Fabrication technique brings metamaterial applications a step closer

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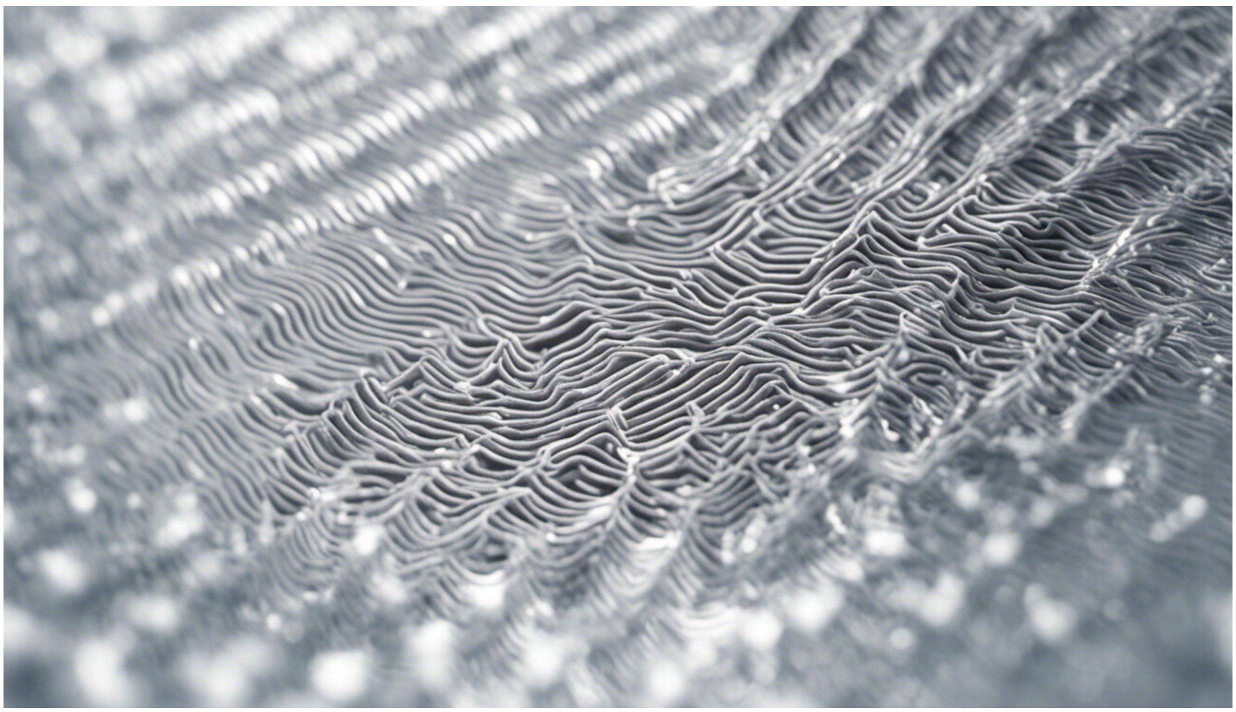

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Metamaterials are engineered to interact with light and sound waves in ways that natural materials cannot. They thus have the potential to be used in exciting new applications, such as invisibility cloaks, high-resolution lenses, efficient and compact antennas, and highly sensitive sensors.

While the theory of this interaction is relatively well understood, it has been challenging to fabricate metamaterials that are large enough to be practical. Now, Yi Zhou and colleagues at the A*STAR Data Storage Institute in Singapore have demonstrated a promising new fabrication technique that can produce large areas of an important class of metamaterial, known as fishnet metamaterials.

Most optical metamaterials consist of tiny repeated metallic structures. When light of a particular frequency falls on them, it establishes oscillating fields inside each structure. These fields can resonate with each other and thereby produce desirable collective behavior. Fishnet metamaterials usually have several vertically stacked repeat units spread out over much larger lateral dimensions. Because they are structured both vertically and laterally, they are called three-dimensional materials.

Fishnet metamaterials are usually made in one of two ways. They can be fabricated by carefully patterning individual films and then stacking these films on top of each other. However, this multilayer process is difficult, as it requires careful alignment of the films.

The second approach is to pattern a sacrificial substrate and then deposit repeated layers onto it. This 'pattern-first' process suffers from its own difficulties, the most important of which is that the total thickness of the final fishnet material is typically limited to tens of nanometers or less. This restricts the kind of resonances that can be achieved and, in turn, the functionality of the final film.

Zhou and colleagues were able to increase the total thickness of pattern-first fishnet films to around 300 nanometers, allowing five bilayers of film to be deposited and resulting in a strong characteristic resonance and pronounced metamaterial behavior. To achieve this, they adopted a technique called trilayer lift-off, which is commonly used in industry but seldom applied in research laboratories. It involves patterning a sacrificial layer of a photoresist resting on a layer of silicon dioxide under which lies a second photoresist layer.

By alternating the patterning and etching steps, the A*STAR team could achieve a film thickness greatly exceeding the size of the lateral patterns etched into the film. "This technique will help researchers design large-area three-dimensional nanodevices more easily," says Zhou, "and help bring the science of metamaterials to reality."

More information: Zhou, Y., Chen, X. Y., Fu, Y H., Vienne, G., Kuznetsov, A. I., & Luk'yanchuk, B. "Fabrication of large-area 3D optical fishnet metamaterial by laser interference lithography." *Applied Physics Letters* 103, 123116 (2013). dx.doi.org/10.1063/1.4821508

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