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Teaching Scientific Ethics Using the Example of Hendrik Schön

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It has been almost 10 years since one of the greatest frauds in the history of physics was uncovered, namely, the case of Hendrik Schön. This case provides a wonderful opportunity to discuss scientific integrity and scientific misconduct with both undergraduate and graduate science students. This article explains the scientific data at the heart of this case of fraud, as well as discusses the numerous ethical issues surrounding this case, including the responsibility of research supervisors as well as the scientific community.

Keywords: Hendrik Schön, scientific fraud, scientific ethics, field effect transistor, Lydia Sohn

Introduction

It has been almost 10 years since one of the greatest frauds in the history of physics was uncovered—the case of Hendrik Schön. This unfortunate episode is, as they say, a teachable moment, an opportunity to educate undergraduate and graduate science students about scientific integrity and that science is very much a human activity that encompasses both the best and sometimes the worst of human behavior. This case also raises important questions about the responsibility of research supervisors as well as the scientific community.

History

This story starts at Bell Labs, when Dr. Bertam Batlogg started a new program to fabricate electronic and opto-electronic devices using the same organic material (Reich, 2009). Up until then, almost all electronic devices like FETs (field effect transistors) were made out of silicon, because a nearly perfect insulating layer of SiO_2 between the gate and the channel is easily fabricated by oxidizing the Si surface. The channel of a FET is the thin layer of silicon just below the oxide layer, as shown in Figure 1. By applying a voltage to the gate, the conductivity of the channel is changed from insulating to conducting. This off-on behavior of the FET channel is used to store and manipulate the binary (zero-one) information that is the basis for all digital electronics. In contrast, almost all opto-electronics devices like light emitting diodes and lasers are made out of III-V materials (compounds consisting of Group III and Group V elements from the periodic table) like gallium arsenide. In order for a semiconducting device to efficiently emit light, the electron must fall from the bottom of the conduction band to the top of the valence band without emitting a sound wave, just a photon of light. This is the case in most III-V materials, but not in silicon.

Bertram Batlogg hired Hendrik Schön in 1997 to be his assistant responsible for device fabrication. A picture of Hendrik Schön is in Figure 2. From 1998-2001, Hendrik Schön reported transistors, lasers,

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Josephson junctions and superconductors made out of organic materials like pentacene and perylene. His results were published in the most prestigious scientific journals, including eight papers in *Science* and seven in *Nature*. By 2002, rumor was that he had been offered an endowed professorship at a major American university and had been nominated for a Nobel Prize, all before the age of 33. It was only through the courage of Lydia Sohn, an untenured assistant professor at Princeton University, that this fraud was uncovered, a full investigation initiated by Bell Labs with the appointment of the Beasley committee, a report issued to Bell Labs by the Beasley committee documenting numerous examples of fraudulent behavior, all of Schön's papers withdrawn and Schön was fired from Bell Labs. A picture of Lydia Sohn is in Figure 3.

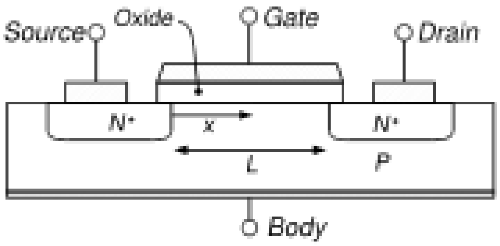

Figure 1. Schematic diagram of a FET (Courtesy of Wikipedia).

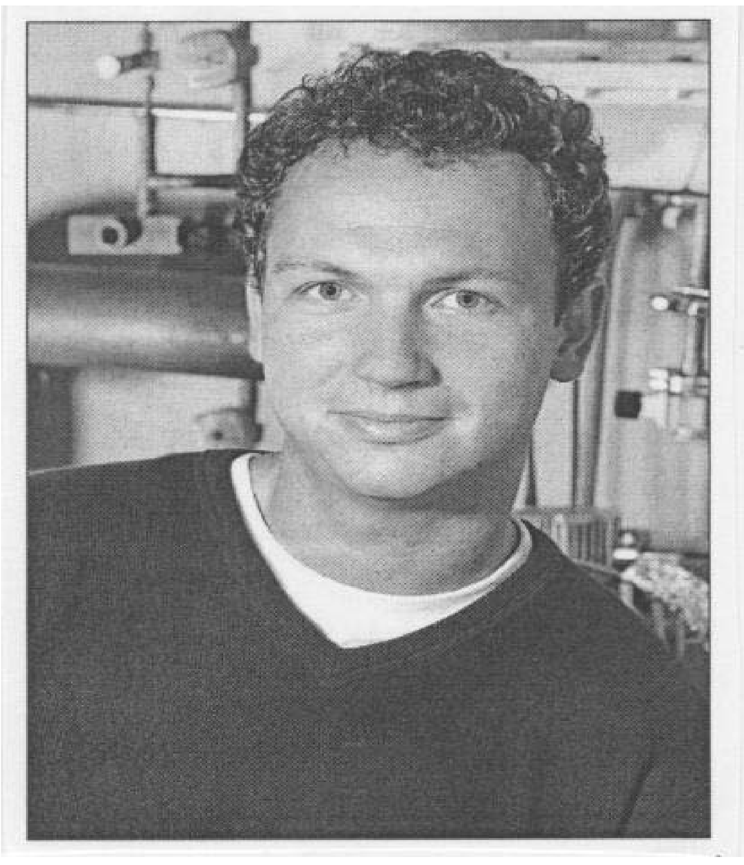

Figure 2. Hendrik Schön. Courtesy of Robert Service (Service, 2002a).

Figure 3. Lydia Sohn. Courtesy of Lydia Sohn (Sohn, 2006).

The Beasley report found nine examples of data substitution, nine examples of unrealistic precision and six examples of results that contradict known laws of physics in the papers of Hendrik Schön (Beasley, Datta, Kogelnik, Kroemer, & Monroe, 2002). It was three cases of data substitution that brought about the end of this fraud (Levi, 2002a). On the left side of Figure 4, the source-to-drain voltage is plotted against the gate voltage for three different organic material FETs reported by Hendrik Schön. In all three plots, the gate voltage is sufficient to turn the transistor on, switching it from an insulating "off" state (high source-to-drain voltage) to a conducting "on" state (low source-to-drain voltage). Noticing on the right side of Figure 4, the high voltage portion of the same three characteristic curves is blown up and has identical shapes, including identical fluctuations from thermal noise. Voltage fluctuations from thermal noise will always be different from one experiment to another, because of the random nature of noise.

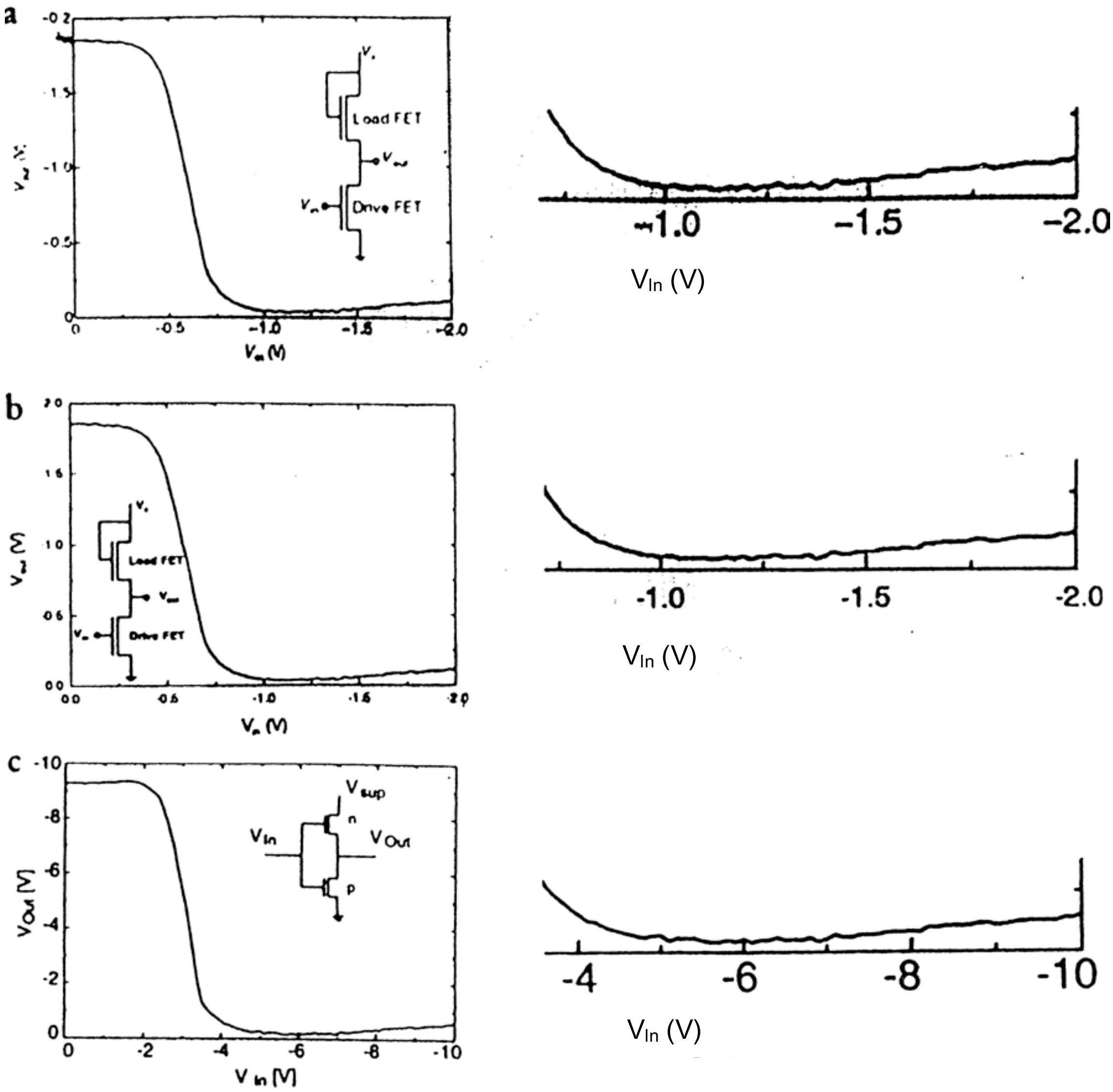

Figure 4. Left side: characteristic curves of three different field effect transistors "fabricated" out of organic materials. The source-to-drain voltage is plotted on the vertical axis against the gate source-to-drain voltage on the horizontal axis. Right side: the high-voltage sides of the three curves on the left are blown up. Courtesy of Barbara Goss Levi (Levi, 2002a).

Lydia Sohn was told of this data substitution by a former colleague at Bell Labs, which convinced her that Schön's work was fraudulent (Reich, 2009). She then risked her professional career by confronting the management of Bell Labs with this fraudulent data and succeeded in persuading Bell Labs to form the Beasley Committee to investigate the work of Hendrik Schön, which quickly led to the firing of Schön and the withdrawal of all of his papers.

Discussion

These events raise a number of important questions. How could Schön pull off such fraud? Why was Bell Labs so gullible? There were a number of elements at work here. Firstly, Schön claimed to have done most of his work in his Ph.D. thesis laboratory in Germany. Consequently, it was easy for him to avoid demonstrating his results and devices to his colleagues at Bell Labs, by giving them the excuse that the devices and materials were in Germany. Secondly, Schön picked up on comments by colleagues who would suggest future experiments. Schön realized that if a scientist suggested a possible experiment and result, he as well as the physics community was much more likely to accept such a result with a minimum of skepticism. Thirdly, Schön took advantage of the Bell Labs' world class reputation; when other scientists could not reproduce Schön's results, it was easy for his colleagues at Bell Labs to believe that Bell Labs was a special place that could do things other labs could not do. Fourthly, Bell Labs was in a precarious financial situation at this time and was inclined to embrace such a set of phenomenal results that would help justify the lab's existence.

This raises a second related question: Why was the physics community so gullible? Part of the answer lies with Schön's supervisor, Bertram Batlogg, who was an internationally known physicist for his work in superconductivity. His name on Schön's papers gave the results instant credibility. Also, the Bell Labs byline added to this credibility. Finally, like Bell Labs, the physics community wanted to believe in organic material-based electronics.

What responsibility did Bertram Batlogg, Schön's supervisor, have in this disaster? The Beasley report was embarrassingly silent on this question. No doubt, Batlogg, whose expertise was in superconductivity, was at a disadvantage in evaluating Schön's work on electronics devices. However, what about Schön's claims of superconductivity? Isn't it reasonable that Batlogg should have insisted on seeing a demonstration of the superconductivity of a new material, before the manuscript went out the door? Isn't reasonable for him to have seen a laser lase, before the manuscript went out the door? Clearly, there was a terrible failure of supervision, and Batlogg must share in the responsibility for this disaster.

What about the importance of reproducibility in the scientific community? Numerous experimental groups around the world were trying to reproduce Schön's results with no success. The major reason for this lack of success was that the FET oxide layers shorted out, due to the high voltages needed to switch on the FETs. There were a few physicists who were expressing serious doubts about Schön's work, but those doubts never reached beyond those few physicists. Meanwhile, tens of graduate students and post docs labored away in futility, including a number who would became so embittered by this experience that they left the field. Isn't it reasonable for the physics community to reserve judgment on any important result until it is confirmed by another lab? Notice that when physicists recently reported that neutrinos traveled faster than the speed of light, the initial reaction of the physics community was skepticism and an immediate expectation that the experiment be repeated in another laboratory. Shouldn't the physics community have the same skeptical reaction for a significant result that they are inclined to believe is correct?

What about Lydia Sohn, the heroine of this story? She risked her career to end this fraud. Her story of courage is just as important, if not more important than Schön's story of fraud. The physics community needs to encourage such heroic behavior in the face of dishonest scientists. And one of the best ways of doing this is by not forgetting but remembering and reminding the physics community of this remarkable display of heroism.

Finally, what about Hendrik Schön, the villain of this story? It is easy to want to forget such an embarrassing tale. However, it is only by remembering this sad tale that we reduce the chances of future frauds being attempted and being successful. This episode reminds us that science is a human endeavor, most times impressive, creative and beneficial, but sometimes, dishonest and harmful.

Conclusions

This case history and the issues it raises provide a wonderful lesson in scientific ethics to beginning undergraduate and graduate science students, and the author has used it as such numerous times. Besides a lesson in science ethics, it is a lesson in human nature. Students should be aware that just because something has been published in a reputable scientific journal does not make it correct. There are numerous examples of the opposite, most times due to honest mistakes but sometimes due to fraudulent behavior. The author's lecture on Hendrik Schön always elicits numerous questions and a very healthy discussion on scientific fraud and the nature of the scientific enterprise.

For those interested in more information about this topic, the book, *Plastic Fantastic: How the Biggest Fraud in Physics Shook the Scientific World*, written by Eugenie Samuel Reich (2009), provides a detailed history of this fraud. For reports about the scandal during its exposure, the series of articles in both *Physics Today* (Levi, 2002a; 2002b) and *Science* (Service, 2002a; 2002b; 2002c) are very well done.

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