacene field-effect transistors," Jan Hendrik Schön and Christian Kloc, *Appl. Phys. Lett.* **79**, 4043 (10 December 2001).

- Allegation IV: Data Substitution: Ring oscillator

XII. "SAMFET"

"Self-assembled monolayer organic field-effect transistors," Jan Hendrik Schön, Hong Meng, and Zhenan Bao, *Nature* **413,** 713 (October 18, 2001).

- Allegation I: Data Substitution: Triode characteristics
- Allegation III: Data Substitution: Inverter characteristics
- Allegation XIX: Contradictory Physics: Unipolar inverter characteristics
- Allegation XVII: Unrealistic Precision: SAMFET width series
- Allegation XX: Contradictory Physics: SAMFET subthreshold swing

XIII. "SingleMolecule"

"Field-Effect Modulation of the Conductance of Single Molecules," Jan Hendrik Schön, Hong Meng, Zhenan Bao, *Science* **294**, 2140 (December 7, 2001).

- Allegation XV: Unrealistic Precision: Conductance quantization
- Allegation XVI: Unrealistic Precision: SAMFET Dilution series
- Allegation XX: Contradictory Physics: SAMFET subthreshold swing

XIV. "Laser"

"An Organic Solid State Injection Laser," J. H. Schön, Ch. Kloc, A. Dodabalapur, and B. Batlogg, *Science* **289**, 599-601 (28 July, 2000).

- Allegation VII: Data Substitution: Laser emission spectrum

XV."Expanded C60"

"High-Temperature Superconductivity in Lattice-Expanded C_{60}," J. H. Schön, Ch. Kloc, B. Batlogg, *Science* **293**, 2432 (28 September, 2001).

- Allegation VIII: Data Substitution: Superconducting Tc versus charge
- Allegation XXIV: Contradictory Physics: Sharp 2-D superconducting transitions

XVI. "NanoSAMFET"

"Nanoscale organic transistors based on self-assembled monolayers," J. H. Schön and Z. Bao, *Appl. Phys. Lett.* **80**, 847 (4 February 2002).

- Allegation XX: Contradictory Physics: SAMFET subthreshold swing

XVII. "TunableWeakLinks"

"Josephson Junctions with Tunable Weak Links," Jan Hendrik Schön, Christian Kloc, Harold Y. Hwang, Bertram Batlogg, *Science* **292**, 252 (13 April 2001).

- Allegation XXI: Contradictory Physics: Hysteretic planar Josephson

XVIII. "PlasticSquid"

"Plastic Josephson junctions," Jan Hendrik Schön, *Appl. Phys. Lett.* **14**, 2208 (11 October 2001).

- Allegation XXII: Contradictory Physics: Low sub-gap conductance
- Allegation XXIII: Contradictory Physics: Squid results

XIX. "Super C60"

"Superconductivity at 52 K in hole-doped C-60," J.H. Schön, Ch. Kloc, and B. Batlogg, *Nature* **408**, 549 (30 November 2000).

- Allegation VIII: Data Substitution: Superconducting Tc versus charge
- Allegation XXIV: Contradictory Physics: Sharp 2-D superconducting transitions

XX.“BandlikeC60”

“Band-Like Charge Transport in C_{60} Single Crystals,” J. H. Schön, Ch. Kloc, and B. Batlogg, *phys. stat. sol.* (b) **225**, 209 (2001).

- Allegation I: Data Substitution: Triode characteristics

XXI. “FETCaCuO2”

"Superconductivity in $CaCuO_2$ as a result of field-effect doping," J.H. Schön, M. Dorget, F.C. Beuran, X.Z. Zu, E. Arushanov, C.D. Cavellin, and M. Lagues, *Nature* **414,** 434 (22 November 2001).

- Allegation VIII: Data Substitution: Superconducting Tc versus charge
- Allegation XII: Unrealistic Precision: Resistance of CaCuO2
- Allegation XXIV: Contradictory Physics: Sharp 2-D superconducting transitions

XXII. “C70”

Superconductivity in single crystals of the fullerene C-70," Schön JH, Kloc C, Siegrist T, Steigerwald M, Svensson C, Batlogg B, *Nature* **413,** 831 (25 October 2001).

- Allegation XI: Unrealistic Precision: Normal-state resistance of gated C70
- Allegation XXIV: Contradictory Physics: Sharp 2-D superconducting transitions

XXIII. “Ballistic”

“Ballistic hole transport in pentacene with a mean free path exceeding 30 μm,” Schön JH, Kloc C, Batlogg B, *J. Appl. Phys.* **90,** 3419 (1 October 2001).

- Allegation XIV: Unrealistic Precision: Ballistic transport

XXIV. “Sputtering”

“Sputtering of alumina thin films for field-effect doping,” J.H. Schön, preprint.

- Allegation XVIII: Unrealistic Precision: Characterization of sputtering process

XXV. “Gate Induced Super”

“Gate-induced superconductivity in a solution-processed organic polymer film,” J.H. Schön, A. Dodabalapur, Z. Bao, C. Kloc, O. Schenker, and B. Batlogg, *Nature* **410,** 189 (8 March 2001).

- Allegation V: Data Substitution: Normal-state resistivity of polythiophene

Appendix G: Questionnaires

I. Questionnaire for Hendrik Schön

June 27, 2002

Dear Dr. Schön:

I write on behalf of the Investigation Committee commissioned by Lucent Technologies to investigate the possibility of scientific misconduct relating to the journal articles of which you are a coauthor, listed below. We understand that you have been informed by Lucent that these articles are under investigation and have been provided documentary evidence pertaining to these allegations.

As a part of its investigation, the Committee has the following initial requests. Please be advised that we may in the future request additional information.

For the papers marked with an asterisk, please provide a listing and copy of all data records upon which the results (in particular the figures) in the papers at issue are based, going back to the original data sets, including but not limited to lab notebooks, data print-outs, etc.

For the papers marked with an asterisk, please describe in detail any procedures applied to the data before plotting, for example smoothing and filtering, selection of histogram bin widths, fitting, interpolation, removal or alteration of points, rescaling etc.

For the papers marked with an asterisk, please provide an inventory of all samples studied. Please state whether the samples still exist and, if so, where they are currently stored.

Please provide the same information as in 1., 2., and 3. above for your technical memorandum entitled, "Sputtering of alumina thin films for field-effect doping".

For all the papers in question, please specify to what degree the results described have been reproduced by you or others to your knowledge, either inside or outside of Bell Laboratories.

Given the seriousness of these matters and the need for expeditious resolution, we ask that you respond within 10 days of receipt of this letter. Please be advised that this request and your response will be treated as official documents of the investigation.

Also, the Committee will be at Lucent sometime during the week of 22 July and would like to meet with you at that time. Please contact Jean Ainge (jba@lucent.com or 908-582-2488) at Lucent regarding your availability.

Thank you for your cooperation.

Sincerely,

Malcolm R. Beasley
Committee Chair

The allegation(s) attached is (are) taken from an overall compilation of allegations developed by the Investigation Committee. This document was prepared as described below.

Comments on the Allegations/Observation Document

(Draft 06/19/02)

This document is intended as a thorough, straightforward compilation of the allegations and observations received by the Investigation Committee to date bearing on possible scientific misconduct by the authors indicated. It is based on the report transmitted to the Committee by Lucent Technologies of their initial inquiry into the allegations, written communications sent directly to the Committee and verbal communications taken to be credible by the Committee.

It contains both entries that suggest directly scientific misconduct and entries that note scientific issues that can reasonably be taken to raise questions as to the validity of the data.

The document does not reflect any rank ordering or any other judgment by the Committee regarding the allegations.

Copies of Allegation Letters Sent to the Committee

(06/19/02)

These are redacted copies of written communications sent directly to the Committee.

Malcolm Beasley
Herb Kroemer
Herwig Kogelnik
Don Monroe
Supriyo Datta

Appendix G: Questionnaire for Hendrik Schön

Questions:

Explain briefly your role in this research.

Please state with specificity what role you played in the material synthesis and/or characterization, sample treatment and/ or device fabrication and characterization for the results in question.

Please state with specificity what role you played in taking, analyzing or preparing for publication the data in question?

Please state whether you reviewed the manuscript prior to publication.

Are there any other pertinent facts or issues you would like to present to the committee?

Please send your response to these questions by email and paper copy directly to Prof. Malcolm Beasley.

Complete List of Allegations and Observations was attached:

II. Questionnaires for Primary Co-Authors (Bao, Batlogg, and Kloc)

June 27, 2002

Dear (Primary Author):

I write on behalf of the Investigation Committee commissioned by Lucent Technologies to investigate the possibility of scientific misconduct relating to the journal articles of which you are a coauthor, attached. We understand that you have been informed by Lucent that these articles are under investigation and have been provided documentary evidence pertaining to these allegations.

As a part of its investigation, the Committee requests that you answer the questions (attached) for each paper at issue. Given the seriousness of these matters and the need for expeditious resolution, we ask that you respond within 7 days of receipt of this letter. Please be advised that this request and your response will be treated as official documents of the investigation.

Also, the Committee will be at Lucent sometime during the week of July 22 and would like to meet with you at that time. Please contact Jean Ainge (jba@lucent.com or 908-582-2488) at Lucent regarding your availability.

Thank you for your cooperation.

Sincerely,

Malcolm R. Beasley
Committee Chair

The allegation(s) attached is (are) taken from an overall compilation of allegations developed by the Investigation Committee. This document was prepared as described below.

Comments on the Allegations/Observation Document

(Draft 06/19/02)

This document is intended as a thorough, straightforward compilation of the allegations and observations received by the Investigation Committee to date bearing on possible scientific misconduct by the authors indicated. It is based on the report transmitted to the Committee by Lucent Technologies of their initial inquiry into the allegations, written communications sent directly to the Committee and verbal communications taken to be credible by the Committee.

It contains both entries that suggest directly scientific misconduct and entries that note scientific issues that can reasonably be taken to raise questions as to the validity of the data.

The document does not reflect any rank ordering or any other judgment by the Committee regarding the allegations.

Copies of Allegation Letters Sent to the Committee

(06/19/02)

These are redacted copies of written communications sent directly to the Committee.

Malcolm Beasley
Herb Kroemer
Herwig Kogelnik
Don Monroe
Supriyo Datta

Appendix G: Questionnaire for Primary Co-Authors

Questions:

Explain briefly your role in this research.

Please state with specificity what role you played in the material synthesis and/or characterization, sample treatment and/ or device fabrication and characterization for the results in question.

Please state with specificity what role you played in taking, analyzing or preparing for publication the data in question?

Please state whether you reviewed the manuscript prior to publication.

Are there any other pertinent facts or issues you would like to present to the committee?

Please send your response to these questions by email and paper copy directly to Prof. Malcolm Beasley.

A List of Allegation(s) was attached for each relevant (co)author.

III.Questionnaires for Secondary Co-authors

June 27, 2002

Dear (Secondary Author):

I write on behalf of the Investigation Committee commissioned by Lucent Technologies to investigate the possibility of scientific misconduct relating to the journal articles of which you are a coauthor, attached. We understand that you have been informed by Lucent that these articles are under investigation. The nature of the allegations regarding your paper is attached.

As a part of its investigation, the Committee requests that you answer the questions (attached) for each paper at issue. Given the seriousness of these matters and the need for expeditious resolution, we ask that you respond within 7 days of receipt of this letter. Please be advised that this request and your response will be treated as official documents of the investigation.

Although the Investigation Committee does not plan to speak with you directly at this time, we will gladly speak with you if you wish. Please contact Jean Ainge (jba@lucent.com or 908-582-2488) at Lucent regarding a meeting if you so desire.

Thank you for your cooperation.

Sincerely,

Malcolm R. Beasley
Committee Chair

The allegation(s) attached is (are) taken from an overall compilation of allegations developed by the Investigation Committee. This document was prepared as described below.

Comments on the Allegations/Observation Document

(Draft 06/19/02)

This document is intended as a thorough, straightforward compilation of the allegations and observations received by the Investigation Committee to date bearing on possible scientific misconduct by the authors indicated. It is based on the report transmitted to the Committee by Lucent Technologies of their initial inquiry into the allegations, written communications sent directly to the Committee and verbal communications taken to be credible by the Committee.

It contains both entries that suggest directly scientific misconduct and entries that note scientific issues that can reasonably be taken to raise questions as to the validity of the data.

The document does not reflect any rank ordering or any other judgment by the Committee regarding the allegations.

Copies of Allegation Letters Sent to the Committee

(06/19/02)

These are redacted copies of written communications sent directly to the Committee.

Malcolm Beasley
Herb Kroemer
Herwig Kogelnik
Don Monroe
Supriyo Datta

Appendix G: Questionnaire for Secondary Co-Authors

Questions:

Explain briefly your role in this research.

Please state with specificity what role you played in the material synthesis and/or characterization, sample treatment and/ or device fabrication and characterization for the results in question.

Please state with specificity what role you played in taking, analyzing or preparing for publication the data in question?

Please state whether you reviewed the manuscript prior to publication.

Are there any other pertinent facts or issues you would like to present to the committee?

Please send your response to these questions by email and paper copy directly to Prof. Malcolm Beasley.

A List of Allegation(s) was attached for each relevant (co)author.

Appendix H: Responses of Authors to this Report

I. Response of Hendrik Schön

Although I disagree with several of the findings and conclusions in the report of the investigation committee on the possibility of scientific misconduct in the work of Hendrik Schön and coauthors, I have to admit that I made various mistakes in my scientific work, which I deeply regret. Some of these mistakes might have been related to difficult circumstances and others I did not realize in time. Nevertheless, it was my responsibility and there are no excuses for these mistakes and would like to apologize honestly for these mistakes to the coauthors and the scientific community.

However, I would like to state that all the scientific publications that I prepared were based on experimental observations. I have observed experimentally the various physical effects reported in these publications, such as the Quantum Hall effect, superconductivity in various materials, lasing, or gate-modulation in self-assembled monolayers, and I am convinced that they are real, although I could not prove this to the investigation committee. Furthermore, I believe that these results will be reproduced in the future and, if possible for me, I am willing to work hard on this task, since reproduction will be the only prove of these scientific effects.

Based on experimental observations I tried to communicate the science that described the experimental findings and that I was convinced of. Although I have made mistakes, I never wanted to mislead anybody or to misuse anybody's trust. I realize that there is a lack of credibility in light of these mistakes, nevertheless, I truly believe that the reported scientific effects are real, exciting, and worth working for.

II. Response of Bertram Batlogg

After having read the draft report, and having heard over the phone of some changes, I would like to submit respectfully a comment.

On the topic of "responsibility of co-authors," I am pleased to find a very high level of agreement between the committee's views, as expressed in the report, and my views as expressed in the telephone interview and the follow-up written Comment. In particular I acknowledge that this topic entails questions that are difficult to answer because of a lack of broadly based discussions and consensus in the scientific community.

In the main text, a sentence reads "A senior co-author who has paid close attention … and who has asked searching questions is in a much better position to support his colleague in defending his work". This sentence, while correct in the abstract, may be taken in this specific case and context to imply that such searching questioning did not take place. Such an impression would be substantially incorrect and counter to the reality as communicated to the Committee. Indeed, questions for additional data and for experimental details have been an important part of the "quality and validity control" exercised by myself, and also by experts at Bell Labs who have not been collaborators. These experts have been explicitly involved in scrutinizing papers for technical correctness. To probing questions I received, and so did those other critical colleagues, answers that appeared at that time reasonable and satisfactory and that would not indicate any reason to doubt the validity of the work. Thus I would have preferred a slightly modified sentence conveys the fact that in the present case such probing questions have indeed been regularly posed by many scientists, particularly also by myself, and that they were met with satisfactory answers.

Once more, I thank the Members of the Committee for their work that has led to this report.