New effort to find why replacement hips and knees go bad

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A Case Western Reserve University chemistry professor has begun imbedding magnetic nanoparticles in the toughest of plastics to understand why more than 40,000 Americans must replace their knee and hip replacements annually.

Anna C. Samia, an assistant professor who specializes in metallic nanostructures, has been awarded a five-year $600,000 National Science Foundation-CAREER grant to create new materials and equipment to test ultra-high molecular weight polyethylene used to make artificial joints. She and her team of researchers will also develop magnetic particle imaging techniques to monitor degradation and wear.

Ultra-high molecular weight polyethylene can be tougher to scratch than carbon steel and as slick as Teflon, which seemingly makes the material an ideal substitute for hardworking joints. There is, however, a weakness: chemical oxidation degrades the plastic.

While that's known, "Studies that have been done don't identify the mechanisms in situ," Samia said. "We will mimic how the implants age in the body and test how the microstructure of the polymer affects its wear properties while being simultaneously subjected to chemical stress ."

Here's how:

Samia will imbed iron oxide-based magnetic nanoparticles, which are biocompatible, in the polyethylene.

Her preliminary research shows that too many nanoparticles weaken the properties of the implant plastic. So, she is tuning the size, composition, and nanoparticle structure and form to develop strongly magnetic polymer composite materials.

This in turn will enable her team to use fewer particles and still get a magnetic signal strong enough to create images that show what's happening to the plastic. The nanoparticles produce distinctive signals when imbedded and when they are free-floating.

Her team will bathe the polyethylene in biological fluids, hydrogen peroxide and strong acids. They will develop techniques to take images while the imbedded plastic is in the baths.

They will also devise equipment to mimic the mechanical stresses – the push and pull of walking or running – and techniques to take images in this process as well.

The images and analysis will show when nanoparticles and plastic fragments are cut free, and under which conditions, and to track where they migrate.

The ultimate goal is to give manufacturers targets they can hone in on to make the implant material more resistant to the environment inside us, so that implants last a lifetime.

Samia will be working with Case Western Reserve's Robert W. Brown, Distinguished University Professor in the department of physics, and Mark A. Griswold, director of MRI Research and professor of radiology at the School of Medicine. Their collaborative research team has been recently awarded an Imaging Guided Biomaterials Development pilot grant by the Institute for Advanced Materials (IAM) at the university.

Beyond artificial knees and hips, Samia said the nanoparticles, methods and technologies developed in this study would also be useful for learning how stents, electrodes, artificial organs and other implants degrade inside the body.

"A lot of other materials are used for implants," she said. "It will be interesting to study them over time."

Provided by Case Western Reserve University

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