Implantable silk metamaterials could advance biomedicine, biosensing

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Researchers at the Tufts University School of Engineering and Boston University have fabricated and characterized the first large area metamaterial structures patterned on implantable, bio-compatible silk substrates.

The research in the journal *Advanced Materials*, provides a promising path towards the development of a new class of metamaterial-inspired implantable biosensors and biodetectors.

Metamaterials are artificial electromagnetic composites, typically made of highly conducting metals, whose structures respond to electromagnetic waves in ways that atoms in natural materials do not. The most futuristic metamaterials would absorb all light, to create heat to destroy cancerous tissue, or bend light completely around an object, rendering that object invisible—an imaginary delight for fans of science fiction or spy novels.

"However, the real power of metamaterials is the possibility of constructing materials with a user-designed electromagnetic response at a precisely controlled target frequency. This opens the door to novel electromagnetic behaviors such as negative refractive index, perfect lensing, perfect absorbers and invisibility cloaks," explains Tufts Professor of Biomedical Engineering Fiorenzo Omenetto, who led the research team. Omenetto also holds an appointment in the Department of Physics at Tufts School of Arts and Sciences.

The team focused on metamaterial silk composites that are resonant at the terahertz frequency. This is the frequency where many chemical and biological agents show unique "fingerprints," which could potentially be used for biosensing.

Small Antennas Act as One

The researchers sprayed gold-based metamaterial structures directly on pre-made silk films with micro-fabricated stencils using a shadow mask evaporation technique. Spraying the metamaterial onto the flexible silk films created a composite so pliable that it could be wrapped into small, capsule-like cylinders.

Silk films are highly transparent at THz frequencies, so metamaterial silk composites display a strong resonant electromagnetic response. Each fabricated sample was 1 square centimeter and contained 10,000 metamaterial resonators with unique resonant response at the desired frequencies.

According to Fiorenzo Omenetto, the research team likens the concept to "a very peculiar kind of antenna—actually, a lot of small antennas that behave as one. The silk metamaterial composite is sensitive to the dielectric properties of the silk substrate and can monitor the interaction between the silk and the local environment. For example, the metamaterial might signal changes in a bioreactive silk substrate that has been doped with proteins or enzymes."

The addition of a pure biological substrate such as silk to the gold metamaterial adds immense latitude and opportunity for unforeseen applications, says Professor Richard Averitt, one of Omenetto's collaborators from Boston University and an expert on metamaterials.

The resonance response could be used as an implantable electromagnetic signature for contrast agents or bio-tracking applications, says co-author Hu Tao, a former Boston University graduate student who is now a postdoctoral associate in Omenetto's lab.

In Situ Bio-Sensing

To demonstrate the concept, the researchers conducted a series of in vitro experiments that examined the electromagnetic response of the silk metamaterials when implanted under thin slices of muscle tissue. They found that the metamaterials retained their novel resonance properties while implanted. The same process could be readily adapted to fabricate silk metamaterials at other frequencies, according to Tao.

"Our approach offers great promise for applications such as in situ bio-sensing with implanted medical devices and the transmission of medical information from within the human body," says Omenetto. "Imagine the benefits of monitoring the rate of drug delivery from a drug-eluting cardiac stent, making a perfect absorber that can be implanted to attack diseased tissue by heat, or wrapping an 'invisibility cloak' around an organ to examine the tissue behind it."

More information: "Metamaterial Silk Composites at Terahertz Frequencies," by Hu Tao, Jason J. Amsden, Andrew C. Strikwerda, Kebin Fan, David L. Kaplan, Xin Zhang, Richard D. Averitt, and Fiorenzo G. Omenetto, *Advanced Materials*, published online July 21, 2010.

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