Materials for the next generation of electronics and photovoltaics

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Mark Hersam, Northwestern University, was named a 2014 MacArthur Fellow

One of the longstanding problems of working with nanomaterials—substances at the molecular and atomic scale—is controlling their size. When their size changes, their properties also change. This suggests that uniform control over size is critical in order to use them reliably as components in electronics.

Put another way, "if you don't control size, you will have inhomogeneity in performance," says Mark Hersam. "You don't want some of your cell phones to work, and others not."

Hersam, a professor of materials science engineering, chemistry and medicine at Northwestern University, has developed a method to separate nanomaterials by size, therefore providing a consistency in properties otherwise not available. Moreover, the solution came straight from the life sciences—biochemistry, in fact.

The technique, known as density gradient ultracentrifugation, is a decades-old process used to separate biomolecules. The National Science Foundation (NSF)-funded scientist theorized correctly that he could adapt it to separate carbon nanotubes, rolled sheets of graphene (a single atomic layer of hexagonally bonded carbon atoms), long recognized for their potential applications in computers and tablets, smart phones and other portable devices, photovoltaics, batteries and bioimaging.

The technique has proved so successful that Hersam and his team now hold two dozen pending or issued patents, and in 2007 established their own company, NanoIntegris, jump-started with a $150,000 NSF small business grant. The company has been able to scale up production by 10,000-fold, and currently has 700 customers in 40 countries.

"We now have the capacity to produce ten times the worldwide demand for this material," Hersam says.

NSF supports Hersam with a $640,000 individual investigator grant awarded in 2010 for five years. Also, he directs Northwestern's Materials Research Science and Engineering Center (MRSEC), which NSF funds, including support for approximately 30 faculty members/researchers.

Hersam also is a recent recipient of one of this year's prestigious MacArthur fellowships, a $625,000 no-strings-attached award, popularly known as a "genius" grant. These go to talented individuals who have shown extraordinary originality and dedication in their fields, and are meant to encourage beneficiaries to freely explore their interests without fear of risk-taking.

"This will allow us to take more risks in our research, since there are no 'milestones' we have to meet," he says, referring to a frequent requirement of many funders. "I also have a strong interest in teaching, so I will use the funds to influence as many students as possible."

The carbon nanotubes separation process, which Hersam developed, begins with a centrifuge tube. Into that, "we load a water based solution and introduce an additive which allows us to tune the buoyant density of the solution itself," he explains.

"What we create is a gradient in the buoyant density of the aqueous solution, with low density at the top and high density at the bottom," he continues. "We then load the carbon nanotubes and put it into the centrifuge, which drives the nanotubes through the gradient. The nanotubes move through the gradient until their density matches that of the gradient. The result is that the nanotubes form separated bands in the centrifuge tube by density. Since the density of the nanotube is a function of its diameter, this method allows separation by diameter."

One property that distinguishes these materials from traditional semiconductors like silicon is that they are mechanically flexible. "Carbon nanotubes are highly resilient," Hersam says. "That allows us to integrate electronics on flexible substrates, like clothing, shoes, and wrist bands for real time monitoring of biomedical diagnostics and athletic performance. These materials have the right combination of properties to realize wearable electronics."

He and his colleagues also are working on energy technologies, such as solar cells and batteries "that can improve efficiency and reduce the cost of solar cells, and increase the capacity and reduce the charging time of batteries," he says. "The resulting batteries and solar cells are also mechanically flexible, and thus can be integrated with flexible electronics."

They likely even will prove waterproof. "It turns out that carbon nanomaterials are hydrophobic, so water will roll right off of them," he says.

Materials at the nanometer scale now "can realize new properties and combinations of properties that are unprecedented," he adds. "This will not only improve current technologies, but enable new technologies in the future."

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