Using reversal imprint lithography to pattern textured metal fims for surface plasmonic device applications

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Sub-wavelength metal hole-array structures exhibiting surface plasmons resonance (SPR) phenomena and extraordinary transmission have been reported recently [1]. It was reported that continuous metallic films with appropriate corrugation could also permit enhanced transmission [2]. However, the fabrication of sub-wavelength hole-array or corrugated structure is complicated due to the etching process and nonlinearity of the photoresist sensitivity. Here we demonstrate a reversal imprint method without additional pressure, named "Reversal imprint in metal, RIM" to pattern metal films with various profiles. Fig. 1 displays the processing steps, a metal film is evaporated onto the surfactant coated mold, and then the mold put on a polymer film coated substrate. After the imprint and UV curing step, a metal film will be stayed on the polymer film and release from the mold because of the surface energy difference between mold/metal and metal/polymer interfaces.

In this study, we demonstrate two RIM processes to fabricate both hole-array and corrugated structures in metal films. As displayed in Fig. 1(a), an inking process was used for patterning metal hole-array. Fig. 2 (a) and 2 (c) are the SEM images of silicon mold with hole-array pattern and the inking result, respectively. As displayed in Fig. 1(b), an embossing process was used for patterning corrugated metal films. Fig. 2 (b) and 2 (d) display the SEM images of silicon mold with pyramidal structures and the embossing result, respectively. Fig. 3 (a) and 3 (b) display the FDTD simulation results of the electric field distribution in the Au film with hole-array and corrugated structures, respectively. The transmittance of Au film can be enhanced as the film is patterned with hole-array and corrugated structures. The resist/corrugated gold film/air structure only has a weak SPR peak at 520 nm near the intrinsic transmission peak of gold. After coating a resist layer as an index matching layer, the transmittance of resist/corrugated gold film/resist dramatically arise to 46% as shown in Fig. 4(a). Fig. 4 (b) indicates that hole array structure without index matching layer still has 50% transmittance, and increasing to 57% in the symmetric structure (resist/ hole array /resist), due to light propagates mainly by SPR effect through the hole to the opposite side of metal film as simulated in Fig. 3 (a). The RIM method could be applied in band-pass filters, color filters, and beam splitters without the need for complex optical multilayer thin film-based filters. This technique could also be used for the preparation of various optoelectronic devices exhibiting increased external quantum efficiencies through surface plasmons phenomena.

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. Wedge, I. R. Hooper, I. Sage, and W. L. Barnes, "Light emission through a corrugated metal film: The role of cross-coupled surface plasmon polaritons," Phys. Rev. B 69, 245418 (2004).

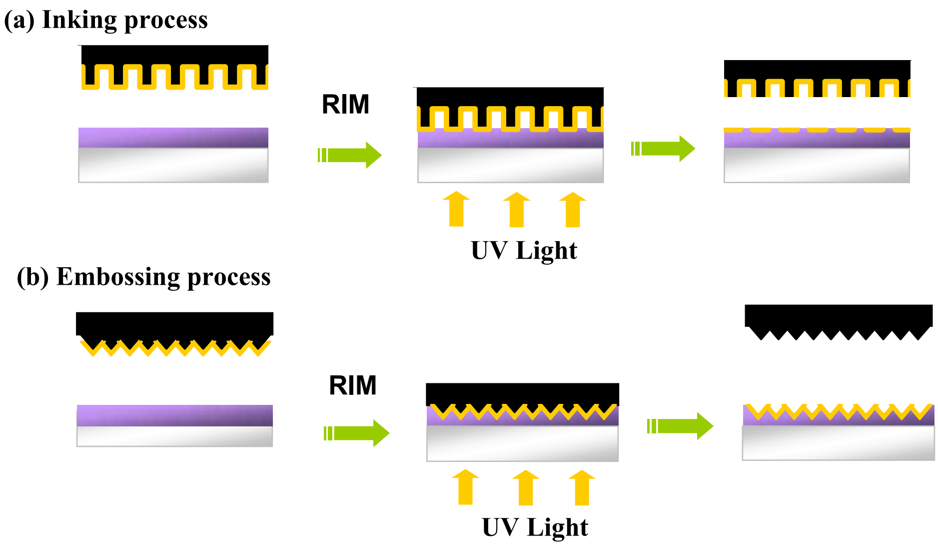

Fig. 1 Schematic diagrams of reversal imprint in metal

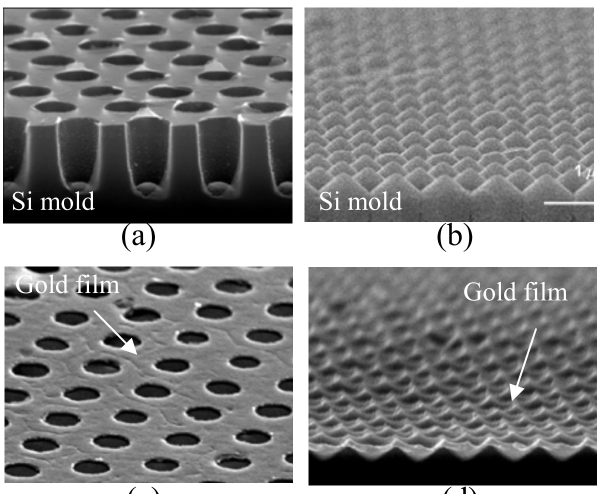

Fig.2 SEM images of (a) mold for inking process (b) mold for embossing process imprinting result of (c) hole array (d) corrugated gold film

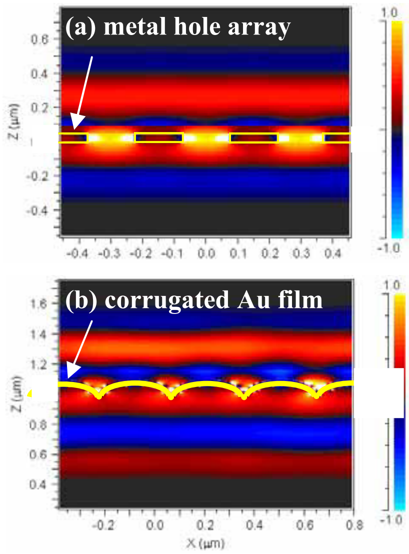

Fig.3 FDTD simulation of electric field distribution in Au films with (a) hole-array (b) corrugated structure

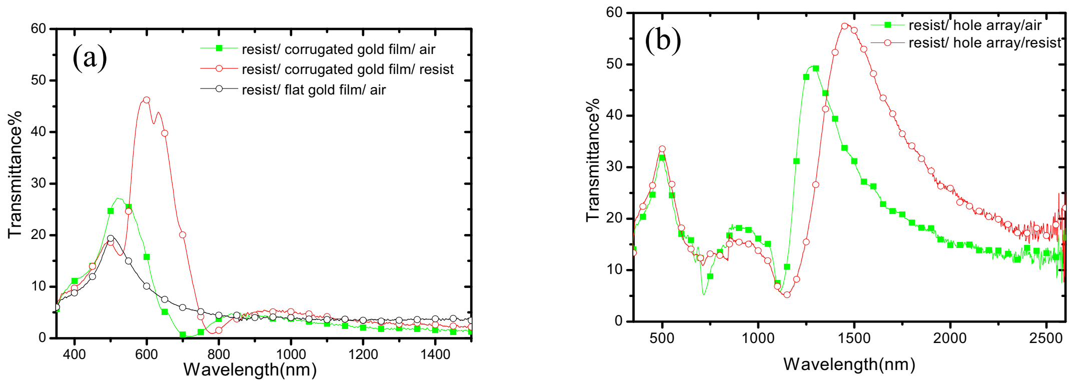

Fig.4 Measured transmittance spectra of (a) corrugated structure in gold films (b) hole-arrays structure in gold film with or without an index matching layer