Meet Professionals

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Education:

- B.Sc., Physics Honors securing first rank in Gauhati University, India
- B.S., Electrical Engineering Indian, Institute of Science, Bangalore, India
- M. Sc., Computer Science University of Alberta, Edmonton, Canada
- Ph.D., Computer Engineering, University of Illinois, Urbana-Champaign

Work Focus:

Mazumder is a Professor focusing on nanoscale VLSI, semiconductor memory systems, nanoelectronics, and biologically inspired algorithms for VLSI systems.

Advice to Students:

"If kids really want to do well, they have to be interested in math, chemistry, and physics -- because basic sciences play a great role."

Links:

- University of Michigan

Interview:

Q: When did you first find that your career path focused on nanotechnology?

Mazumder: To answer your question, my Ph.D. focus was on random-access memory – that was already advancing rapidly and in every couple of years it was quadrupling in terms of memory cells on a chip. Even though at that time it was not nanoscale, the memory technology was indeed moving from the deep submicron scale to the nanoscale dimension. My research initially was to address some of the complexities involved in terms of designing and testing multimegabit memories, such as: What are the memory system design problems? What are the technology-related testing problems? How do you contain the testing costs? How do you ensure high reliability?

But then from 1992 onwards, I started looking into the next generation technologies which involve quantum tunneling transport phenomenon. Since then my research mainly focused on the next generation technologies: first the quantum tunneling devices, then quantum dots, and later spoof surface plasmon polariton based emerging technology. So I will say that I have been working for the next generation technology for over the last 25 years. I had acquired six years of industrial R&D experience prior to doing my PhD degree. Instead of taking advantage of my industrial background to do the current generation work, I moved into the next generation problems. When I worked on my PhD thesis, it was a little bit ahead of the memory technology curve since memory chip manufacturers did not realize what the issues would be in terms of testing costs of the future generation of DRAM chips. The testing community at that time started to recognize the testing complexity of DRAM chips as the integration density surpassed 1 Mega bit per chip. Six years after I completed my thesis by demonstrating a cost-efficient way of testing DRAM chips, memory manufacturers started using the design-for-testability techniques I had developed in my thesis. So in some sense, the word nano had become a vision in my research since 1985 when I started my doctoral work.

Q: What current nanotechnology applications are you working on?

Mazumder: As a professor, I think research is the most important component of our educational activities. Research is a tool to push technology far beyond what the current state is. Being academics, we have certain amount of latitude to charter the course of our research, and we fully exercise our intellectual latitude to look for something which may or may not be applied right now, but which might find commercial applications within the next 10 years. I have legs firmly planted on the practical side involving today's technology because we produce a lot of trained engineers who go to industry to work. But at the same time, in research, we try to look for something that will really make transformative impact, and can potentially make an economic difference. This has been my philosophy for the last 25 years.

We also need to prepare the next generation of doctorate engineers and researchers who will keep this frontier of semiconductor and microchip revolution moving. Sometimes when students join my research group to work on their doctoral dissertation, they express legitimate concerns about their future marketability. If they spend five years or so learning something that is somewhat off-beat and out-of-the box, then how that esoteric knowledge and experience will help them to get a relevant job. However, after finishing their doctoral work they often find out that the kind of knowledge and training they have acquired is very privy. Most my doctoral students receive multiple job offers from leading VLSI and EDA companies. The R&D labs in industry are not looking for someone who can just incrementally change a product or an existing system by tweaking a few things. When the top-notch industrial R&D labs recruit someone with a PhD degree, they want their brain and the big ideas they can conceive, and not the incremental chores that industry can get accomplished by regular engineers with a bachelor or master degree.

Q: What's the most rewarding thing about working with nanotechnology?

Mazumder: My first degree (BSc Honors) was in physics, the second (BSEE) was in electrical engineering, the third (MSc) in computer science, and the fourth (PhD) in computer engineering. So in some sense, my perspective on nanotechnology is quite a bit different from many other researchers who may be concentrating on nanoparticles, or trying to develop some new sensing techniques using nanostructures. My perspective is a holistic view of nano-system design, starting from physics all the way to the system applications. I don't think if I had stuck to just one type of work, I would have imbibed this type of expansive expertise. I have to continuously educate myself, and I have to navigate between materials scientists, device engineers, circuit engineers, and many other specialists. So, in some sense it is very challenging, especially training the students so that they can work on visionary research projects right after they come to my research group with an undergrad degree. This is also a very big challenge and a daunting task for students to meet the expectations of research sponsors. The multi-disciplinary perspective helps when you keep on doing cutting-edge research by securing competitive research grants -- and when we succeed in regularly graduating students who get good jobs and publish archival papers; probably, that is the overall satisfaction in our teaching career.

Q: Is there an example you can provide that shows how something you've worked on has positively impacted the world?

Mazumder: My in-line (parallel) testing techniques have been adapted by major semiconductor memory manufacturers to reduce the testing cost considerably. In other areas also, we have done some very interesting work. I will say that the one that impacted the commercial companies the most is in the semiconductor memory area.

I also developed the genetic algorithm based VLSI system design. I was always interested by the fact that the science imitates nature in the sense that many computational models are inspired by the way nature continually adapts in its ever-evolving environment -- particularly how artificial neural networks and evolutionary algorithms are modeled by mimicking nature.

When I joined the University of Michigan, I developed a new course on electronic design automation, and I followed it up by beginning some research work on the genetic algorithm. At that time, the computing industry was moving from the mainframe computer to the desktop. Most of the design automation tools were written to run efficiently on a single processor. So by networking thousands of computers on engineers' desks frequently sitting idle, we wanted to take advantage of the latent computing resource by developing EDA algorithms that could run efficiently in parallel. There are some mathematical applications of the genetic algorithm like functional optimization which really works very well. The chromosomes of genetic representation mostly comprise straightforward strings of 1's and 0's. But trying to apply this to a real life problem, like the cell placement in a VLSI chip, designing optimal layouts, or testing VLSI chips, then it becomes a very difficult task. Working with Dr. Elizabeth Rudnick, the coauthor of our book on genetic algorithms for VLSI problems, we spent a lot of time (about six years of my research) developing clever types of chromosome models for VLSI design problems. Our idea was to develop genetic algorithm based EDA tools to run efficiently on a network of computers. I believe that our work made good impact and we were the first generation genetic algorithm researchers who have very comprehensively adopted the algorithm for VLSI applications.

I have a few good advisors at the University of California at Berkeley, and they followed my research over many years. They advised me at that time to concentrate in nanoelectronics since with my engineering background I would do much better in nanoelectronics than in developing faster combinatorial optimization algorithms since I am not a mathematician by training. So, in order to move over to nanoelectronics completely, I coauthored a definitive book on genetic algorithms. We demonstrated how genetic algorithms can be applied to a wide class of multidimensional optimization problems with a view to challenging mathematicians to develop robust theoretical framework that will allow experimentalists to improve the performance of their empirically driven tools. Even though I cannot really pin down how many people are using genetic algorithms being inspired by our book and what applications they are working on, I do know that there has been a catalytic impact of our research work in various engineering fields.

Q: What do you think is the single greatest impact nanotechnology has had on the world thus far?

Mazumder: No matter whom you ask, we are confined by our own limitations of knowledge and technical expertise. For me -- because I directed a National Science Foundation program involving nanotechnology, with nanoelectronics, photonics, and biological computing as its chief areas of research-- I had got a rare opportunity to witness what is going on nationally in universities, government laboratories as well as in industries. Collectively, our research endeavors make significant impact when we create innovations and transformative ideas by leveraging the triumvirate synergy between universities, industries and local and federal governments to build a research infrastructure and nexus that can propel the accelerated economic growth and sustain the U.S. competitiveness in the global high-tech market.

From my personal viewpoint, the CMOS industry has basically progressed following the trajectory of the Moore's law which prognosticated that every 18 months or so technological feature sizes in VLSI chips would decrease by a factor of two. Now, that has happened mostly by continually shrinking the dimensions of transistors, wires, and other devices within a chip. This scaling trend had started from the 1970’s, and it is still continuing well after four eventful decades. For the past twenty years, the crystal-gazing pundits in microelectronics have been periodically forecasting "Oh, CMOS will hit the ultimate red brick wall and stop growing in density of integration." Common people believe that companies like Intel and IBM have been achieving the major breakthroughs in their research laboratories to sustain CMOS forever. However, if you look at this matter more carefully, you will find that in the last 15 years federal funding agencies such as NSF, DARPA, ONR, AFOSR and ARO, have collectively provided over several hundred million dollars per year to foster research and education in nanotechnology that helped train the engineering workforce. Many of these researchers had worked on nanoparticles, quantum dots, nanowires, and all sorts of out-of-the-box stuff. After graduating these engineers had joined companies like Intel, IBM and AMD and utilized their training in universities to push the edge of the CMOS technology overcoming all sorts of perceived barriers. New materials, new process technologies, new circuit design ideas, and many such innovations have brought about the nanoscale CMOS revolution. I do believe that the biggest contribution of the nanotechnology research is the preparation of the next generation of engineers for CMOS industry.

Q: Please give an example of what you envision nanotechnology applications leading to in the future.

Mazumder: Again, I will confine my answer to nanoelectronics. I will not get into materials science, chemical engineering, mechanical engineering. They have plenty of applications too. From the nanoelectronics point of view, I believe that at some point there are certain areas where nanoelectronics will make an impact. One is the area of terahertz; maybe not so much in computing, but in communications, health sciences, and sensing of explosives, biohazards, and biomaterials such as DNA. These are new frontiers of nanotechnology research which will make commercial impact. The other area where nanoelectronics could make impact is in the convergence of communication and computing at higher and near terahertz frequencies. Currently, wireless systems operate at a frequency in the regime of 70 gigahertz. But in the future, optical communications will be co-integrated in VLSI chips for ultra-fast information processing. Therefore, nanotechnology research in photonics, plasmonics, and electronics will dramatically increase bandwidths for computing and communications.

Q: Do you find yourself working more in a team situation, or more alone?

Mazumder: It's a combination, actually. You just cannot be by yourself and like Archimedes you cannot expect to get out of your bath tub proclaiming a new discovery as fundamental as buoyancy. You cannot remain disconnected. But at the same time, the creativity comes from individual effort to a large extent. All these routine things like project reports, group meetings, e-conferences, and managing a research center can devour your valuable time impairing inventions, creativity and imagination.

Q: If you work more as a team, what are some of the other areas of expertise of your team members?

Mazumder: Right now I work with professors at various universities including my colleagues at the University of Michigan. Recently, I led a ten million dollar collaborative proposal involving sixteen different universities. I invited distinguished researchers including some members of national academy of science and national academy of engineering. I don't know if our proposal will be ultimately funded or not since we are still running through various hoops like pre-proposal, full proposal and site visit. If our proposal is funded, this will give us a wonderful opportunity to work with 25 different researchers from 16 different universities. More than before, now it is important to make effective connections that transcend the geographical boundaries. Having Internet, Skype, Webex, Twitter and other social network gizmos definitely helps in these days allowing us to work in a virtual research center.

Q: Did your university training help you in your nanotechnology work?

Mazumder: No, very little in actuality. This is because I am not working in device technology. In that case, I would have taken advantage of the excellent fabrication facilities the University of Michigan has established in its Lurie Nanofabrication Laboratory. My nanotechnology research straddles over different fields of study in information science and technology that largely depend on computer modeling and developing theoretical insights.

Q: Do you have a mentor? Did you in your college years?

Mazumder: The mentor-protégé relationship is not like the advisor-advisee relationship, it's more inspirational. Sometimes the people who are working with you in your own organization, including senior professors in your department, cannot be an effective mentor due to intrinsic conflict of interest. On the contrary, somebody from outside of your own university who has no direct day-to-day dealings with you may have insightful viewpoints that become much more efficacious feedback for you to improve yourself. You can trust them also because they are not directly competing with you for resources. As an example, when I originally wrote a 120-page review paper on VLSI cell placement, it was distributed to over one hundred universities in the form of a technical report. Out of nowhere, a world-renowned professor from the University of California at Berkeley contacted me evincing a great interest in my research work. He was the most renowned and decorated professor in VLSI design automation field of research. I was at that time just a new assistant professor at the University of Michigan. Very fortunately for me, he came to visit Michigan for an unrelated meeting after I published my paper. Apparently, on his own he came to the UM engineering building and met my chairman to set up a meeting with this new professor named Mazumder. He served as the Dean of Engineering at the University of California and my chairman was puzzled why a so highly esteemed senior professor was eager to meet an assistant professor who just began his research career! Ever since I have valued the feedback he had provided to me regarding my research activities and I consider him as my mentor. His name is Professor Ernest S. Kuh (http://www.eecs.berkeley.edu/~kuh/). You never know how a mentor relationship spawns from unexpected events in life.

Q: If you had to do it all over again, would you still focus on nanotechnology applications?

Mazumder: I was born in India in a Hindu family. So I am predisposed to believe in the reincarnation theory, so this is absolutely possible! If I have to re-select my career, I think I will concentrate on my tennis though after a bad ankle injury a few years ago I am hobbling now and have stopped playing competitive club tennis.

At some point in my life, I was just debating whether to play more tennis or do my PhD. As a matter of fact, because of that conundrum I was harboring in my mind, I turned down PhD admission from a top-ranked US university at that time and joined a semiconductor company in India to play more tennis. I thought that I would just work for 8 hours and then play a lot of tennis to hone my skills to get even against those mighty players who used to bagel me. That dream remained unfulfilled, and I concentrated on my engineering research instead. There are huge challenges and rewards in a research career. I have two kids who were born when I was doing my Ph.D. So, it was always very difficult for me to balance what is good for my family with my own work interests. Some people regret this arduous journey for the toll one has to pay. My kids are doing fine that gives me some solace. We, the research professors, become obsessed with our own work and regrettably become disconnected from normal people in the society. However through my tennis games, I managed to stay connected with a lot of people in different walks of life. Advantage tennis: sometimes you are beaten in tennis match by a 60-year-old skilled player and sometimes you play hard to beat an energetic 18-year-old high school player. The bandwidth of my interaction with people outside of my research domain is very wide. That is how I retain my sanity and get re-energized for my research.

Q: If a high school or college student was interested in nanotechnology, what advice would you give them to help prepare take on those roles?

Mazumder: The fundamental basis in science and technology is math and physics. That is the foundation, and it allows you to do better work for a longer duration. If kids really want to do well, they have to be interested in math, chemistry, and physics -- because basic sciences play a great role in shaping their career. If I had not obtained my first degree in physics, I would have just focused on semiconductor memory research work. I think the foundation in basic science is very important for a long career in research and education.

Nanotechnology on the experimental side looks very exciting, and I find that there is a lot of excitement and curiosity among K-12 students when we talk about nanotechnology. It is important to reach out to K-12 students, undergraduates, females, and minorities to broaden the impact of our research projects. National Science Foundation specifically stresses this dimension in every research project it funds so that every member of the larger segments of the US society can participate in research and higher education in science and engineering. At the University of Michigan, we try to address the societal aspects of our research also to a great extent. There are many outreach programs such as Computer Science for High School, Grace Hopper Project and Girls in Science and Engineering to benefit the community at large. I am presently working on plasmonics, nanoparticles and nanowires which tend to light up with the movement of information. School kids and undergraduate students can be easily excited by such demonstrative research. It is very visual, very imaginative. It is easy to inspire a kid who is already excited and convinced that instead of playing basketball he wants to participate in research and do some exciting science project. But the difficult part is showing K-12 students the potential of other forms of nanotechnology that are purely knowledge based.