

Resilient Living Materials Built by Printing Bacterial Spores



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Refreshments at 3:30 pm | 116 Upson Hall

ABSTRACT

A route to advanced multifunctional materials is to embed them with living cells that can perform sensing, chemical production, energy scavenging, and actuation. A challenge in realizing this potential is that the conditions for keeping cells alive are not conducive to materials processing and require a continuous source of water and nutrients. Here, we present a 3D printer that can mix material and cell streams in a novel printhead and build 3D objects. Hydrogels are printed using agarose, which has a low melting temperature (65°C) consistent with thermophilic cells, a rigid storage modulus ($G' = 6.5 \times 10^4$ Pa), exhibits shear thinning, and can be rapidly hardened upon cooling to preserve structural features. Spores of *B. subtilis* are printed within the material and germinate on its exterior, including spontaneously in cracks and new surfaces exposed by tears. By introducing genetically engineered bacteria, the materials can sense and produce chemicals on demand. Further, we show that the spores are resilient to extreme environmental stresses, including desiccation, solvents (ethanol), high osmolarity, low pH, 365 nm UV light, and g-radiation. As a demonstration, we print a tailored 3D patch for a model wound composed of a hydrogel embedded with bacteria that can sense or kill *Staphylococcus aureus*. The construction of 3D printed materials containing spores enables the living functions to be used for applications that require long-term storage, in-field functionality, or exposure to uncertain environmental stresses.

BIOGRAPHICAL SKETCH

Lina M. González worked as a post-doc in the Voigt lab at MIT, working on 3D printing of cells to make living materials. She obtained her M.S. and Ph.D. degrees in Mechanical Engineering from Carnegie Mellon University under the supervision of Prof. Philip LeDuc and Prof. William Messner. Her thesis work was on studying magnetotactic bacteria swimming behavior with respect to magnetic field gradients. Lina attended Hunter College and obtained her B.A. degree in Physics with a minor in chemistry. As an undergraduate, Lina joined the MURF program and worked in the Dickinson Lab at Caltech for two summers (2007 and 2008) on flight behavior of fruit flies. While getting her baccalaureate degree, Lina was also part of the MBRS-Rise program and she worked in Prof. Steve Greenbaum's NMR lab. She received the prestigious NSF Graduate Research Fellowship in 2011 and the Alfred Sloan Foundation Scholarship in 2010 and Ford Foundation Diversity Fellowship Honorable Mention in 2009.