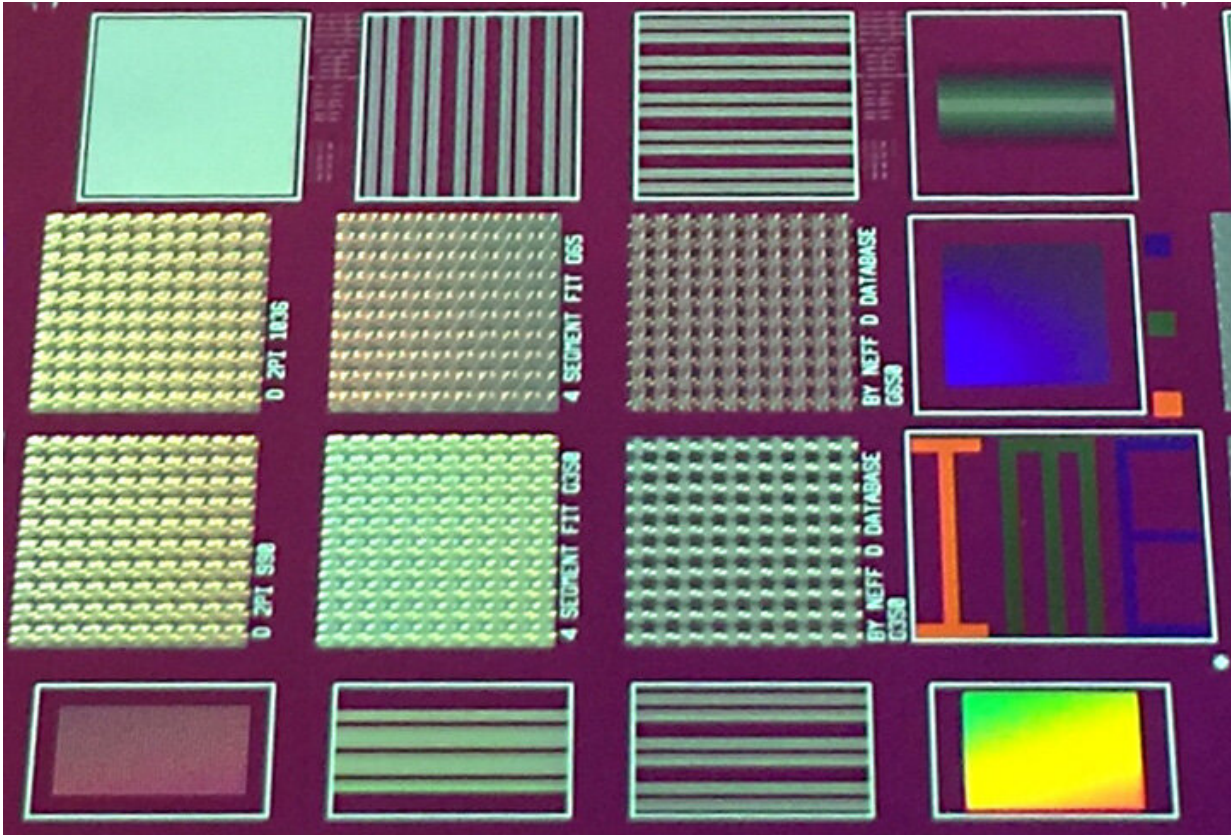


Mass manufacturing of metasurfaces

March 18 2019



The metasurface's nano-pillar arrays displaying the letters I, M and E in red, green and blue, respectively. Credit: Reprinted with permission from ref 1, The Optical Society (OSA)

The mass production of flat optical devices with sub-wavelength structures could soon be a reality, thanks to a metasurface fabrication technique developed by researchers at A*STAR.

Metasurfaces are synthetic, two-dimensional materials covered in tiny individual shapes with sizes and spacings smaller than the wavelengths of visible light. These 'sub-wavelength' structures enable scientists to precisely control the propagating shape, or wavefront, of [light beams](#). As such, [metasurfaces](#) show promise for many applications from high-resolution imaging and [color printing](#) to controlling light polarization. Mass production of metasurfaces, however, has proven challenging, limited by the complexity of realizing such precise patterns.

Now, Ting Hu and his colleagues at A*STAR's Institute of Microelectronics (IME) have developed a method of building silicon-based metasurfaces by introducing existing techniques from semiconductor fabrication. Their new [metasurface](#) design can produce high-resolution red-green-blue (RGB) color displays.

Until now, metasurfaces have mainly been fabricated via [electron beam lithography](#) (EBL), which is not applicable to [mass production](#), as Hu explains:

"With EBL, the focused electron beam moves slowly, step by step, across the metasurface substrate. Metasurfaces with millions—possibly billions—of elements require a very long time to be patterned via EBL. We desired a faster and more efficient way of patterning."

Hu and the team based their technique on '[immersion lithography](#)', which has long been used to etch patterns on to electronic components. With multiple exposures, complex patterns can be built up. The researchers used ultraviolet-based (UV) lithography for initial patterning on to silicon substrates, followed by plasma etching to form the designs in small pixel blocks that were assembled into a 12-inch display surface (see image).

"Our UV lithography tool is a scanner, which can pattern a whole 12

inch wafer with designed devices within half an hour," says Hu. "We designed the physical dimensions of the nano-pillar arrays of the metasurface to accurately display colors, with fantastic results, for example displaying the letters I, M and E in red, green and blue respectively."

Hu and the team hope to optimize their design and improve the etching process to minimize losses induced by light scattering and defects in the nano-structure arrays. They are also making efforts to realize flat, lightweight 'meta-lenses' and dot projectors with potential uses in facial recognition technologies.

More information: Ting Hu et al. Demonstration of color display metasurfaces via immersion lithography on a 12-inch silicon wafer, *Optics Express* (2018). [DOI: 10.1364/OE.26.019548](https://doi.org/10.1364/OE.26.019548)

Provided by Agency for Science, Technology and Research (A*STAR), Singapore

Citation: Mass manufacturing of metasurfaces (2019, March 18) retrieved 26 April 2024 from <https://phys.org/news/2019-03-mass-metasurfaces.html>

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