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Enhancing Security with Superlens-Enabled Laser Direct Marking of Anti-counterfeiting DotCode

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Abstract: We report a novel anti-counterfeiting laser marking technology based on superlens-assisted nanoscale marking of 2D Dotcodes, which replaces conventional TEXT or other 2D code schemes for enhanced security.

1. Introduction

Laser marking has been widely used as an effective tool in anti-counterfeiting applications [1]. Compared to ink-based marking, laser-marked patterns are difficult to rub off, making them an ideal solution for traceability and anti-counterfeiting purposes. Laser marking creates a permanent and indelible mark [2]. However, with the rapid growth of laser technology, especially fiber laser technology, the prices of conventional laser marking systems have considerably dropped in recent years, which has led to an increase in counterfeiting activities. Therefore, we need new innovations to enhance the security level of our markings, preventing counterfeiters with laser marking systems from copying or reproducing our marks. To achieve this, we propose a novel two-level security marking approach: first, we encode text-to-be-marked into a DotCode; second, we add nanoscale features to the dots with the assistance of superlens. These nano features add enhanced security to our marking, providing an effective anti-counterfeiting solution for protecting authentic products.

2. Methodology

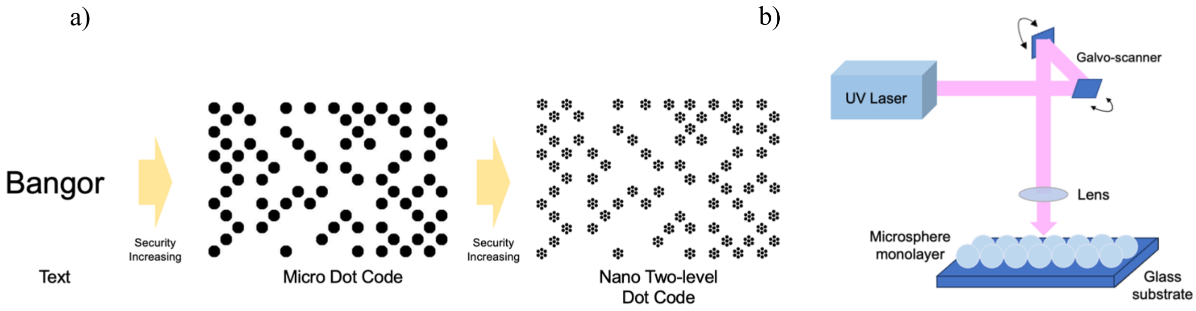

Fig. 1. a) Conventional laser text to micro DotCode and to nano DotCode marking by superlens. b) Schematic of the experimental setup.

Figure 1a illustrates the conversion process from conventional laser text marking to micro DotCode marking and further to nano DotCode marking, assisted by an array of particle superlenses. To meet the demand for a low-cost solution, we explored the use of a superlens-assisted marking technique employing a 355 nm UV laser with a repetition rate of 50 kHz. Figure 1b presents the schematic of the experimental setup used to produce a large-area monolayer of microsphere arrays on a glass surface sample.

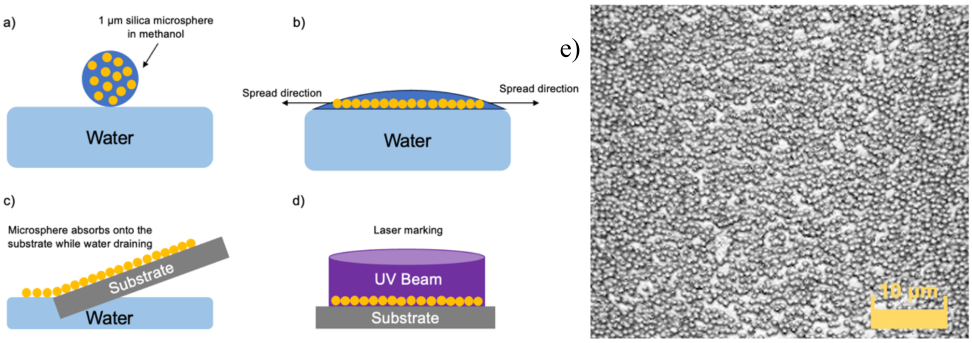

Fig. 2. a) - d) Illustration of the preparation of silica monolayer. e) Micro-image of prepared silica monolayer.

The deposition of arbitrary spherical particles was achieved by submerging the substrate in water. The particles in suspension were deposited onto the water/air interface to self-assemble inside an area-confining barrier. Subsequently, as the water was released from the apparatus, the monolayer formed on the water/air interface was lowered onto the substrate below [3]. It is well-known that water, along with mercury, has the highest surface tension among all liquids. The idea behind this approach is to allow colloidal microspheres to self-assemble on the water's surface and then lower them onto a substrate, as illustrated in Figures 2a to 2d. Figure 2e showcases regions of 1 µm silica monolayers, exhibiting multiple areas of aggregations that directly depict the self-assembly of latex colloids.

3. Results and Discussion

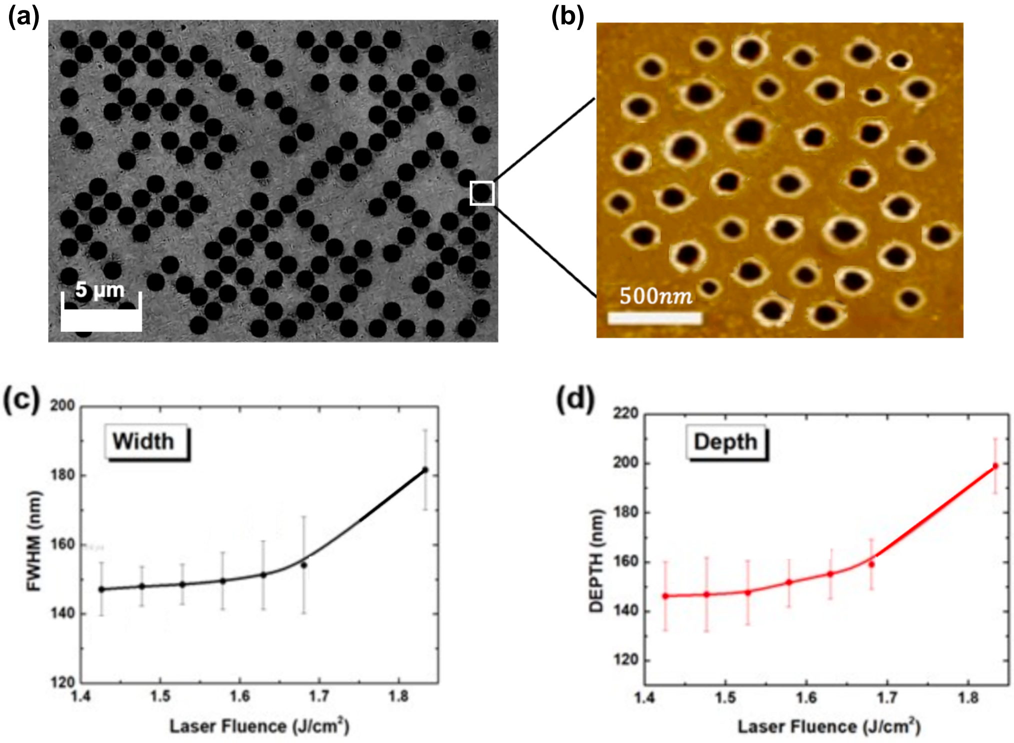

Fig. 3. DotCode ‘Bangor University’ superlens nano marking by UV laser. (a) Microscope, (b) AFM image marking at 1.83 J/cm^2 laser fluence. (c) Width of nanoholes at FWHM. (d) Depth of the nanoholes.

Figure 3a and 3b display the fabricated sample after laser marking of the DotCode "Bangor University" using a particle superlens on top at a laser fluence of 1.83 J/ cm^2. It shows the most well-defined patterns under this energy level, with a strong contrast between the laser-processed areas (black) and non-processed areas (gray). Each laser-processed spot contains a cluster of nanoholes with a size of approximately 180 nm, which were generated by the particle superlens as shown in the AFM image. The measured nanohole width at FWHM and depth under different energy fluences ranging from 1.42 to 1.83 J/ cm^2 were summarized in Figure 3c and 3d, respectively, with error bars indicating size variations of about 10 to 20 nm. A general tendency is observed, indicating that both the width and depth of the nanoholes increase with laser fluences.

4. Conclusion

In summary, we have developed a new laser-based anti-counterfeiting technology based on the novel concept of utilizing particle superlens to generate subwavelength nanoscale holes within each laser processing spot. This technology provides an added level of security protection in combination with the DotCode scheme, surpassing conventional laser marking methods. Using 1 µm silica microspheres and a 355 nm UV laser source, the fabricated hole size (FWHM) typically ranges around 180 nm at a laser fluence of 1.83 J/ cm^2.

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