Optical indicators based on cholesteric liquid crystal polymers

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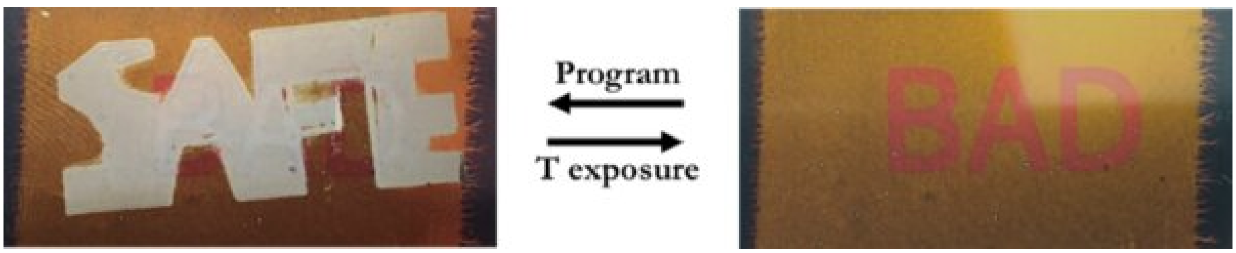

Credit: Eindhoven University of Technology

Optical indicators based colored polymers are autonomous responsive labels that provide an optical signal to represent a specific exposure over time. Polymers that possess a high degree of order can establish structural color, which originates from the interaction of light with a periodic nanostructure, causing a specific wavelength to be reflected. These optical properties can be used for the fabrication of battery-free indicators that show color changes upon exposure to a stimulus.

For his Ph.D. research, Ir. Yari Foelen, explored novel features and response modes for chemical indicators and time-temperature integrators based on cholesteric liquid crystal polymers. These optical indicators can serve as detection systems for unsafe conditions or as an alternative for static expiration dates for food and pharmaceutical products.

Speaking in colors

Is there any signal that is easy to interpret than color? Our eyes intuitively perceive optical signals and subconsciously associate specific feelings or interpretations to different colors. Traffic lights demonstrate how universally effective the use of color as a signal is. The next generation of trackers and indicators are non-electronic and therefore made of materials that deliver an autonomous response to a stimulus. One of these materials are cholesteric liquid crystal polymers, which offer an unparalleled versatility to design a responsive indicator.

Liquid crystal polymers are composed out of molecules with liquid crystalline properties, which enables order in the alignment of these molecules due to their anisotropy. The exact composition of these molecules defines the reflected wavelength to specify the pristine color. Through molecular engineering, functional end groups can be embedded in the polymers to insert a chemical or temperature response.

Capture and tell

One approach developed a safety indicator that captures a nerve gas simulant inside a cholesteric liquid crystal polymer. "This decontamination device swells when organophosphate vapors, used in chemical warfare and pesticides, are absorbed. At ambient conditions, these vapor molecules are retained in the photonic absorbent without release to the environment. Simultaneously, the reflected color of the polymer changes according to the absorbed amount which indicates the presence of the nerve agent," says Yari. The underlying principle can be applied in the neutralization of other gasses and the elimination of bad odors.

Print with intensity

Next, Yari Foelen demonstrated how UV intensity during photopolymerization allows to control the reflected color of a cholesteric liquid crystal polymer coating: A facile method applied an intensity filter to create multicolor images in one polymerization step. Simultaneously, the glass transition temperature of the polymer is tuned by the applied UV intensity. "This feature increases the versatility in design and response of shape memory time-temperature indicators. Now it is possible to imprint a message or image during processing for a clear response," Yari says.

Visualize exposure history

New indicator response mechanisms were achieved by synthesized molecules to create non-covalent crosslinked polymers. These photonic polymers established time-temperature dependent color changes in order to track temperature exposure over time. "First, we figured out how to exploit the phase transition to induce a permanent color loss," Yari explains. "This happens during exposure to the conditions required during successful steam sterilization in an autoclave."

He follows up with the evolution of this concept: "The temperature response of a supramolecular crosslinked polymer was altered to respond to lower temperatures through changes in the chemical composition. With this new system, we achieved an additional response, already at room temperature, without undergoing a phase transition."

Soon, easy to interpret visual indicators can contribute to a more conscious storage and consumption management for pharmaceuticals and food products, which consequently reduces waste and the burden on valuable resources. Future research efforts will tailor existing systems to match the exact needs for specific applications.

Provided by Eindhoven University of Technology