Chasing Nano

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Through the window in this building set back almost among the eucalyptus trees on the hill above the University of California's Berkeley campus, there's a panoramic view of the San Francisco Bay: Sunlight reflects dazzlingly off the bay's waters. However, we're not here for the view. Professor Arunava Majumdar has brought us to this conference room because, he says, we have a better chance of being undisturbed here than in his office.

Since we've arrived for this interview, students and colleagues have knocked on Majumdar's office door every minute or so. We've already had to wait a week for him to get off the road. Majumdar is on the U.S. Department of Energy's Council on Energy Engineering Research and advises NASA, among many other activities, and, as vice chairman of Berkeley's Department of Mechanical Engineering, he has a big meeting in an hour. Altogether, Majumdar is a man who's much in demand.

That's because he's among the vanguard of those thinkers who are making nanotechnology into a real science. Nanotech — machinery engineered on the scale of the vanishingly small — was an obviously cool idea when physicist Richard Feynman proposed it in a 1959 lecture, “There’s Plenty of Room at the Bottom.” In the 1980s, K. Eric Drexler’s book, Engines of Creation, generated wider enthusiasm for the concept, without providing answers to — or, indeed, showing much understanding of - the immense practical problems of architecting real molecules. It has taken people like Doctor Majumdar to begin doing that.

We wondered what impelled Majumdar to embrace nanotechnology at the beginning of the 1990s, a decision that conceivably could have sent him down an unproductive avenue during some of his potentially most productive years.

“Firstly, nobody else was doing nano,” Majumdar says. “Then, it was clear to us — me, my students and some colleagues — that the science changed when you went down to those scales. And whenever there’s new science, there are opportunities for new engineering. Certainly, there’ll be blind alleys. But whenever you’re doing research, you’re going into the unknown. It’s not science otherwise.”

As it turned out, Majumdar’s work gained him the National Science Foundation’s prestigious Young Investigator Award in 1992, which translated into both financial support and visibility. Furthermore, he says, the research itself had tremendous implications that have extended to the present day. “For instance, we developed a microscope which enabled us to diagnose things down to the 0.05 micron level. Then, in 1993, we published our first paper on how we could image a single transistor’s temperature distribution. So that kind of chip diagnostic device is one outcome of that research. Beyond that, we were led to some beautiful science about heat transport and such, which even the physicists didn’t fully understand.”

At the nanoscale, Majumdar explains, heat conduction in solids looks much like optics and the theories for optics are equally valid for heat.

“In other words,” he tells us, “heat moving through a solid has the same wave-particle duality as light. You can think about heat as a wave and as a particle. This was theoretically expected as far back as Einstein, but to exploit those effects at the nanoscale you must build materials and devices at that scale. That wasn’t possible ’til now.”

We stare through the window at the blazing sun. Hints of the possible advantages of exploiting quantum effects in relation to heat are, tantalizingly, just beyond our comprehension. If you can use these effects, we ask, what might you do?

“You might develop generators and batteries — things about the size of a cigarette lighter cartridge — that could power your laptop for a year,” Majumdar says. “The knowledge we’ve gathered over the last decade about how physics happens at the nanoscale has let us design materials with extremely high or extremely low thermal conductivity. With optics, if you put multiple materials together — alternate materials A and B, A and B, and so on — you can build optical filters such that light cannot go through. We can do the same for heat. If we alternate materials A and B, and A and maybe C, we can design materials so that they’re 10 or 20 molecules thick and function as a super-insulator — or as a super-conductor because, once you understand physics at that level, you can go either way. Think about a technology that’s superior to current batteries by a factor of five or 10. That’s what we’re shooting for.”

Nowadays, Mujumdar’s group is researching another arena where potential applications for nanotechnology abound. Back when nanotech was just science fiction, its proponents countered naysayers’ claims about nano-sized machines’ impossibility by pointing out that biological cells are such mechanisms. As nanotechnology has actually developed, it’s transpired that a fruitful approach is to study biological mechanisms in order to make machines using biological principles.

“Initially,” Majumdar continues, “the two questions we asked were: What can biology do for the non-biological sciences and — the other way around — what might the non-biological sciences do for biology? In the latter area, we’re getting funded by the National Cancer Institute to develop technology for cancer detection and molecular profiling. So disease detection and, maybe, drug discovery are what non-biological technology can do for biology.”

This technology will come in a watch-size array: a chip with multiple wells, with each well detecting a specific protein or other biological molecule. Majumdar says he and his researchers are also trying things the other way around: They’re attempting to use biology to make non-biological materials. “A DNA molecule, besides being a wonderful information storage medium, is extremely small and robust. So one asks, could it assemble materials like semiconductors, metals and ceramics to achieve properties which one mightn't get otherwise?"

We realize that our time is up. Majumdar has to leave for his next appointment. So we ask quickly: Is that really possible?

"Oh yes," Majumdar answers casually. "People are using DNA — with limited success so far — to assemble silicon devices which, while they're not at the microchip level, are very, very small." He shakes our hand and moves toward the door.