# Extraordinary transmittance in three-dimensional metal structure prepared through reversal imprinting of metal films

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SPR-induced extraordinary transmittance has attracted much attention, it occurs when the transmission of a metallic material featuring specific sub-wavelength structures is much higher than that expected from classic diffraction theory [1-2]. We used a reversal imprinting-in-metal (RIM) process to fabricate various three-dimensional (3D) metal structures under low pressure. Molds featuring different shapes were used to pattern various sub-wavelength metal structures, including pyramidal, hole-array, and crater-like structures. As shown in Fig.1, the thin film of gold was deposited onto a surfactant-coated silicon mold, which then directly contacted with resist. The adhesion between the gold film and the resist was affected through the monomer units undergoing crosslinking to form a hard epoxy under exposure to UV light. Finally, the silicon mold was removed to reveal the designed metal patterns on the resist-coated substrate.

Fig. 2 (a) reveals the structure of a pyramid-shaped mold having a height of 120 nm and a period of 400 nm. After performing the RIM process, we obtained a corrugated gold film having a period of 400 nm (Fig. 2 (b)). Fig. 2 (c) displays the image of a silicon mold having a feature depth of 900 nm, a hole diameter of 400 nm, and a period of 800 nm. Patterning of the contact area between the gold film and the polymer provided a flat gold film possessing periodic holes (Fig. 2 (d)). Figure 3(a) presents a schematic representation of a 3D crater structure fabricated using the RIM process. A sharp mold possessing features having a height of 1 μm and a period of 800 nm was used in the imprinting processes. The mold displayed in Fig. 3(b) for patterning the 3D crater structure. After reversal imprinting, Fig. 3 (c) reveals that we obtained a gold crater structure featuring hole-arrays having a thickness of 45 nm and a height of 200 nm.

The FDTD simulations in Fig.4 (a) indicate the electric field distribution in the crater film structure. Significant electric field amplitude appeared in each cavity. Enhanced confinement of the optical field in the crater structure allows more energy to pass through the sub-wavelength holes. Fig. 4(b) displays the simulated transmission spectra of various structures in the near-field regime. We also observed highe electric field intensity in a crater structure possessing elongated cavity walls. The maximum electric field intensity of the 3D crater-array structure was 26.9. For the same height (200 nm) metallic structure, the electric field intensity of the hole-array structure dropped dramatically to 6.91. Thus, the maximum value of the electric field intensity of the crater hole-array structure was nearly 3.9 times greater than that of the empty hole-array structure in the near-field regime, revealing that the gold crater structure provides a significantly enhanced transmission.

1. T. W. Ebbesen, H. J. Lezec, H. F. Ghaemi, T. Thio, and P. A. Wolff, “Extraordinary optical transmission through sub-wavelength hole arrays,” Nature 391, 667 (2005).
2. S. Y. Chuang, H. L. Chen, S. S. Kuo, Y. H. Lai, and C. C. Lee, “Using direct nanoimprinting to study extraordinary transmission in textured metal films,” Optics Express, No. 4, 2415-2422 (2008).

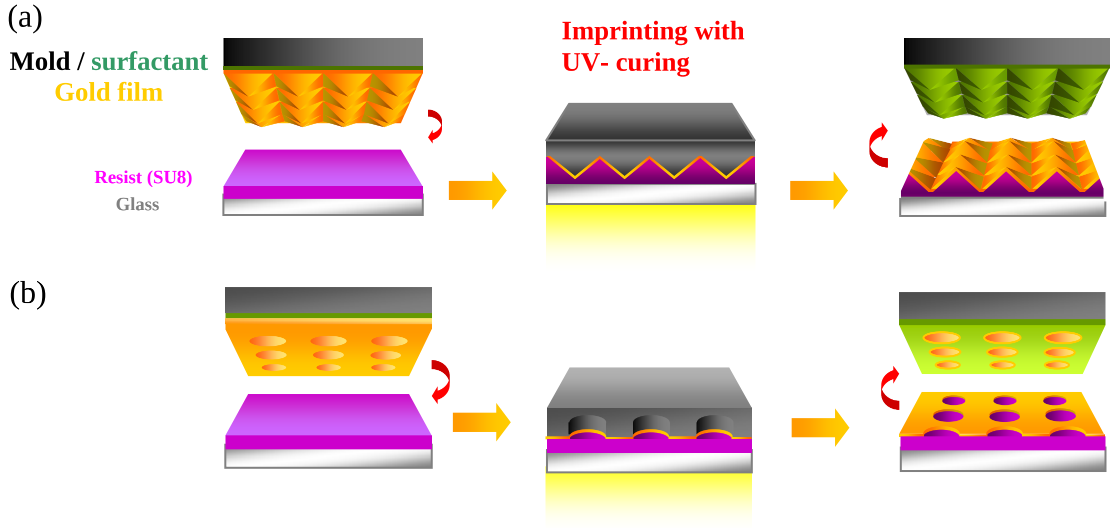
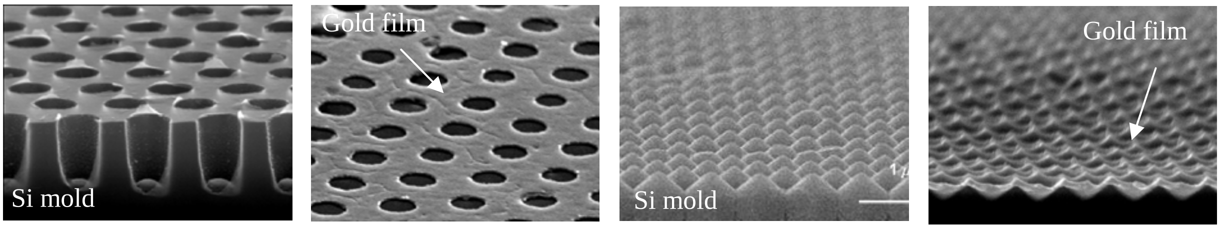


Fig. 1. Schematic representation of the RIM process for the preparation: (a) a two-dimensional corrugated metal film and (b) a metal hole-array structure.



(a) (b) (c) (d)

Fig.2 SEM images of (a) mold for inking process (b) mold for embossing ; RIM result for 45 nm Au (c) metal hole array with 800nm period (d) corrugated gold film with 400nm period

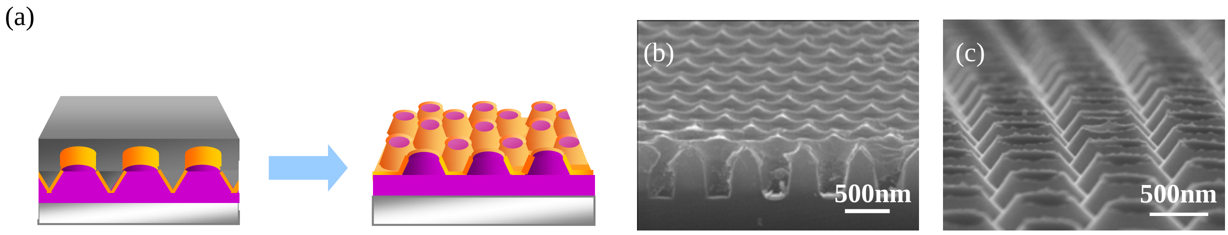


Fig. 3. (a) Schematic representation of a crater-like structure fabricated using the RIM process. (b, c) SEM images of (b) a sharp silicon mold and (c) a gold crater structure.

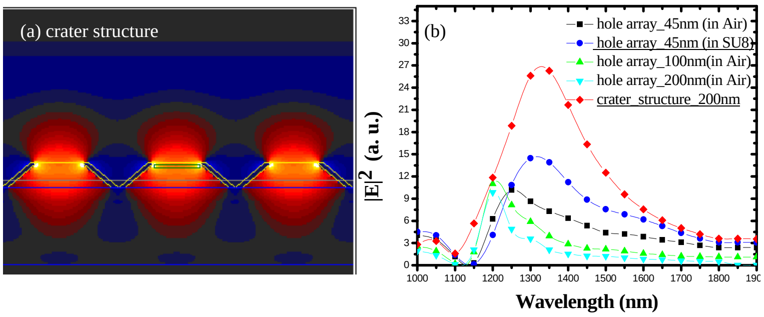


Fig. 4. (a) FDTD-simulated diagram of a crater structure having a height of 200 nm. (b) Electric field intensities determined from a near-field analysis of hole-array structures of various depths and crater structures.