Researchers successfully fabricate a metamaterial using a lotus leaf as a template

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Scientists at Tokyo Institute of Technology have created an ultrathin, light-absorbing 'biometamaterial' using gold sputtered onto a lotus leaf. The natural nano-scale structures on the surface of the leaves created a material with very low reflectivity, which absorbs almost all light on the visible spectrum. Figure: Lotus flower, lotus leaf and scanning-electron microscope image of lotus leaf

Metamaterials are man-made substances whose properties are determined by their meticulously-designed structure. For example, metamaterials can be fabricated so that they interact with light or sound in a specific way. Unique surface structures play a vital role in metamaterials, and scientists have begun looking to nature itself for patterned surfaces from which to draw inspiration.

Now, Kotara Kajikawa and Yuusuke Ebihara at Tokyo Institute of Technology, together with Masayuki Shimojo at the Shibaura Institute of Technology, Japan, have fabricated a new 'biometamaterial' using a lotus

leaf as a template. The new substance is capable of almost total absorption of light across the entire visible spectrum.

The researchers took advantage of the unique structure of the cells on the surface of a lotus leaf. The cilia on the leaves are in the form of tiny, randomly-orientated, macaroni-like nanorods, each measuring around 100 nanometers (nm) in diameter (see image). The team hypothesized that such a structure might confine light effectively.

Kajikawa and his colleagues coated a number of different leaves in a thin layer of gold film, applied in two different ways. Vacuum evaporation using thermal heating destroyed the nanorod structures on the leaf surface, but a spray 'sputtering' technique was far more successful. The resulting gold coating ranged in thickness from 10 nm to 30 nm on different samples. As well as lotus leaves, they also used leaves from three other plants as controls.

The researchers found that the 10 nm-thick gold biometamaterial created using lotus leaves exhibited reflectivity of less than 0.01 through the whole visible spectrum. Calculations showed that the low reflectivity, which results in almost complete absorption of light on the material's surface, appears to stem from the randomly-orientated nanorods on the leaf's surface.

Further work is in progress to see if Kajikawa and his team can find an easy and effective way to remove the gold biometamaterial from the leaf template once it is created.

Advances in metamaterials

Creating synthetic materials in order to manipulate electromagnetic waves is not a new concept. Indeed, the idea for metamaterials has been around for at least 100 years, but it is only in recent decades that the

technology has really begun to take off. By designing the shape, geometry and orientation of a material with precise accuracy, properties can be achieved that are not possible in nature.

This is not to say that nature doesn't play a significant role in the design of such materials. Recently, researchers have begun to investigate the nano-scale surface structures and cell patterns in plants with the hope that natural surfaces will provide inspiration and templates for new 'biometamaterials'.

Recent technologies built using metamaterials include light absorbers, sensors, optical filters and cloaking devices, to name but a few. There is great potential for new metamaterial designs with unique and precise properties.

Methodology

The biometamaterial fabricated by Kotaro Kajikawa and co-workers uses the unique nanoscale structures on lotus leaves – the primary role of which is to create a highly water-repellent surface to the leaves. These structures are in the form of randomly-orientated nanorods, which the team believed would provide a useful template for a metamaterial designed to absorb light.

The researchers trialled two methods for creating a gold-based metamaterial on the surface of the leaves – vacuum evaporation using heat and a 'sputtering' technique. The first of these resulted in a completely smooth, golden reflective surface because the nanorod structures had collapsed on heating. Sputtering worked much better – scanning electron microscopy images revealed the intact randomly-orientated nanorods were preserved, and promising results were achieved in a biometamaterial made from a very thin 10 nm layer of gold.

This study highlights the potential in using naturally-occurring surfaces to generate very precise metamaterials for specific purposes. The team are now working on ways of removing the biometamaterial from the leaf once it is created, a tricky process which the researchers believe can be achieved with a form of chemical treatment.

More information: Yuusuke Ebihara et al. Biometamaterials: Black Ultrathin Gold Film Fabricated on Lotus Leaf, *Scientific Reports* (2015). DOI: 10.1038/srep15992

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