Researchers design shape-memory polymers for biomedical applications

Inside a thermo-mechanical test frame, a shape-memory polymer fractures as it stretches past its deformation limit. This testing allows the researchers to determine the maximum possible shape change from the permanent to temporary shape and vice versa. Credit: Gary Meek

Researchers at the Georgia Institute of Technology are developing unique polymers, which change shape upon heating, to open blocked arteries, probe neurons in the brain and engineer a tougher spine.

These so-called shape-memory polymers can be temporarily stretched or compressed into forms several times larger or smaller than their final shape. Then heat, light or the local chemical environment triggers a transformation into their permanent shape.

“My focus has been to optimize these polymers for many different biomedical applications. My lab studies how altering the chemistry and structure of the polymers affects their chemical, biological and mechanical properties,” said Ken Gall, a professor in the George W. Woodruff School of Mechanical Engineering and School of Materials Science and Engineering.

The mechanical properties of these polymers make them extremely attractive for many biomedical applications, according to Gall, who described his research in this area during two presentations at the Materials Research Society’s fall meeting in November.

Engineers are always searching for materials that display unconventional properties able to satisfy the severe requirements for implantation in the body. Particular attention must be paid to the biofunctionality, biostability and biocompatibility of these materials, which come into contact with tissue and body fluids.

With funding from the National Institute of Biomedical Imaging and Bioengineering of the National Institutes of Health (NIH), Gall proposed replacing metallic cardiovascular stents with plastic ones because polymers more closely resemble soft biological tissue. Plus, polymers can be designed to gradually dissolve in the body.

“Metal stents are frequently covered in plastic anyway, so we set out to remove the metal leaving just a polymer sheath,” explained Gall. “Also, polymers are more flexible and do not stress the artery walls like the metals.”

Gall’s research group has designed a shape-memory polymer stent that can be compressed and fed through a tiny hole in the body into a blocked artery, just like a conventional stent. Then, the warmth of the body triggers the polymer's expansion into its permanent shape, resulting in natural deployment without auxiliary devices. This work was published in the journal *Biomaterials* earlier this year.

For another project, Gall and graduate student David Safranski have been investigating how altering a polymer's chemistry changes its properties, such as stretchiness. This project was funded by MedShape Solutions, an Atlanta company that Gall co-founded to develop medical devices primarily for use in minimally invasive surgery.

"You can tailor the polymer to moderate its strength, stiffness, stretchiness and expansion rate," noted Gall.

They found that by changing the chemistry of the polymer backbone to include special side groups, they could increase of the amount of strain the polymer could withstand before failing without sacrificing stiffness. This discovery enabled the creation of polymers that could stretch farther and also push harder during recovery.

Gall and graduate student Scott Kasprzak are exploring how these polymers might be used as a deployable neuronal probe, with funding from the National Institute of Neurological Disorders and Stroke of the NIH.

"We're looking for smart materials that can be synthesized in the size range of 100 microns – similar to the size of a strand of hair – and then be inserted into brain tissue," explained Gall. "This type of probe would need to slowly change shape inside the brain as to not disturb any surrounding tissue."

Another project in Gall's laboratory is examining the use of these polymers for the spine. Most spinal surgeries are currently not performed arthroscopically, so Gall sees benefits in using these shape-memory materials to enable minimally invasive spinal surgery.

With funding from the National Institute of Arthritis and Musculoskeletal and Skin Diseases (NIAMS), Gall and graduate student Kathryn Smith are developing shape-memory polymers for the spine that are tough – meaning they stretch far and support a lot of weight like native spinal disks.

"This would improve the deliverability and life of artificial disks currently used in the spine. Essentially, we're just trying to engineer tougher synthetic polymers that can be easily delivered," explained Gall, who is collaborating on this project with Barbara Boyan and Johnna Temenoff, both of the Coulter Department of Biomedical Engineering at Georgia Tech and Emory University.

In addition to exploring different biomedical applications for shape-memory polymers, Gall has also turned his attention to manufacturing them. Walter Voit, a graduate student in the Technological Innovation: Generating Economic Results (TI:GER) program, is investigating how to produce shape-memory polymers at a low cost. More specifically, Voit is examining different types of materials and processing methods that can be used to commercially produce quality polymers for lower cost medical applications.

Source: Georgia Institute of Technology