New method speeds up 3-D printing of millimeter-sized imaging lenses

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The team's new method uses 3D printing to make high-quality customized lenses quickly and at low-cost. Credit: Northwestern University

A new method to make a low-cost, high-quality lens quickly using a 3D printer has promising potential to create optical imaging lenses, customized contact lenses for correcting distorted vision, or to even turn iPhones into microscopes for disease diagnosis.

Developed by Northwestern Engineering researchers after two years of research, the customized optical component, which is 5 millimeters in height and 5 millimeters in diameter, can be 3D printed in about four hours.

"Up until now, we relied heavily on the time-consuming and costly process of polishing lenses," said Cheng Sun, associate professor of mechanical engineering and whose lab developed the 3D printing process. "With 3D printing, now you have the freedom to design and customize a lens quickly."

The research was published on March 24 in *Advanced Materials*. It includes images taken with the lens connected to an Apple iPhone 6s, including high-quality detailed images of a sunset moth's wing and a spot on a weevil's elyta.

Like all 3D printing, creating these lenses involves placing layer upon layer of material. Sun likened building the lens to running a film projector. "Instead of projecting one frame, one image after another, we layer one frame on top of another," Sun said. "It is like playing a movie in a vertical fashion."

But when researchers first printed the lens, its curved layers, made of a photo-curable resin, created a visible stepping.

"We realized that the layers on top of each other created surface roughness. The layer thickness is typically 5 microns, while the wavelength of visible light is around 0.5 micron. This creates an optically rough surface," he said. "That was the bottleneck. The roughness made the lens incapable of clear optics."

This lead to the group's simple guiding research question: Can we make the surface smooth without slowing down the printing speed? To solve

that challenge, Sun's group developed a two-step process of layering and polishing.

"First, we used grayscale images to create more transitions between steps," Sun said. "Then, we coated the surface with the same photo-curable resin. That then forms the meniscus that further smooths the surface."

The result: a transparent lens with a smooth surface.

"I must have tried more than 100 times to get this just right," said Xiangfan Chen, a PhD candidate in mechanical engineering and lead author on the study.

This lens, however, is not the first high-quality lens created by 3D printing. German-based company Nanoscribe has developed a high-precision femto-second 3D printer with 150 nanometer precision, but it builds the lens in a point-by-point fashion instead of layering, Sun said.

"It is a time-consuming process. That is their limitation," he added. "We wanted to make something comparable but faster and with better quality."

"If you want to make a lens, do you want to make it in two hours or two weeks?" Chen said. "We are very excited about this lens."

This process could lead to a plethora of new devices with a wide variety of applications in optics and biomedical imaging, Sun said.

Next, the group will experiment in making larger lenses as well as investigating how to integrate the 3D-printed lens with medical devices, such as an endoscope or optical microscope. "These lenses could help detect some genetic disease or cancer," said Biqin Dong, a post-doctoral

fellow focused on biomedical and mechanical engineering, who also worked on the research.

Dong also envisions that these lenses could be used by doctors in underdeveloped areas for diagnostic imaging or by field scientists as portable microscopes. The lens could also be fashioned into a customized contact lens for people with distorted corneas caused by keratoconus. "The contact lens would feature the customized surface, matching it to the shape of the patient's cornea," Sun said.

More information: Xiangfan Chen et al, High-Speed 3D Printing of Millimeter-Size Customized Aspheric Imaging Lenses with Sub 7 nm Surface Roughness, *Advanced Materials* (2018). DOI: 10.1002/adma.201705683

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