Ashutosh Sharma

Ashutosh Sharma (Department of Chemical Engineering, Indian Institute of Technology, Kanpur) was awarded the Infosys Prize for Engineering and Computer Science in 2010. He delivered the first lecture in the series organized by the Infosys Science Foundation to popularize science in the country. He gave a talk on technologies inspired by nature at Infosys, Bangalore, on 22 September 2011. In his talk Sharma said that the years and decades to come will foresee an increased use of nanotechnology. According to him, nanotechnology is not the 'high-tech' science and impacts everyday life; it finds application in stain and wrinkle-proof clothes, in tennis balls and skin creams. He firmly believes that 'creativity is all about finding connections between things that are unrelated' and that 'the problem is more important than the methodology'. *Current Science* interviewed Sharma after his talk. The following are excerpts from the interview.

About your work on nanotechnology ...

Even before nanotechnology became a buzzword, we were looking at nanomechanics. In nanomechanics, we try to understand how small-scale systems self-organize. A major contribution of my group has been in understanding self-organization, guiding it and controlling it on small scales; and then we use that as a tool of micro/nano fabrication. We recently made nanolenses by self-organization, which turned out to be a useful product, both in terms of fundamental science and technology applications. We also look at micro- and nano-patterning of surfaces; to make surfaces more functional, to control friction on the surface, adhesion or wetting properties (like water repellence). Nanotexturing surfaces in the conventional way would be expensive. So we develop new techniques based on self-organization to functionalize coatings.

We work on carbon materials and devices, in particular amorphous carbons (of varying graphitic content and properties) derived from polymer precursors. We are developing new techniques for fabrication of micro/nano devices and materials that are based on carbon. In particular, we are looking at fabrication of catalytic filters, sensors, electrochemical systems and microbatteries, all of which require new nano-architecture. Our other work is related to adhesion, where we look at two basic problems – making sticky surfaces of non-sticky materials, and making non-sticky surfaces of the materials that are sticky, but the constraint is to do these transformations without changing the material or its chemistry!

We are now looking at some aspects of drug delivery using carbon capsules. Amorphous carbon is biocompatible and can be functionalized; you can seek the drug target, and the toxic material is hidden inside the capsule. You can also synthesize nanomaterials at high temperatures within the carbon capsule, which could not be done with microemulsions. I also have a project with a medical college in Lucknow and this involves looking at more efficient markers for MRI imaging. The materials that are used for imaging are highly toxic and get dispersed in the body. If you encapsulate these materials in carbon capsules, you can do imaging and the particles will not come in contact with the tissues.

Areas you will look at over the next five years ...

We will continue to work on nano-mechanics and self-organization in soft nanostructures, drug delivery, bio-imaging and bio-sensing. We are also going to work on how to increase the area of heterojunctions to make more efficient solar cells. We have a lot of industrially relevant projects. One such project is related to detergency – how does a particle stick onto a surface, what forces are involved and how can we control those forces to remove the particles? We would continue our work on catalytic webs and filters using nanofibres for environmental remediation. Besides, we are making carbon devices.

Your approach to research ...

We combine the mechanics, materials and manufacturing aspects, rather than looking at each one of them in isolation. We pay special attention to things that are scalable for manufacturing and techniques that are portable across a variety of materials, such that the technique of fabrication is not something that works only with one material. We always keep in mind whether what we are proposing can be used for mass manufacturing or the technique is limited only to research. No matter how powerful a technique is, if you cannot make one million pieces using the same technique then it is not going to serve the purpose. This is something very few scientists appreciate. There are lots of breakthroughs, but they are limited to labs.

The philosophy I have had about doing research is that if I know everything about an area, I don't work on it any further. So, every five–six years we change the areas we work on. It does mean a lot of wastage also in the sense that we have to put in a lot of new energy and time in understanding and doing something new in an area in which you don't have a background. It is good for personal growth, even though it may not always be good for professional growth because there is a lag time before we catch up with other people. However, we learn something in the process and sometimes basic simple things that most specialists would overlook do turn up!

Taking published work to the layman ...

It is a question of details that reach the layman. The work we do reaches the layman through the popular press. But you cannot get accurate scientific reporting in our country! What I tell reporters and what they write sometimes has no correlation. Early on in my career I used to work in biomedical areas like corneal wound healing, dry eyes and stem cells for cornea. I was a full-time research faculty at the School of Medicine in the US before I returned to India. At the time when we were developing therapies and understanding the cause of dry eyes, one of the national newspapers reported a fancy story about a 100% effective therapy that I have developed. I received letters from people all over the world asking for help. I had never said to the reporter that I had a therapy; I told him that we are looking at it. But unless popular press reports a therapy, nobody would take an interest in reading it; so they make the story sensational. This process conveys an impression that is scientifically inaccurate or dishonest. So I am wary of popular press. I wrote letters to the management complaining that inaccurate things are being reported and they should have a reporter with a science background. So one link of getting to the layman about science is the popular press, but if that is not functioning well you can never get anything to the layman. You only get stories, not science.

From laboratory to industry and marketplace ...

This is a very complex issue. Technology is not a single thing. For instance, if you use a detergent, it is not a single technology; there are several aspects of making a good detergent. A couple of those aspects might have come from my group, and a couple might have come from somewhere else, and hundreds of them already existed. The value addition to technology is finally incremental. It is not that you are going to discover a new detergent; that will not happen because it is an old-age technology. You cannot say when it is going to be in the market. In any case our agreements with the companies never tell us what is in the market and what is not. That is about complex technologies, a combination of several factors.

On the other hand, a single technology can be immediately seen in the market. Technology transfer of a single product or a single process depends largely on the industry that is going to pick it up and on the intermediaries or start-ups, which will produce a prototype and then coordinate with the industry to sell it. The industry will then have to mass manufacture or market the product. This period can be anywhere between five years to infinite years. It cannot be less than five years. If it is a health product, then it could be much longer; you need to carry out animal and human testing, take FDA approvals, etc. and it could have a large gestation period.

It is not reasonable to expect a professor to raise money for research, carry out research, guide students, publish papers, keep accounts, teach, go to conferences and meetings, do administration and then also do technology transfer, which means run after a lot of companies, and then see what is the economy of scale and what is the market for it. It does not happen and will not happen. So unless we have a streamlined system such as many start-ups, which takes things from academia, translates them, develops prototypes for few years, gets funding from somewhere (including industries), knows where the requirements are, this process of technology transfer will never be complete.

Nanotechnology research in India on the world scene ...

China is clearly quite ahead of us. Although DST's nanomission has made tremendous impact by jump starting the nano-research in India, we need to scale-up our efforts and numbers and quality a lot. Computer science is one of the strengths of the Indian economy, because compared to many other industries, the IT sector has done rather well. We have not been so competitive in manufacturing. Even in the sector where we have done well, we have not produced Ph Ds in sufficient numbers. If we look at China I think it produces 3000 Ph Ds per year in the same sector. There is absolutely no comparison between where we are and where we want to be. We do need Ph Ds; we need people who have some advanced knowledge about certain things and who have spent more time thinking deeper about the problems and how to solve them. If you look at the national institutes of technology, I think half their faculty may not even have Ph Ds. If we don't have quality researchers and quality teachers, we are not going to produce a second generation of quality researchers.

Nanotechnology courses at the undergraduate level ...

I always thought about this as not being a great idea. In limited quantities and at a few places it is still not a problem and it is also fairly clear that most universities around the world don't have a degree programme in nanotechnology at the undergraduate level. There are some that have gone ahead with it, but these numbers are sufficiently small and they will have a market. After graduating most of these people might pick up another degree, and do some more work. Nanotechnology is on a diversifying mode, it is not a single discipline; so one could be a health researcher, a physicist, a chemist, or an engineer of ten different kinds, doing nanotechnology.

Funding, the reason behind nanotechnology catching up ...

It is a global phenomenon; it is not limited to India. There is certainly more funding for nanotechnology; I would say roughly 60–70% of the funding globally, no matter in which area, is related in some way to nano. It also means that more people work in that area and it is very competitive. If you go to the US, the chances of getting funding for a project in a traditional research area are nearly zero. Things that were funded twenty years ago will not get funded today. This clearly means that there are more people and there is acknowledgement of the field, and this holds promise for the future. There is more funding because there is perceived need and more people working in the area.

About the threats and scepticism surrounding the use of nanoparticles in everyday products ...

Every new technology has concurrent ethical concerns and carries with it a certain amount of risk. Nanotechnology is no different; it is a very alive area of research. At the moment I don't know if there is a great risk from nanotechnology but there is intense research surrounding these issues.

One could look at what could be the health effects of nanoparticles of different kinds, or of nanomaterials and nanodevices, but I don't think there is anything out there which affirms that there is great threat of any kind. Standards are being evolved. Like for any other technology, you need to have standards for its use. Clearly you should not inhale particles and you should not eat them. There are clear guidelines for how you will manipulate or deal with nanomaterials. There will be more research, more reports and standards, but it is not something you can roll back. Even if certain things are found to be hazardous; you will find ways to deal with those hazards, but you won't say that you will not pursue nanotechnology.

The way chemical engineering has evolved from your graduate days up to now ...

There is not a great deal of change in teaching. Some of the courses follow the same textbooks that were followed when I was an undergraduate. It is nearly 30 years now that I graduated. And those textbooks were already 30 years old when I was a student, or maybe 50.

Research has completely changed. There is little continuity of what people were doing back then to what people are doing now. For instance, much of the research in chemical engineering at that time was concentrated on petroleum refining, chemical complexes and chemical manufacturing. However, there is little research that is needed anymore because these things have become standard. Now there are new challenges to pursue. At that time the challenge was in processes; now it is in materials; there is a shift from process to product of a material. That is one change that I have seen in my lifetime. There was also more emphasis on mathematics and mathematical modelling; now you don't need as much maths when you want to design a new material. There is also a rise of mathematics in another guise, which is molecular modelling. If you bring a professor from 30 years ago to today, he would both be surprised and happy.

The boundaries between different subjects of science are dissolving and at the same time, there is increasing specialization in subfields ...

Specializations did not exist about a century ago. There came a phase where there was fragmentation of knowledge and people created these compartments out of nothing. Now there is push-back to dissolve these boundaries because this fragmentation has become extreme. There was a need for fragmentation; clearly that's why it happened. There is a need for dissolving these boundaries because the challenge with energy, health and water requires a multidimensional approach; you require people who can think outside their domains.

My take on this is to have departments only for undergraduate teaching, but in terms of research don't belong to one particular department. This would be the right way to organize universities, so that people don't get too possessive about their turfs, both in terms of what areas of research they want to pursue and whom they can guide. Every Ph D student, once admitted to a university, should be free to choose where she would work and the area in which she would work. This kind of crosstalk and mobility across the departments is far more common and acceptable in the US. We need to do a lot more in this direction.

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