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Molecular scientists develop color-changing stress sensor

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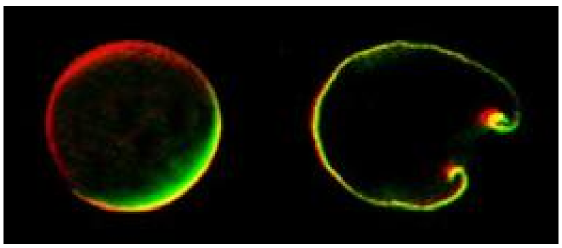

This is an enhanced image of a polymersome changing color under stress. Credit: Neha Kamat, University of Pennsylvania

It is helpful — even life-saving — to have a warning sign before a structural system fails, but, when the system is only a few nanometers in size, having a sign that's easy to read is a challenge. Now, thanks to a clever bit of molecular design by University of Pennsylvania and Duke University bioengineers and chemists, such warning can come in the form of a simple color change.

The study was conducted by professor Daniel Hammer and graduate students Neha Kamat and Laurel Moses of the Department of Bioengineering in Penn's School of Engineering and Applied Science. They collaborated with associate professor Ivan Dmochowski and graduate student Zhengzheng Liao of the Department of Chemistry in Penn's School of Arts and Sciences, as well as professor Michael Therien and graduate student Jeff Rawson of Duke.

Their work was published in the journal *Proceedings of the National Academy of Sciences*.

The researchers' work involves two molecules: porphyrins, a class of naturally occurring pigments, and polymersomes, artificially engineered capsules that can carry a molecular payload in their hollow interiors. In this case, Kamat and Liao hypothesized that polymersomes could be used as stress sensors if their membranes were embedded with a certain type of light-emitting porphyrins.

The Penn researchers collaborated with the Therien lab, where the porphyrins were originally developed, to design polymersomes that were studded with the light-emitting molecules. When light is shined on these labeled polymersomes, the porphyrins absorb the light and then release it at a specific wavelength, or color. The Therien lab's porphyrins play a critical role in using the polymersomes as stress sensors, because their configuration and concentration controls the release of light.

"When you package these porphyrins in a confined environment, such as a polymersome membrane, you can modulate the light emission from the molecules," Hammer said. "If you put a stress on the confined environment, you change the porphyrin's configuration, and, because their optical release is tied to their configuration, you can use the optical release as a direct measure of the stress in the environment."

For example, the labeled polymersomes could be injected into the blood stream and serve as a proxy for neighboring red blood cells. As both the cells and polymersomes travel through an arterial blockage, for example, scientists would be able to better understand what happens to the blood cell membranes by making inferences from the stress label measurements.

The researchers calibrated the polymersomes by subjecting them to several kinds of controlled stresses — tension and heat, among others — and measuring their color changes. The changes are gradations of the near infrared spectrum, so measurements must be made by computers, rather than the naked eye. Rapidly advancing body-scanning technology, which uses light rather than magnetism or radiation, is well suited to this approach.

Other advances in medicine could benefit, as well. As cutting-edge pharmaceutical approaches already use similar molecular technology, the researchers' porphyrin labeling system could be integrated into medicine-carrying polymersomes.

"These kinds of tools could be used to monitor drug delivery, for example," Kamat said. "If we have a way to see how stressed the container is over time, we know how much of the drug has come out."

And, though the researchers chose the engineered polymersomes due to the wide range of stress they can endure, the same stress-labeling technique could soon be applied directly to naturally occurring tissues.

"One future application for this is to use dyes like these porphyrins but include them directly in a cellular membranes," Kamat said. "No one has taken a look at the intrinsic stress inside a membrane so these molecules would be perfect for the job."

Provided by University of Pennsylvania