Engineers design color-changing material that could help diagnose concussions

September 29 2015, by Evan Lerner

The precise link between concussions and debilitating conditions like chronic traumatic encephalopathy is still being explored, but as the name suggests, repeated head injuries are a main culprit. Unfortunately, unlike a broken bone or a torn ligament, concussions are invisible and tricky to diagnose.

With this in mind, Shu Yang, a professor in the Department of Materials Science and Engineering in the University of Pennsylvania's School of Engineering and Applied Science, has led a team of researchers in developing a polymer-based material that changes colors depending on how hard it is hit. The goal is to someday incorporate this material into protective headgear that could give an early warning sign of a concussion.

"If the force was large enough, and you could see that as easy as reading a litmus test, then you could immediately seek medical attention," Yang said.

Yang Lab members Younghyun Cho, Su Yeon Lee, and Gaoxiang Wu contributed to the work, and the Penn team collaborated with Gang Feng's group at Villanova University and Jie Yin's group at Temple University. They published their results in the journal *Advanced Functional Materials*.

Using holographic lithography—a laser-based method for patterning nanoscopic features into a three-dimensional material—Yang's team has previously made photonic crystals that feature carefully designed internal structures. Like opals, these structures refract light into a particular color. Concussive force can deform the crystals, changing the arrangement of those structures and, thus, the crystal's color.

In their new study, Yang and her colleagues developed an easier way of producing this effect that could hasten its adoption in consumer products like football helmets.

The key difference was using a polymer that could be coaxed into forming the same internal structures as found in their specialized photonic crystals. First, the polymer was melted and poured into a mold consisting of silica beads. After the polymer solidified and the beads were removed, the polymer crystals were able to act as "inverse opals" and mimic these light-refracting features.

The researchers then applied varying amounts of force to the polymer crystal and recorded the color change. A strong hit caused it to change from red to green, while a stronger one changed it from red to purple.

"The strength of these forces are right in the range of a blast injury or a concussion-causing hard tackle," Yang said.

Crucially, the color change in the polymer version of the crystal is permanent. Once hit with high enough force, the crystal structure is permanently deformed, making it ideal for recording the strength of the impact.

More information: "Elastoplastic Inverse Opals as Power-Free Mechanochromic Sensors for Force Recording." *Adv. Funct. Mater.*. doi: 10.1002/adfm.201502774

Provided by University of Pennsylvania