Lecture-2. Nano in Your Life.

Kevlar was developed by DuPont back in the 1960s — a particularly turbulent time in U.S. history. It turns out that DuPont had a track record in nylon and other fibers that gave them an incentive to look for even better fibers. At some point, they set a goal for themselves of creating a fiber with super-heatresistant properties (like asbestos, but without the health risks and lawsuits) and with a stiffness almost like glass. Kevlar was the answer: It's made up of something called an aramid fiber, and it has about five times the strength of steel. You might find Kevlar in products such as bulletproof vests, fire-blocking fabrics, cables used in a whole bunch of applications, or even materials for reinforcing tires or airplane fuselages.

When Kevlar was developed, in the pre-nanomania 1960s, there were a great many hurdles DuPont had to jump — and it had to call on lots of disciplines to get that job done. At times, current thinking had to be circumvented in order to move forward. No surprise that an environment that encouraged questions and challenges to the status quo was a key to the Kevlar success story. When you look at it phase by phase, this project is a great example of what it means to bring molecular-level products from concept to market.

To everybody's surprise, the opaque polymer spun quite well, and made a kind of super-fiber. In fact, its stress-strain curve — a standard measurement of fiber strength — was startling, so startling that the lab had to test the results over and over before anybody believed what they were seeing. Almost as an added bonus, the heat resistance was just what they were looking for. The bad news was that the raw material was very expensive. To find a cheaper alternative, a huge program was launched to try to understand the physical chemistry of this type of polymer. In the process, they found something called PPD-T, a suitably similar type of polymer made from lower-priced ingredients. But that wasn't the end of their problems. It turned out that in order to put the cheaper polymer through the spinneret, they had to dissolve it in sulfuric acid, something that tends to burn a hole through people. In addition, the sulfuric acid mixed with the polymer was so thick (viscous to all you chemist types out there) that it wasn't practical to get the spinneret up to the required speed to get it to spin into fiber. The researchers weren't about to give up, so they went to the manufacturingand-engineering groups. These farsighted engineers essentially told them to go jump in the nearest lake. The spinning solvent, they said, was too out-there — and really corrosive to boot. The yields were very low, and the investment was high. Luckily, researchers on the threshold of a discovery aren't easily dissuaded, so they ignored the engineers. Folks around the lab felt that a concentration of polymer greater than 10 percent would be too thick. But one bright researcher tried a 20 percent mixture at a high temperature. To everyone's surprise, it worked — and allowed the materials to be spun at much higher concentrations, making the process economically feasible. A second important discovery involved the way in which the fiber is quenched with water to cool it as it comes out of a spinneret. This alert researcher realized that if they added an air gap between the spinneret and the water, stress on the fiber caused the polymers coming out to align in the same direction. When the fibers cooled down, they froze with that same alignment, resulting in a much stronger fiber. This was a horse of a different color: PPD-T now deserved some corporate attention. The product was unusual, the process used to produce it looked scaleable, and the dollars and cents made sense. The manufacturing engineers admitted the value, accepted the risks of building a plant using hot sulfuric acid as a spin solvent, and jumped on board.

We've seen the scenario in a slew of science fiction movies — whenever a scientist discovers something new, some hideous green monster forms out of the goop and attacks its creator. Nanotechnology may not suffer the same fate as Baron von Frankenstein, but it is playing around with some things we've never played with before, and that concerns some people. Over the last ten years or so, work with nanomaterials has moved along smartly — and by now we're using them in a whole bunch of products such as semiconductor chips and drugs. Tests for toxicity that might result from using these materials have been much slower to appear. Still, some experiments have shown there is cause for concern — and several groups are expressing concern because hundreds of products using nanomaterials are already on the market and more are on the way. Nanotechnology is likely to become a trillion-dollar industry in less than ten years. With that kind of explosive growth, some kind of watchdogging is indicated.

No technology exists in an economic vacuum; nano is no exception. Its development requires high levels of investment and an already-advanced technology. What happens to countries that don't have those? Well, the development of HIV/AIDS drugs may offer a sobering example: When the rich countries of the world developed them, the poorer countries — whose need became even greater — couldn't possibly afford to buy them. Many people are worried about a similar divide occurring when the wealthier countries that are pioneering nanotechnology research file all the patents and reap all the rewards. Countries with less-educated workforces won't be able to compete in the nanotechnology-related future. Benefits in medicine and other areas may "follow the money" and not be shared equally.