New plastics 'bleed' when cut or scratched — and then heal like human skin

March 26 2012

A new genre of plastics that mimic the human skin's ability to heal scratches and cuts offers the promise of endowing cell phones, laptops, cars and other products with self-repairing surfaces, scientists reported today. The team's lead researcher described the plastics, which change color to warn of wounds and heal themselves when exposed to light, here today at the 243^{rd} National Meeting & Exposition of the American Chemical Society (ACS), the world's largest scientific society.

"Mother Nature has endowed all kinds of biological systems with the ability to repair themselves," explained Professor Marek W. Urban, Ph.D., who reported on the research. "Some we can see, like the skin healing and new bark forming in cuts on a tree trunk. Some are invisible, but help keep us alive and healthy, like the self-repair system that DNA uses to fix genetic damage to genes. Our new plastic tries to mimic nature, issuing a red signal when damaged and then renewing itself when exposed to visible light, temperature or pH changes."

Urban, who is with the University of Southern Mississippi in Hattiesburg foresees a wide range of potential applications for plastic with warn-and-self-repair capabilities. Scratches in automobile fenders, for instance, might be repaired by simply exposing the fender to intense light. Critical structural parts in aircraft might warn of damage by turning red along cracks so that engineers could decide whether to shine the light and heal the damage or undertake a complete replacement of the component. And there could be a range of applications in battlefield weapons systems.

Plastics have become so common, replacing steel, aluminum, glass, paper and other traditional materials because they combine desirable properties such as strength, light weight and corrosion resistance. Hundreds of scientists around the world have been working, however, to remedy one of the downsides of these ubiquitous materials: Once many plastics get scratched or cracked, repairs can be difficult or impossible.

Self-healing plastics have become a Holy Grail of materials science. One approach to that goal involves seeding plastics with capsules that break open when cracked or scratched and release repairing compounds that heal scratches or cuts. Another is to make plastics that respond to an outside stimulus — like light, heat or a chemical agent — by repairing themselves.

Urban's group developed plastics with small molecular links or "bridges" that span the long chains of chemicals that compose plastic. When plastic is scratched or cracked, these links break and change shape. Urban tweaked them so that changes in shape produce a visible color change — a red splotch that forms around the defect. In the presence of ordinary sunlight or visible light from a light bulb, pH changes or temperature, the bridges reform, healing the damage and erasing the red mark.

Urban cited other advantages of the new plastic. Unlike self-healing plastics that rely on embedded healing compounds that can self-repair only once, this plastic can heal itself over and over again. The material also is more environmentally friendly than many other plastics, with the process for producing the plastic water-based, rather than relying on potentially toxic ingredients. And his team now is working on incorporating the technology into plastics that can withstand high temperatures.

More information:

Abstract
Although the last decade has brought self-healing materials on the forefront of scientific interests, combining repair and sensing attributes into one material entity have not been addressed. These studies report the development of poly(methyl methacrylate/n-butylacrylate/2-[(1,3,3-trimethyl-1,3-dihydrospiro[indole-2,3'-naphtho[2,1-b][1,4]oxazin]-5-yl)amino]ethyl-2-methylacrylate) [p(MMA/nBA/SNO)] copolymer films that upon mechanical scratch undergo color changes from clear to red in the damaged area, but upon exposure to sunlight, temperature and/or acidic vapors, the damaged area is self-repaired and the initial colorless appearance is recovered. The process is reversible and driven by the ring-opening-closure of spironapthoxazine (SNO) segments to form merocyanine (MC), which are recovered back to the SNO form. Upon mechanical damage, SNO segments of the neighboring copolymer segments form inter-molecular H-bonding that stabilizes copolymer backbone, that remains in an extended conformation. External stimuli, such as light, temperature, or acidic environments cause a dissociation of the H-bonded MC pairs, which are converted back to SNO. This process is associated with the p(MMA/nBA/SNO) backbone collapse, thus pulling entangled neighboring copolymers to fill removed mass and repair a scratch. Mechanical nano-indentation analysis combined with molecular modeling and spectroscopic measurements confirm this behavior. The enclosed video clip illustrates molecular repair processes induced by visible light monitored by in-situ Raman imaging spectroscopy. These materials may find numerous future applications, where coupling of simultaneous color changes and reversible self-repair responses may lead to new technological paradigms.

Provided by American Chemical Society