Nano World: Nano for self-healing material

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Nanoparticles dispersed throughout a material can migrate to cracks, potentially leading to self-healing composites in everything from cockpits to microelectronics, experts told UPI's Nano World.

"Imagine having glasses that get scratched or cracked. The process described here could be used to make the glasses scratch-free or scratch resistant. For soldiers in the field, this has clear implications," researcher Thomas Russell, director of the Materials Research Science and Engineering Center at the University of Massachusetts Amherst. "In multi-layered microelectronic systems or in laminates, repairing cracks is something that could be done by the system itself. Consequently, repairs could be done with minimal external invasion."

Russell, along with polymer theoretician Anna Balazs at the University of Pittsburgh and synthetic chemist Todd Emrick at the University of Massachusetts Amherst and their colleagues, experimented with composites made up of transparent plastic loaded with spherical particles only about five nanometers or billionths of a meter wide underneath brittle silicon oxide. At high temperatures, cracks form in the brittle silicon oxide because it and the plastic bonded to it expand at different rates in response to heat.

With the right coating, which in this case was an organic compound known as PEO, the nanoparticles automatically migrate toward cracks in the silicon oxide. This is essentially because the molecules the plastic is made of are about the same size as the nanoparticles, making it hard to mix them, Russell explained. When a crack forms, the plastic has a chance to force the particles out. The nanoparticles burrow past the molecular chains making up the plastic like meatballs slipping through spaghetti, with the chains rebounding after the particles move past to leave the plastic intact. The scientists reported their findings in a paper published online February 12 by the scientific journal Nature Materials.

This ability to migrate toward and cluster around the cracks depends very much on the size of the nanoparticles, Balazs explained. If the nanoparticles are just two nanometers or so too small, the forces they experience are not enough to propel them a significant distance, but if they are too large they will move too slowly to be of use.

"The results are interesting and pose some new opportunities for many types of nanocomposites," said mechanical engineer and materials scientist Cate Brinson at Northwestern University in Evanston, Ill. "Benefits are immediately obvious for microelectronics where layered composites with a brittle surface layer could benefit from the nanoparticle migration to the cracks and subsequent healing."

While the researchers have demonstrated composites where embedded nanoparticles migrate to and cluster around cracks, Emrick stressed they still have to develop a material where such nanoparticles can then seal the crack. The scientists will experiment with coatings for the nanoparticles that can bind them all together when exposed to light, heat, ultraviolet rays or some other trigger. The scientists are working to commercialize their advance for industry giant Kodak in Rochester, N.Y., and St. Louis, Mo.-based films and solutions company Solutia.

Brinson noted another challenge was determining whether the migrating nanoparticles fill cracks in a sufficiently packed and stable manner. She noted she might adapt this method for other kinds of composites, where nanoparticles would help mitigate the formation and growth of microscopic cracks in materials.

In future, the scientists will also experiment with rod-shaped nanoparticles in addition to spherical ones, as well as further exploring the level of migration seen with nanoparticles with varying coatings and sizes. Their research was funded in part by Army Research Laboratory via a Multidisciplinary University Research Initiative and the Department of Energy's office of basic energy science.