EDS Women In Engineering

Women in EDS and Computational Electronics

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Since I was a child, I have been interested in electrical circuits. I made my circuits successfully many times but also blew up several fuses in my parent's house. My favorite subject in primary and high school was physics. I was fascinated with nuclear physics and initially wanted it to be my major and professional focus in life. By the end of high school, I became more interested in practical applications of physics and decided to apply to the Faculty of Electrical Engineering and Information Technologies (FEEIT), University Ss Cyril and Methodius, Skopje, Republic of North Macedonia. I was extremely excited and motivated to become an engineer. I graduated in 1985 with the highest honors and the highest GPA ever since FEEIT was founded. After graduation, I was offered a Lecturer position. As the first woman ever hired in the FEEIT Electronics group, I accepted without reservation. I wanted to be a professor, to teach students how electrical circuits work, and to encourage young women to choose electrical engineering as a career.

In December 1990, I moved with my husband to the United States, where we were accepted into the Ph.D. program at Arizona State University (ASU). To me, the concept of a centralized campus was fascinatingly different from how most universities are situated in Europe. For example, while working on my master's degree in North Macedonia, I often struggled to get a publication that I really needed for my research. It was those times before the internet revolution, so access to literature was very difficult. In contrast, at ASU, I could spend days and nights at Noble Science Library. Everything was within reach: books, periodicals, journal papers…. It was like Disneyland to me. Once my Mom asked me why I wanted to stay in the United States, I pointed her to the Noble Science Library.

I was fortunate to have Prof. David Ferry as a Ph.D. advisor. I learned from him about semiclassical and quantum transport. I also developed an interest in modeling and simulation, which nowadays is recognized as a third mode of investigation, in addition to theory and experiments. The greatest joy of anybody developing simulation software is when you discover a bug in your program, sometimes while asleep. I was fascinated with Richard Feynman's contributions to quantum physics and carefully read his lectures on physics. I was also fascinated with his charisma and read numerous non-scientific books authored by him, such as "The pleasure of finding things out." I decided to make my Ph.D. dissertation work in quantum field theory. I was among the first to apply the near-equilibrium Green's function formalism to modeling low-dimensional systems such as silicon inversion layers and to investigate the impact of collisional broadening of the states on the electron density of states function and electron mobility [1]. Prof. David Ferry made it possible that, while being a poor Ph.D. student at ASU, I attended many scientific conferences and met scientists that I admire, such as Karl Hess from the University of Illinois at Urbana Champaign (UIUC).

After graduation, I spent two years as a post-doc at the Center for Solid-State Electronics Research at ASU (1995–1997). The focus of my research was modeling discrete impurity effects in nanoscale transistors that gave rise to fluctuations in device parameters, such as the threshold voltage (Figure 1), of devices fabricated on the same wafer. Our group pioneered the real-space molecular dynamics treatment of electron-electron and electron-ion interactions within particle-based device simulators in 1999 [2]. We were also among the first to develop a 3D Schrödinger-Poisson solver to model electrostatics in quantum dots.

After being a post-doc for two years, it was time for a real job, and my heart was set on academia. Although there were a lot of research opportunities in industry and in the national research laboratories, they all lacked one key component: the rewarding interaction with students. I strongly believe that helping students to think clearly, to reason logically, to be both imaginative and curious, regardless of their level of knowledge, is essential to society's and our own future development. In August 1997, I was offered an Assistant Professor position at ASU, which became my permanent home. I still enjoy being in Arizona and teaching and doing research at ASU. It was difficult at times to be a young faculty, teach new subjects, prepare lecture notes for classes, guide graduate and undergraduate students, and at the same time work on research projects and proposals to secure funding, but it was worth the effort. Seeing students start from knowing virtually nothing and grow into successful researchers is a privilege, and I enjoy it. The hard work paid off, and in 1998 I won the National Science Foundation (NSF) CAREER award, which strengthened my position at ASU. Afterward, I won many grants from NSF, Office of Naval Research (ONR), Semiconductor Research Corporation (SRC), and others related to semiconductor device modeling.

It was at the Computational Electronics Conference in Osaka, Japan (1998), when Prof. Mark Lundstrom (Purdue University) and Prof. Umberto Ravioli (UIUC) introduced the idea of developing a platform for dissemination of tools to non-experts in modeling and simulation. I immediately bought-in to their idea and suggested my Schred [3] tool. Schred is a tool to calculate quantum-mechanically the electron density and the subband energies in silicon inversion layers (MOS Capacitors). It considers the quantum-mechanical size quantization effects that manifest as bandgap widening and an increase in the average displacement of the carriers from the semiconductor oxide interface. This, in turn, degrades the device transconductance of a MOSFET. In 1999 Schred was deployed on the Purdue University Network Computing Hubs (PUNCH), sponsored by NSF. PUNCH is the predecessor of nanoHub, an NSF-sponsored multi-institution science gateway for the dissemination of tools and educational materials worldwide. One of the firsts on nanoHUB, Schred remains among the most cited tools on the platform.

During my first sabbatical (Dec. 2005–Aug. 2006), in collaboration with Prof. Gerhard Klimeck's group, I ported the PN-junction lab based on the PADRE simulation software. MOSCAP, MOSFET, BJT, and MESFET labs followed in the same way. As a multi-institutional group, we introduced on nanoHub the concept of "tool-based curricula": a collection of tools and educational materials on a particular subject. Soon after, ABACUS (Assembly of Basic Applications for Coordinated Understanding of Semiconductors), AQME (Advancing Quantum Mechanics for Engineers), and ACUTE (Assembly for Computational Electronics) were released. Currently, I am the 3rd largest contributor to nanoHUB from over 2600 contributors from all over the world, and my educational materials served more than 7,000 users in 480 courses from 47 institutions. The usage statistics of my tools deployed on nanoHUB are shown in Figure 2.

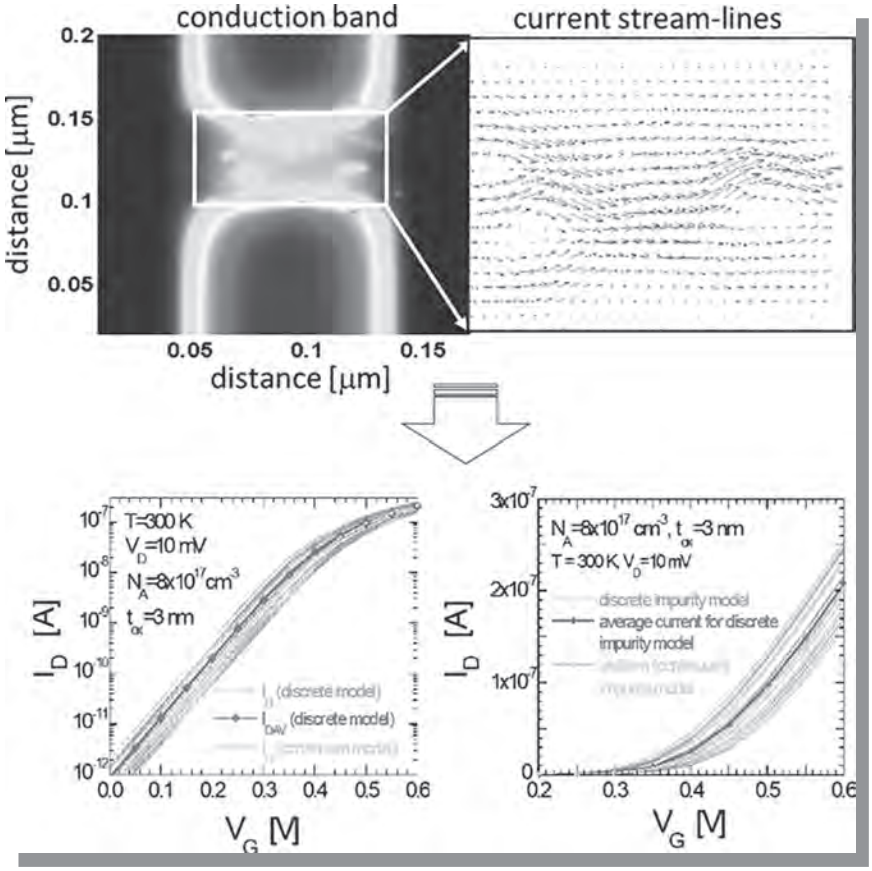

Figure 1. Fluctuations in the confining potential due to the discrete nature of the impurity atoms in the active channel region of the device (top left) that lead to non-uniform current flow (top right). The discrete nature and the different number and distribution of impurities in devices fabricated on the same wafer give rise to threshold voltage fluctuations (bottom).

At ASU, I continue to initiate collaborations with colleagues on topics related to semi-classical and quantum transport modeling. For example, in 2000, based on Feynman's and Kleinert's idea, Prof. David Ferry, introduced the concept of effective potential approach, which mimics the quantum-mechanical space-quantization effects in classical device simulators. The idea was immediately implemented in our in-house 2D Monte Carlo device simulator [4]. In 2008 my PhD student Katerina Raleva (now Professor at FEEIT) was the first to couple particle-based device simulators with energy balance solvers for the acoustic and the optical phonon baths [5], to study self-heating effects in nanoscale transistors as shown in Figure 3. (This work was done in collaboration with Prof. Stephen Goodnick from ASU). My long-time friend and colleague Mary Jo Rack (at that time Intel employee) used to say: "Our transistors are frying!" My postdoc Denis Mamaluy (now at Sandia National Lab) together with my

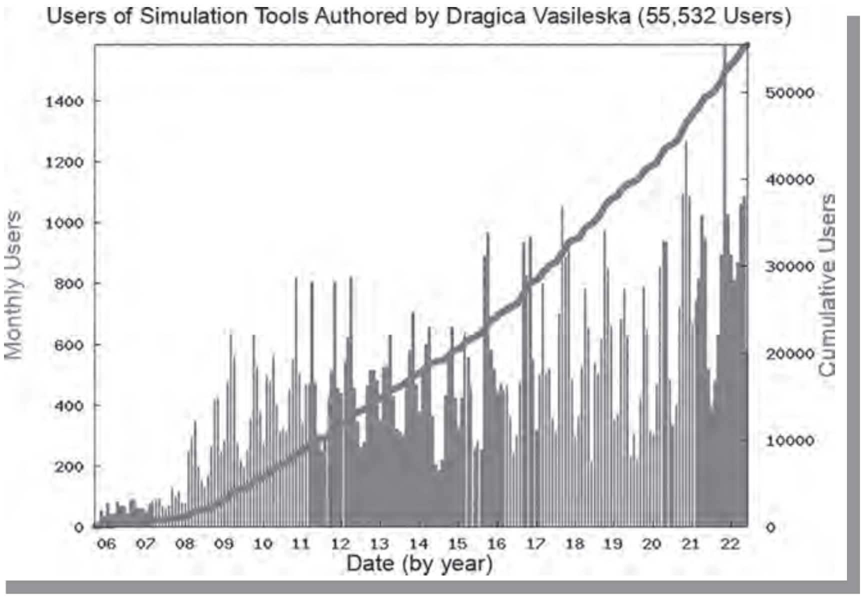

Figure 2. Cumulative User of tools authored by Prof. Vasileska residing on nanoHUB.org.

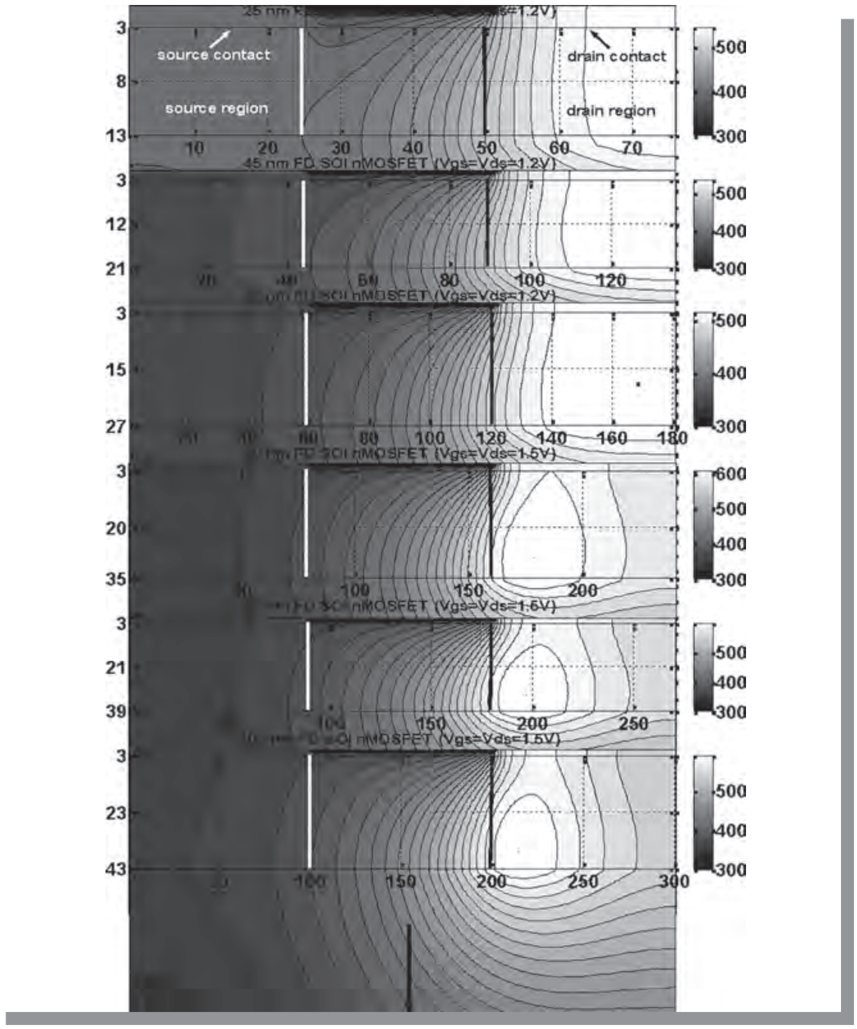

Figure 3. Self-heating in fully-depleted (FD) SOI devices. Here are the lattice temperature profiles for different technology generations in the thin silicon film of the device [6].

PhD student Hasanur Rahman Khan (now at Intel) developed the 3D Contact Block Reduction method in 2006 [6], which was the first tool to study ballistic transport in FinFETs. Several of my Ph.D. students chose careers in academia and the others chose in industry. They are all successful scientists and professionals, and I am proud of them.

I have many collaborations outside of ASU as well: the group of Prof. Peter Vogl at the Walter Schottky Institute in Munich; the group of Prof. Siegfried Selberrher at the Technical University in Vienna (including Prof. Hans Kosina and Mihail Nedjalkov) where I spent my second sabbatical (Sep. 2012 to Dec. 2012); Prof. Asen Asenov's and Prof. John Barker's groups at Glasgow University; and many others. In collaboration with Ben Kaczer and Eric Bury at IMEC, Katerina Raleva and I contributed to the extraction of test device hot-spot temperature using the heater-sensor approach [7] via numerical simulation and comparison with experiments. This collaboration spawned a focus on global thermal modeling in my group. Global thermal modeling is extremely important because the mean free path of phonons is much larger than the mean free path of electrons in silicon. This difference necessitates the use of a global thermal solver that accounts for heat dissipation through the interconnects and the package. My collaboration with Prof. Gilson Wirth and his team at Universidade Federal do Rio Grande do Sul (UFRGS), Porto Alegre, Brazil, spans years, working on random dopant and random telegraph noise fluctuations in nanoscale transistors.

A few years back, my research interests also included modeling the reliability and metastability of CdTe solar cells. This project was initiated by researchers from First Solar and was sponsored by two multi-university research grants from the U.S. Department of Energy (DOE), in which ASU was the lead. PVRD-FASP [8], a tool currently used at

First Solar, was developed by my Ph.D. student Abdul Rawoof Shaik (now at Samsung).

To me, there are many components to success in teaching. For example, a primary goal should be to bring students to a level of understanding that will allow them to independently analyze complicated physical problems. In today's world, engineers require not only technical expertise, but also self-confidence and maturity to implement their ideas and the ideas of others. I believe that it is our obligation to educate rather than train students, give them a strong mathematical foundation, introduce them to state of the art technology, and teach them to be effective team members. Since the designs of the future will need even greater use of computer tools for product development, I also think that we need to:

- Include this new mode of investigation in the undergraduate electrical engineering curricula along with the traditional theoretical and experimental methods, and
- Train graduate students to develop and use such tools with thorough understanding of the physical phenomena involved, so they can interpret the results of the computational simulations realistically and critically.

I equally enjoy teaching specialized graduate-level classes and undergraduate classes. Throughout my time at ASU, I have co/developed and taught numerous courses at undergraduate and graduate level. Sharing knowledge is, in my opinion, most important for the future development of science and technology. I have aggregated selections of my lecture notes, my research work, and the work of my students into three textbooks: *Computational Electronics* (with S. M. Goodnick, Morgan & Claypool publisher), *Computational Electronics: Semi-Classical and Quantum Transport Modeling* (with S. M. Goodnick and G. Klimeck, CRC Press), and *Modeling Self-Heating Effects in Nanoscale Devices* (with K. Raleva, A. Shaik, and S. M. Goodnick, Institute of Physics Publishing, Morgan & Claypool).

While at FEEIT and ASU, I have promoted the inclusion of women in engineering disciplines. For example, I was part of the WISE (Women in Science and Engineering) initiative at ASU for many years, teaching young girls (middle-school and high-school) Boolean algebra and how to make a motor using wire, a battery, magnets, and rubber bands. I enjoyed every moment spent with these young and enthusiastic girls and hoped they became motivated to choose electrical engineering. Women CAN succeed in male-dominated disciplines and become successful professionals in their respective fields. I will continue to introduce women to computational electronics at the undergraduate and graduate levels. I will recruit women into my research activities. Of my 19 PhD and 30 MS students, 4 were women.

I hope that many young women will follow my example and be more successful in the electrical engineering discipline.

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