Anatomy of a Discovery

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Pratik Mankidy (seated) and Ramakrishnan Rajagopolan study polymer fibers with the Scanning Electron Microscope.

"The seeds of great discoveries are constantly floating around us, but they only take root in minds well prepared to receive them." Joseph Henry, American physicist (1797-1878)

Some Eureka moments are more drawn out than others. For Pratik Mankidy, a Ph.D. student in the Department of Chemical Engineering at Penn State, the timeframe from "aha" to understanding took the better part of a year.

"We were working with a NSF grant to develop a nanochannel reactor, a type of template for a polymeric reaction that we hoped would grow polymer nanofibers. We introduced a monomer on one side of the template, an anodized alumina membrane with thousands of pores, with the catalyst in the walls of the membrane. We hoped polymer fibers would come out the other side of the template," Mankidy says about the research project that led to his discovery.

When the diameter of fibers is shrunk to the submicron or nanometer scale, the result is much superior tensile strength and a large surface to volume area ratio. The industrially produced fibers have already been used for nanofiber reinforced composites, cosmetics, tissue templating, wound dressing, protective clothing and some electrical and optical applications. By coating a tightly woven filter of nanofiber material with the proper agent, a good defense could be made against chemical and biological threats. Mankidy hoped to find an easier way to produce the nanofibers.

One day last summer, Mankidy placed the disc-shaped membrane he was using for the experiments under a scanning electron microscope and saw something unexpected. Patterns of nanofibers had sprouted on his membrane in places that he had touched. The fibers were hundreds of microns in length with a typical diameter of 200 to 250 nanometers, which is comparable to the size of fibers produced industrially. "Usually to create nanofibers like these you would need to use high voltage and ultrahigh vacuum. We were getting amazing reactions in room conditions without having to treat the air," Mankidy says.

What followed was a frustrating seven months seeing the nanofibers appear and disappear. "We made our discovery during the summer, but when we tried to replicate our experiment in the fall and winter, we had trouble. I had six fellow graduate students sitting around arguing about our experiments, giving us all kinds of suggestions. We just weren’t getting the results," Mankidy recalls.

Maybe if the young researchers had spent more time in front of the television instead of in the lab, the answer would have come to them sooner. In order to work with the template, Mankidy and Ramakrishnan Rajagopolan, a research associate at Penn State's Materials Research Institute, had attached it to a flat metal washer using a liquid monomer, commonly known as Super Glue®, which they purchased by the gallon at the local CVS pharmacy. The use of Super Glue® as an investigative tool is a staple of forensic detective shows like CSI Miami and others. In those shows, a vapor of the glue is sprayed over a surface and latent fingerprints appear. The process works best in high humidity, typical conditions for a central Pennsylvania summer.

"I began to read up on cyanoacrylate, the basic ingredient of Super Glue®, and found that it has long been used by forensic scientists in a vapor form to bring out fingerprints. When we began conducting humidity experiments, we became sure that fingerprints had something to do with initiating the growth. It was a relief to finally make that discovery," says Mankidy, who with his advisor, professor of chemical engineering and chemistry Henry Foley, and Rajagopalan have authored a paper for the Royal Chemical Society's *Chemical Communications*. "Our next step became to find out what it was in the fingerprint that caused the reaction."

They discovered that fingerprints were a complex mixture of several constituents, including compounds that initiated the nanofiber growth. They tried each of the initiators separately – sodium chloride, stearic acid, palmitic acid and amino acid. The results were poor. It turned out that the dense nanofibers were a result of the complex interaction of several chemicals in conjunction with high humidity. The non-initiators played a role as well by dispersing the initiators, a process that is still not completely understood.

Eventually the researchers were able to form a synthetic mixture of linoleic acid and aqueous sodium chloride, which they could stamp like ink or spray on a surface. By using different initiators and by varying the relative humidity, they were able to grow either fibers, films, or spheres.

Rajagopalan is still amazed by the discovery. "There are so many things you can do with this. It is easily scaled up, and it can grow on surfaces. We began to realize it had so many possibilities. Because it is a living polymer, it will continue growing. Perhaps the most interesting applications are for wound dressings, or as a scaffold for making other interesting fibers. You can use it as a surface treatment for textiles, or as a spray-on bandage."

"You could expose a part of your skin to humidity and your sweat will initiate the process," Mankidy excitedly completes the thought, his eyes brightening with a visionary gleam. To the prepared mind, the seeds of discovery are everywhere.

Citation: "Facile catalytic growth of cyanoacrylate nanofibers" Pratik J. Mankidy, Ramakrishnan Rajagopalan and Henry C. Foley (*Chem. Commun*, 2006, Issue 10, p1139 - 1141).

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