Understanding at every level

Growing up in Guwahati, Assam in India, Pinaki Mazumder didn't recognize the Canadian legend Wayne Gretzky until he was in his late 20s, earning his master's degree in computer science at the University of Alberta in Edmonton, Canada. But a quote from the hockey great helped shape Mazumder's thinking about his own work:

"A good hockey player plays where the puck is. A great hockey player plays where the puck is going to be."

In the rapidly evolving field of computing, Mazumder learned to raise his eyes to look for the next frontier, and that perspective helped him to become a leader in the field of VLSI (very large-scale integration). His contributions have been widely recognized, as he was made a Fellow of the Institute of Electronics and Electrical Engineers in 1999 and of the American Association for the Advancement of Science in 2007. He also served as a program director for the National Science Foundation.

But by the time Mazumder was inspired by Gretzky's observation, he had already built himself a firm foundation from which to explore next-generation concepts, starting with the fundamentals that underpin everything.

Mazumder knew as a teenager that he wanted to be an electronics engineer, but his teachers advised him to be a scientist, and his father—a high-ranking official in the Indian government—had different ideas. Young Pinaki would need a degree in the sciences or humanities to be eligible for a coveted government administrative appointment, so physics was the compromise.

"I kind of satisfied everybody, but ultimately I did whatever I wanted to do," he said.

Once he had finished a bachelor's of physics (honors) degree at Guwahati University, graduating first in a class of over 100,000, he put in another three years at the Indian Institute of Science in Bangalore to pursue his own interest in electrical engineering. Mazumder earned his second bachelor's degree in 1976 and took a job with Bharat Electronics Ltd. in Bangalore.

At the time, microprocessors were the hot new thing with the launch of Intel's 8-bit model. Mazumder would have liked to help develop them in India, but his supervisors assigned him to integrated circuits for consumer electronic products. Still, he embraced the role and became an expert in design and applications of integrated circuit chips.

In June 1980, Mazumder's parents sent him a photograph of a beautiful young woman, telling him that he would marry her in December. Her name was Deepika, and she was studying to be a medical doctor.

"Mostly, marriages in India were arranged through the families in those days. They wanted to verify the family compatibility and astrological charts. It's really weird, actually, but that's the way it was. I just got a photograph," he said with a laugh. "My request to chat with her over a cup of coffee was summarily rejected, as my parents thought that I would appear too bold to the elderly members of Deepika's family."

The next level

As Deepika finished her residency, Mazumder was weighing his options to learn more about computer architectures and software, building on his more fundamental knowledge of physics and circuits. He decided on a master's degree in computer science, choosing the University of Alberta in part because the program required in-depth thesis research. He left Bangalore shortly after his son, Bhaskar, was born. The family reunited a year later when Deepika, now a full-fledged physician, brought Bhaskar to Canada.

When he started his thesis in 1984, Mazumder first encountered Gretzky's perspective on greatness. While industry was focused on improving single processors, Mazumder recognized that VLSI chips were capable of supporting more than one processor at a time, and his thesis addressed theoretical issues in multicore chips. It was an idea 25 years ahead of its time.

Upon graduation, Mazumder's rare combination of circuit and software knowledge made him a shoe-in at AT&T Bell Labs, where he initiated a software development project for automatically generating digital chips from circuit models written in the programming language C. But when Mazumder's senior colleagues saw his master's thesis and journal articles, they encouraged him to get a PhD.

At the University of Illinois, Mazumder took on a Semiconductor Research Corporation (SRC) sponsored project to develop faster testing methodologies for the future-generation semiconductor memory chips. At the time, memories contained hundreds of thousands of cells—a lot, but it was still manageable to test each cell individually for manufacturing defects.

But Mazumder was again looking ahead to where the puck was going to be for these memories. As the cell numbers climbed to the millions and billions, testing time was a problem on the horizon. He combined the concepts of VLSI process technology, memory layout, circuit design, and mathematical techniques to design a circuitry for the memory that helped reduce chip-testing time by more than one hundredfold.

A decade after Mazumder's doctoral work, several semiconductor manufacturers started adopting his inventions in their memory products. "Dr. Mazumder was the first to argue that testing of random-access memories will require parallel and built-in testing of RAMs. This is now the practice in both offline and built-in testing of RAMs," Professor Sudhakar Reddy of the University of Iowa, a pioneer in the field of VLSI testing, wrote in 1997.

Evolving memories and algorithms

After completing his doctoral degree in 1987, Mazumder wanted to stay in academic research. He began looking for a position as an assistant professor of electrical engineering and computer science.

"I had job offers from a whole bunch of places," said Mazumder. "I considered only universities where they had a medical school as well as a good engineering college. The versatility and reputation of the U-M academic units attracted me the most."

He brought his family of four, including his one-year-old daughter Monika, to Ann Arbor. Deepika became a member of the research faculty at the U-M Health System.

Mazumder continued his research in semiconductor memories and introduced innovative architectures such as self-healing memories and error-correcting circuitry. Mazumder's students conducted research into memories using memristors and quantum tunneling as well as nanomagnetic memory, resulting in multiple patented inventions.

"Dr. Mazumder also initiated the area of built-in self-repair for memories. He was the first to develop designs for embedded repair of memory and computational arrays," Kent W. Fuchs, who is currently the president of University of Florida at Gainesville, wrote in 1995.

In 1989, software development was transitioning from powerful, stand-alone computers to a network of inexpensive desktop computers. Mazumder recognized the need for a new suite of algorithms that would run in parallel, taking advantage of the new distributed computing platforms.

For this purpose, he developed algorithms to solve various types of VLSI layout problems by mimicking the Darwinian principle of “survival of the fittest” for biological species. Electronic design companies subsequently adopted genetic algorithms for VLSI layout design tools as well as simulation and testing software.

“In physical design, he is one of the top leaders, especially in developing placement techniques. The genetic algorithms of which he is a pioneer in applying to CAD has paid off,” Ernest Kuh of UC-Berkeley, a pioneer in VLSI computer-assisted design (CAD), wrote.

Into computer architectures

After receiving tenure in 1992, Mazumder expanded his work to integrate quantum tunneling and memristors into other parts of computer architectures, such as processing and communications. He also developed “spintronic” devices that encode information in electron spins rather than charge. Using computer modeling of circuits and quantum physics, his group demonstrated how quantum tunneling might be used in digital systems and neural (brain-like) computing.

“Dr. Mazumder is unquestionably one of the principal leaders in the design of resonant tunneling circuits, and also unquestionably has simulated the largest systems based on these devices. His designs of RTD [resonant tunneling diode]/transistor circuits have provided some of the first looks at this technology,” Alan Seabaugh of Raytheon TI Systems, who led the QMOS (quantum metal oxide semiconductor) consortium, observed in 1997.

“Dr. Mazumder is regarded as being a leading professional in the field of quantum functional circuit design,” Masafumi Yamamoto of NTT Research Laboratories in Japan concurred.

Mazumder advanced the industry-standard circuit simulator, “SPICE” (Simulation Program with Integrated Circuit Emphasis), and championed the development of the Quantum SPICE simulator. The latter played a key role in designing numerous large-scale quantum tunneling integrated circuits, which were fabricated and tested by Texas Instruments, Raytheon, and Hughes Research Laboratories in the U.S., Nippon Electric Company in Japan, and Korea Advanced Institute of Science & Technology in South Korea.

“I have studied his simulation work for quantum devices (e.g., his extensions to the SPICE program) and found it insightful, solid and practical, a necessary step to extend the research in this area,” Richard Newton, Dean of Engineering of University of California at Berkeley and a co-inventor of SPICE, wrote in Oct. 1996.

In 1999, Mazumder launched a startup company, Nanosys, Inc., for designing nanoscale CMOS (complementary metal oxide semiconductor) VLSI memories that could self-test and self-heal, but the process was derailed in 2000 after tragedy struck his family. Deepika died while participating in an undisclosed drug trial at Michigan Medical School, which led to a decade-long legal battle. It was resolved in 2011 with a scholarship in Deepika’s name for a medical student to advance ethical practices in medicine, particularly in clinical trials.

The panoramic view

Through the turmoil, Mazumder found reprieve in his research, bringing in more than fifty research grants from multiple federal funding agencies during that time. In 2007, Mazumder took a position as a program director for the National Science Foundation (NSF). He led the emerging models and technologies program, funding research in quantum computing, biologically inspired computing and nanoelectronics.

“It was like bathing in a cosmic shower of knowledge from all these different fields,” said Mazumder. “In order to select the proposals that have a high potential for transformative impact, I had to apply my own assessment and that meant voracious reading.”

Since returning from the NSF in 2010, Mazumder has focused on research in neural computing and terahertz engineering, still looking ahead to the next wave in information processing. Mazumder specifically credits program directors at funding agencies for helping him identify research projects that would help enable technologies a decade or more ahead of commercial adoption.

“They nudged me to look at more difficult problems by applying basic sciences in engineering problems. The real excitement with embryonic technologies is to navigate radar-less on uncharted oceans to discover a purpose at the end of the journey,” he said.

Mazumder is a co-author of six advanced VLSI books—two on high-density semiconductor memories, one on routing algorithms for integrated chips, another on genetic algorithms, and two recent books on neuromorphic computing. He is also a co-author of more than 300 archival journal and reviewed conference articles and a co-inventor of 12 U.S. patents. Tapped as an international authority on semiconductor memories, Mazumder has testified on behalf of companies such as Apple, Samsung, Hynix, Xilinx, Micron Technologies, and Hyundai in major lawsuits in USA and Europe.

By Kate McAlpine for The Michigan Engineer*. Posted October 31, 2018*