Entering a new dimension: 4-D printing

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Imagine an automobile coating that changes its structure to adapt to a humid environment or a salt-covered road, better protecting the car from corrosion. Or consider a soldier's uniform that could alter its camouflage or more effectively protect against poison gas or shrapnel upon contact.

A trio of university researchers from the University of Pittsburgh's Swanson School of Engineering, Harvard School of Engineering and Applied Sciences, and the University of Illinois is proposing to advance 3D printing one step—or rather, one dimension—further. Thanks to an $855,000 grant from the United States Army Research Office, the team hopes to develop 4D materials, which can exhibit behavior that changes over time.

The team includes principal investigator Anna C. Balazs, the Robert v. d. Luft Distinguished Professor of Chemical Engineering in Pitt's Swanson School of Engineering and a researcher in the computational design of chemo-mechanically responsive gels and composites. Co-investigators are Jennifer A. Lewis, the Hansjo?rg Wyss Professor of Biologically Inspired Engineering at the Harvard School of Engineering and Applied Sciences and an expert in 3D printing of functional materials; and Ralph G. Nuzzo, the G. L. Clark Professor of Chemistry and Professor of Materials Science and Engineering at the University of Illinois, a synthetic chemist who has created novel stimuli-responsive materials.

The three scientists will integrate their expertise to manipulate materials at nano and micro levels in order to produce, via 3D printing, materials that can modify their structures over time at the macro level. Three-dimensional printing, also known as additive manufacturing, is the process of creating a 3D object based upon a digital model by depositing successive layers of material.

"Rather than construct a static material or one that simply changes its shape, we're proposing the development of adaptive, biomimetic composites that reprogram their shape, properties, or functionality on demand, based upon external stimuli," Balazs explained. "By integrating our abilities to print precise, three-dimensional, hierarchically-structured materials; synthesize stimuli-responsive components; and predict the temporal behavior of the system, we expect to build the foundation for the new field of 4D printing."

Lewis added that current 3D printing technology allows the researchers to build in complicated functionality at the nano and micro levels—not just throughout an entire structure, but also within specific areas of the structure. "If you use materials that possess the ability to change their properties or shape multiple times, you don't have to build for a specific, one-time use," she explained. "Composites that can be reconfigured in the presence of different stimuli could dramatically extend the reach of 3D printing."

Since the research will use responsive fillers embedded within a stimuli-responsive hydrogel, Nuzzo says this opens new routes for producing the next generation of smart sensors, coatings, textiles, and structural components. "The ability to create one fabric that responds to light by changing its color, and to temperature by altering its permeability, and even to an external force by hardening its structure, becomes possible through the creation of responsive materials that are simultaneously adaptive, flexible, lightweight, and strong. It's this 'complicated functionality' that makes true 4D printing a game changer."

Provided by University of Pittsburgh