

NANOTECHNOLOGY

Stamping Out Metamaterials for Real-World Use

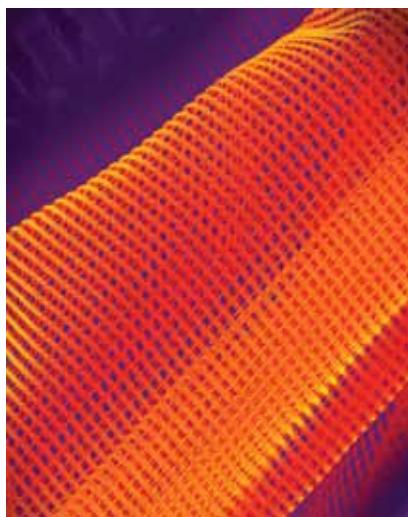
A new process for making metamaterials — artificial materials with properties not readily found in nature — could hold promise for using these fantastical materials in real-world applications.

The process, developed by Univ. of Illinois professor of materials science and engineering John Rogers and his colleagues, uses a nanopatterned stamp loaded with thin layers of ink to print the metamaterial onto a substrate.

The material created by the Univ. of Illinois team is a negative-index metamaterial (NIM) with a particular three-dimensional structure that causes light passing through it to bend in the opposite direction to what is expected. Rogers' team was able to produce a sample of the NIM approximately 36 in.², which is quite large compared with the samples measuring several hundred square microns that have been made in the past.

Metamaterials represent a relatively new class of materials, with the first NIM discovered as recently as 2008 (*CEP*, Feb. 2011, pp. 7–9). Their unique properties, such as the ability to render objects invisible, derive from the metamaterials' structure rather than their chemical composition. While they hold great promise, a key challenge has been fabricating them in the sizes and at throughputs required for real-world applications, such as lenses, resonators, and other photonic components, Rogers says.

Previous methods for making these optically counterintuitive materials involved depositing a uniform film of multiple layers on a substrate and then using ion beam lithography to carve out the 3-D structure. While this process creates NIMs with the desired feature resolution, it is slow and cannot produce large amounts of



▲ This colorized scanning electron micrograph shows a flexible sheet of artificial, negative index metamaterial. The structure consists of a multilayer stack of silver and magnesium difluoride, formed in a nanoscale, fishnet geometry by a transfer printing process. Image courtesy of J. Rogers, Univ. of Illinois.

material, Rogers says.

“As a result, people have been able to generate these types of structures for scientific study, but if you want to think about making an invisibility cloak or a large-scale sheet of this stuff for use in a practical application, it becomes very difficult,” Rogers adds.

Funded with a grant from the Office of Naval Research, the team focused on the most advanced NIM — a multilayer stack of alternating sheets of silver and magnesium difluoride (MgF_2), which is cut into a geometry resembling a fishnet, with the mesh holes on the order of 100 nm.

To make their material, the researchers first create a stamp — a slab of polymer with features of relief on its surface in the geometry of the fishnet structure. Next, they deposit alternating layers of the metal and dielectric via evaporation onto the flat raised and recessed surfaces of the stamp. Finally, they contact the inked stamp with a polydimethyl-siloxane (PDMS) substrate.

So far the researchers have been able to create a NIM that operates in the near-infrared wavelength region. The next step will be making the material with smaller features so that it bends light in the visible region. Rogers does not think this will be a problem. “We haven't published the results, but conceptually there's no problem and we have some initial demos indicating that's possible,” he adds.

Conductive Fibers Weave Flexible Electronics

A new conductive fiber coating could enable wearable electronics without the wires. Potential applications include patient clothing that tracks heart rate, body temperature, and movement, as well as sensors for environmental monitoring.

The new coating was created with atomic layer deposition (ALD) — a technique that sequentially exposes a surface to different chemicals to build up a thin film. The research team, led by North Carolina State Univ. assistant professor of textile engineering, chemistry and science Jesse Jur, used ALD to grow layers of electronic materials on various textiles, including woven cotton and nonwoven polypropylene.

“We have been researching a wide range of coatings by atomic layer deposition, from metals to transparent conductors as well as semiconductors and insulators — the major components needed for microelectronic devices,” Jur says. “We now have methods for growing these materials on a variety of textiles and synthetic nonwoven fiber materials, including polypropylene, nylon, and polyesters.”

The researchers formed zinc oxide (ZnO) films with thicknesses ranging between 20 nm and 100 nm using ALD at 115°C on woven cotton substrates. When they compared the conductivity of the ZnO-coated cotton fibers to that of the ZnO-coated cotton



▲ A natural fibrous material is shown here with (small swatch) and without the conductive coating. Adding electronic functionality to fabric systems is important for new applications in healthcare and environmental monitoring. Photo courtesy of Jesse Jur and Gregory Parsons, North Carolina State Univ.

paper and flat silicon substrates, they found that the effective conductivity of the ZnO films was about the same on woven cotton and paper substrates — demonstrating that ALD can produce similar conductivity values for different fiber materials.

Electronic fabrics are not new. Many of these materials, however, consist of an electronic component sewn to a fabric or textile. Cambridge, MA-based mc10, for example, is developing stretchy electronic patches that can be incorporated into fitness apparel to measure everything from heart rate and blood pressure to joint injuries.

The North Carolina State team takes this one step farther by actually turning the fibers themselves into electronic devices.

“Our research team is attempting to blur the physical distinction between the fabric and the device by integrating these conductive layers directly into the textile, and this results in ‘all-fiber’ devices,” Jur notes.

The researchers do not speculate on when these electronic materials will be on store shelves, but say that their work is “advancing the technology much quicker toward commercialization.”

Their next step will be to combine the different layers (conductors, semiconductors and insulators) to form the actual microelectronic devices. They also plan to build more prototype materials to demonstrate how these textiles can be used, Jur says.

BIOTECHNOLOGY

Synthetic Gel Could Give Voice to Damaged Vocal Cords

A new polymer gel that mimics the key properties of human vocal cords could be the answer for people with voice disorders.

The gel, which is based on polyethylene glycol (PEG), has been successfully tested in canines and will likely be tested in a small human trial next year.

Existing methods to address vocal cord damage have focused on repairing the scarred tissue. For instance, some doctors treat scarring with materials normally used in dermatology and plastic surgery in an attempt to soften the vocal cords. Others have tried to develop drugs to dissolve the scar tissue. These approaches work for some cases, but not all. In addition, they mask instead of solve the underlying problem.

Researchers led by Robert Langer, a professor of chemical engineering at



▲ This snapshot is from a high-speed video recording that documented a sample of PEG gel vibrating in response to voice-like airflow. Image courtesy of MIT and MGH. (The video is available at www.youtube.com/watch?v=10JAW0K1RTs.)

the Massachusetts Institute of Technology (MIT), and Steven Zeitels, a professor of laryngeal surgery at Harvard Medical School, took a different approach.

“We looked at this as a mechanical problem,” says Sandeep Karajanagi, a former MIT researcher who helped develop the gel. “We said, ‘Let’s not look at the scar itself as a problem, let’s think about how we can improve the voice despite the presence of the scar tissue,’” says Karajanagi, who is now an instructor of surgery at Harvard Medical School and a researcher at the Center for Laryngeal Surgery and Voice Rehabilitation at Massachusetts General Hospital (MGH).

The researchers chose PEG as the starting material because of its biocompatibility and track record with the U.S. Food and Drug Administration (FDA), Langer says. They made a range of different structures by cross-linking the PEG and tested the materials’ shear and stress-strain properties, he explains. They then selected the material with the same viscoelastic properties as human vocal cords. Viscoelasticity is a crucial property because it determines how the vocal cord tissues vibrate when exposed to air from the lungs, thereby creating sound.

The chosen material, which the researchers have named PEG30, was shown to restore vibration to damaged vocal cords.

“We injected the gel into the vocal folds of dogs and took high-speed videos of vocal cord vibration,” Langer says. “These showed maximum vibratory amplitudes that were essentially the same as the controls,” he adds. Furthermore, the gel did not cause inflammation or irritation.

The researchers are now developing a manufacturing process to make larger quantities of the gel, which will be needed for future clinical trials.

Update continues on pg. 8