NEW HOT PAPERS - 2009

March 2009

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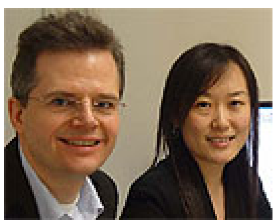
Harald Giessen & Na Liu talk with *ScienceWatch.com* and answer a few questions about this month's New Hot Paper in the field of Materials Science. The authors have also sent along images of their work.



Article Title: Three-dimensional photonic metamaterials at optical frequencies

Authors: Liu, N;Guo, HC;Fu, LW;Kaiser, S;Schweizer, H;Giessen, H
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SW: Why do you think your paper is highly cited?

Following the initial realization of optical metamaterials (Linden S, *et al.*, "Magnetic Response of Metamaterials at 100 Terahertz," *Science* 306: 1351-53, 2004) experimental and theoretical work grew rapidly in this field. Metamaterials are structures which are much smaller than an optical wavelength and often consist of metallic, plasmonic nanostructures. They might have the potential for perfect lensing and optical cloaking. However, most realizations of optical metamaterials were just surfaces.

In order to obtain real three-dimensional materials, stacking techniques were required. We give the first account of a stacking technique to obtain 3D metamaterials which is, in principle, not limited to a certain number of layers. This work inspired a lot of follow-up papers which deal with the optical properties of multi-dimensional, stacked metamaterials. Coupling is very important in such structures, and its role needs to be clarified.

SW: Does it describe a new discovery, methodology, or synthesis of knowledge?

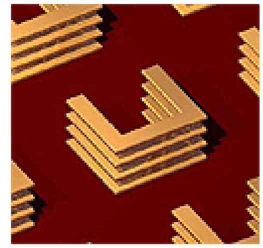
We have described how to manufacture 3D metamaterials with a planar stacking technology which is industry compatible. In principle, a semiconductor electronics lab could use our technology to produce up to 20-layer, 300 mm diameter, sub-100 nm structure size metamaterials.

Following our paper, other authors have come up with alternative methods for 3D metamaterial fabrication (such as direct laser writing). Compared to our planar stacking technique, there are advantages and disadvantages to these other methods.

SW: Would you summarize the significance of your paper in layman's

terms?

We describe a manufacturing method for 3D metamaterials. The method works layer-by-layer, just like "building" a hamburger slice by slice until it is really big and three-dimensional. The key to our method is to get the layers planar after every step and to align the individual layers to each other. You know this problem from a hamburger: if the layers are not aligned, for example, the cheese might come out at the side.



Concept drawing of stacked split-ring resonators made from gold and stacked on a glass substrate with polymer spacer layers.

SW: How did you become involved in this research, and were there any problems along the way?

We have been working on nanoplasmonics since the late 1990s, mostly in the field of metallic photonic crystals, which have sizes on the order of half the optical wavelength. Going to even smaller structures was the logical consequence. Stacking is not trivial with electron-beam lithography systems. We had to develop the planarization and alignment technology.

View/download four accompanying slides and descriptions.

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SW: Where do you see your research leading in the future?

With our nanotechnology, we are free to fabricate any layered nanophotonic structure. This adds a whole number of degrees of freedom for the design of such structures. For instance, it is possible now to not only use electric dipoles that couple to each other, but also higher-order multipoles such as quadrupoles or even magnetic resonances. This "optical magnetism" opens a whole new door to building artificial functional nanostructures with completely new properties that cannot be found in nature, for example, a negative refractive index.

SW: Do you foresee any social or political implications for your research?

Actually, there are already theoretical concepts that describe optical cloaks. This would mean that Harry Potter's vision of covering up might come true one day. This would certainly have a lot of applications, and only your own imagination would limit the possibilities of such a device.

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KEYWORDS: NEGATIVE REFRACTIVE-INDEX; CRYSTAL; HYBRIDIZATION; MODES.

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