Metasurface-based nanoprinting: Displaying optical images at the nanoscale resolution

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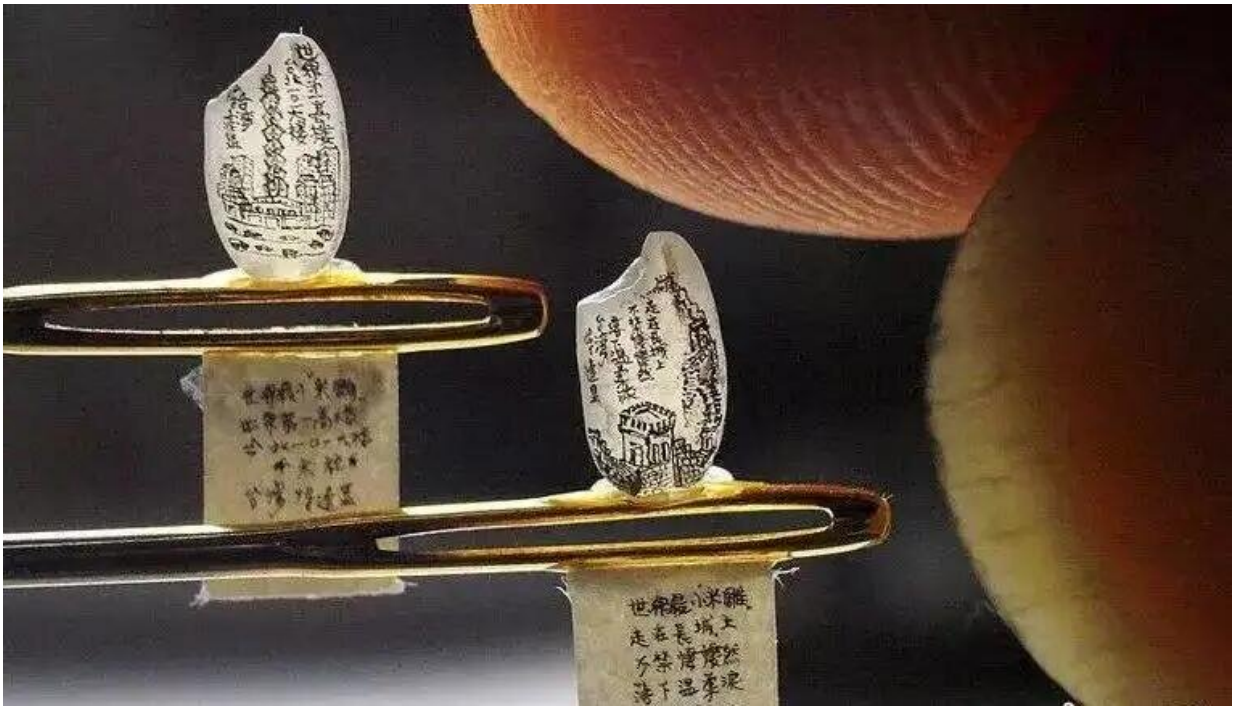


Rice sculpture art exhibition. Credit: OEA

There is a long-standing folk art in China called "rice carving," in which lifelike artistic patterns are carved on rice with a length of only about 5 mm. These works need to be appreciated with a magnifying glass.

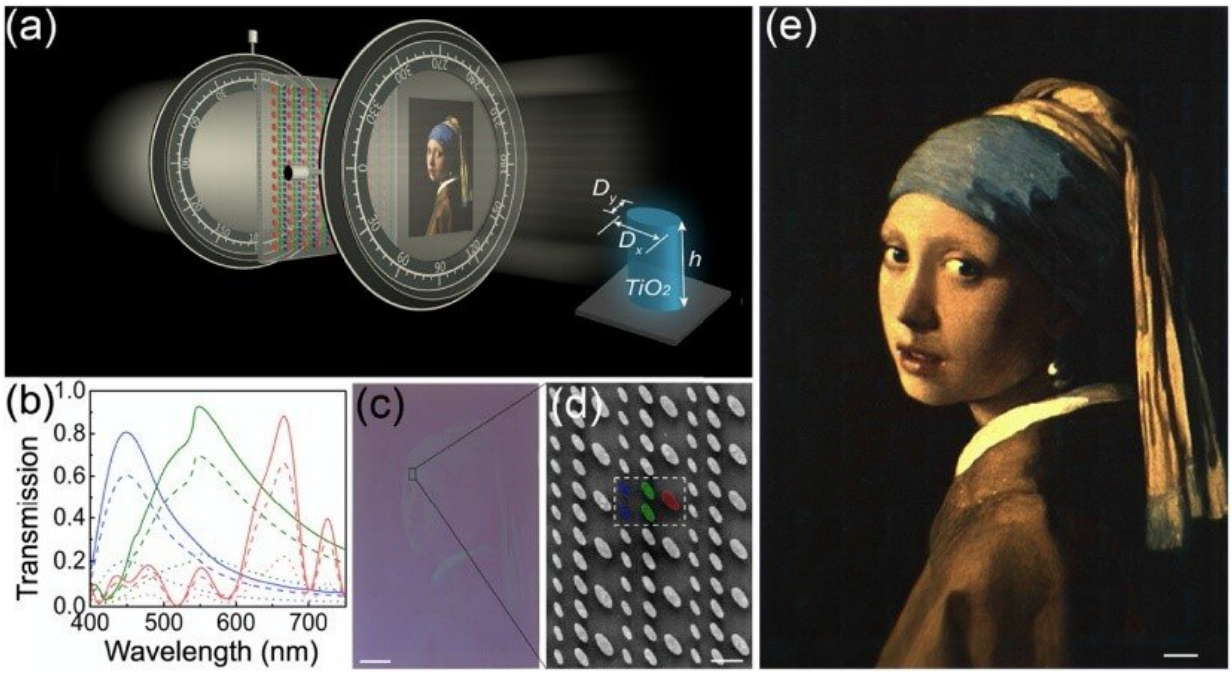
Rice carving can be regarded as a printing technology based on a special

material. Printing technology refers to the whole process of transferring images and information to the surface of paper, textiles, plastics and other materials. It is an important part of the information industry. As an energy-saving, environment-friendly and difficult-to-copy printing method, ink-free color printing is becoming a new area of printing technology development.

The ink-free color printing uses laser engraving, holographic technology, electron beam, ultra-precision numerical control processing, electrochemical and other micro processing technologies to form digitally programmed micro-nano structures on the surface of printed products. Ink-free color printing can generate physical phenomena such as diffraction, reflection, refraction and transmission of light, and thus display characters and images of different colors. The complex micro structure manufacturing process makes it difficult to be copied.

Therefore, ink-free printing technology is widely used in packaging, labeling, anti-counterfeiting and other applications, and it has the characteristics of ultra-high resolution and can display micron level characters. However, due to the limitation of its simple light field manipulation principle, ink-free printing technology has difficulty producing more abundant colors and complex image information, and it has encountered great technical obstacles in its deep application.

There is demand for a full-color, continuous grayscale, high-resolution and simple structure color ink-free printing refresh technology to play a key role in fields such as optical encryption and anti-counterfeiting, AR / VR, printing and packaging, art creation, information storage and so on.



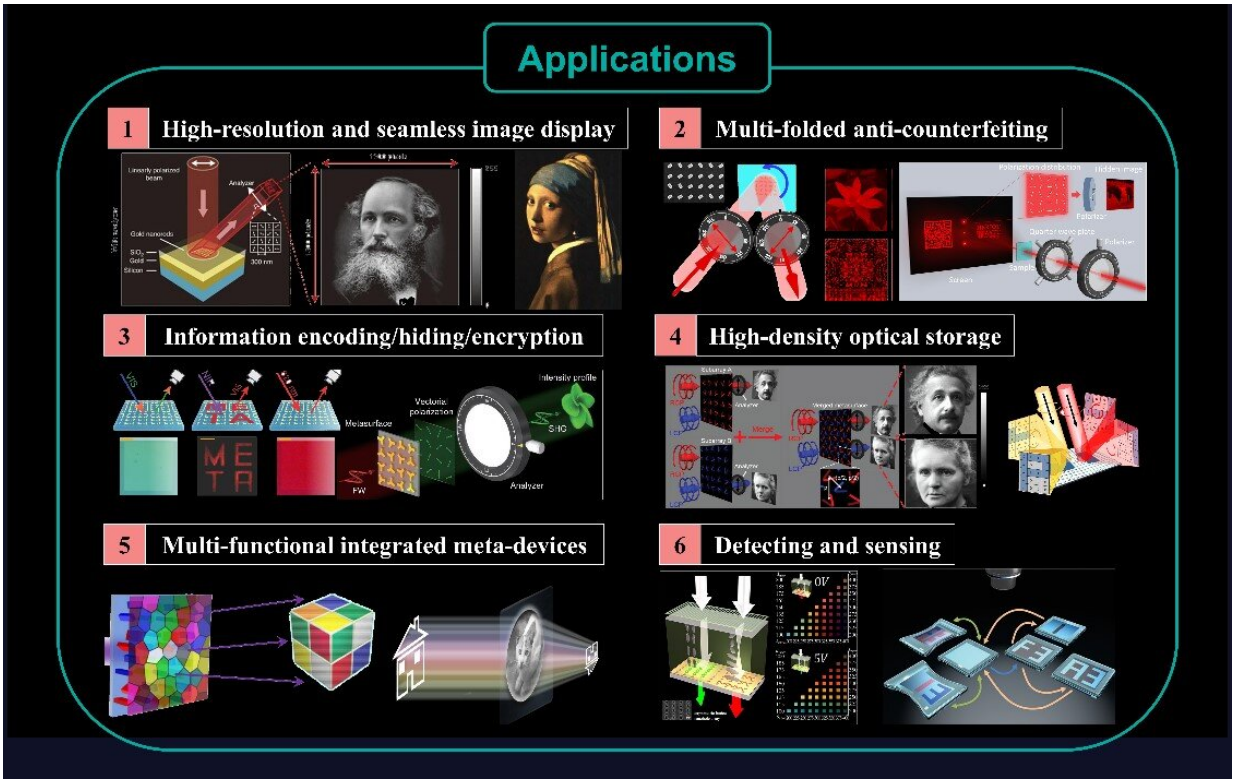
Metasurface-based nanoprinting to reproduce the oil painting art of The Girl with the Pearl Earring. Credit: OEA

Metasurface is a new type of artificial structure material developed rapidly in recent years. It is composed of periodic subwavelength structures deposited on planar substrates. In the optical band, by reasonably designing the geometry, size and orientation of the sub-wavelength structure, metasurfaces can flexibly manipulate the basic optical parameters such as amplitude, phase and polarization state of incident light at the nanoscale. It is the preferred technology for storing and displaying nanoprinting images with ultra-high resolution.

As a new type of optical image storage and display platform based on metasurfaces, the resolution of the stored image is as high as 80K DPI, which not only far exceeds the traditional printing technology (such as gravure printing, which is generally only 5K DPI), but also has the

outstanding characteristics of long life, zero pollution and rich color. Shown below are the results of recording and reproducing the The Girl with the Pearl Earring with a metasurface with an overall size of about 0.6 mm ´ 1 mm.

More importantly, the rich design freedom of metasurfaces has made the metasurface-based nanoprinting technology develop from the original single-channel to current multi-channel, multi-function integration and even dynamic display, showing attractive application prospects in the fields of information storage, optical anti-counterfeiting, information encryption and ultra-compact display, as shown below.



Typical applications of metasurface-based nanoprinting. Credit: OEA

In a study published in *Opto-Electronic Science*, researchers have summarized the development of metasurface-based nanoprinting in recent years. Based on the physical principle of metasurface-based nanoprinting, this paper reviews in detail the research progress of single-channel metasurface-based nanoprinting, multi-channel metasurface-based nanoprinting, dynamic metasurface-based nanoprinting and multi-functional metasurfaces combining nanoprinting with holography or metalens.

The authors also discuss the applications of metasurface-based nanoprinting in image display, vortex beam generation, information decoding and hiding, information encryption, high-density optical storage and optical anti-counterfeiting, and finally summarizes the opportunities and challenges that metasurface-based nanoprinting currently faces.

More information: Rao Fu et al, Metasurface-based nanoprinting: principle, design and advances, *Opto-Electronic Science* (2022). DOI: 10.29026/oes.2022.220011