Directly patterning metal films by nanoimprint lithography for surface plasmonic device applications

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Nanoimprint lithography has great potential as a candidate of next generation lithography for their low-cost, high-throughput and high-resolution. The imprint process is accomplished by heating a resist above its glass transition temperature and imparting a force to transfer the image into the heated resist. Recently, a process of direct imprint in gold films with ultra-high pressure (several hundreds MPa) was reported. This method is a promising way to fabricate optical elements on gold films, but there is a fatal drawback of ultra-high imprint pressure [1]. Therefore, reducing imprint pressure would accomplish this method for optical device fabrications. As shown in Figure 1, we demonstrated an imprint method named nano-imprinting in metal /polymer bi-layer structures for patterning metal films with varied profiles. Converse with conventional nanoimprint lithography, the patterned mold is directly imprint in metal films not in polymer based resists. In general, direct imprint in metal films need ultra-high pressure or temperature to form patterns. We improve the direct imprint processes by using a sharp mold and an underlying soft pad layer for the reduction of the imprint pressure and temperature. The imprint pressure can be reduced to be compatible with the conventional nanoimprint instrument.

The silicon mold used in our experiments was fabricated using electron beam lithography followed by the anisotropic reactive ion etching process. The bias and RF power of RIE are the critical parameters for controlling the mold profile. As shown in Figure 2 (a) and 2 (b), the sharp mold can be fabricated by optimization the etching processes. Figure 2 (c) and 2 (d) shows the scanning electron microscope image of the cross-section of gold film stack patterned by using direct imprint method with large area. As shown in Figure 2 (e), the two-dimensional wavy gold structure can also be easily fabricated by directly imprinted metal method with two times. The surface of the gold film stack was found with sinusoidal variation. Figure 3 shows the depth of surface-profile in gold films can be tuned by using different imprint pressure. According this result, we can obtain the desired curvature of shape by using different imprint pressure. For rapid fabrication metallic gratings, this method is also suitable to fabricate a grating-coupler that could be used to replace a prism-coupler for surface plasmon resonance (SPR) based biosensor. Two-dimensional metal structures can dramatically enhance transmission of metal films for surface plasma effects [2]. As shown in Figure 4, the transmittance is dramatically increased from 3% to 50% near 700 nm by increasing imprint pressures. This technique can be used in various optoelectronic devices for increasing their efficiency. Detailed analysis and results will be reported in the conference.

1. H. Yoshihiko *et. al.*, Proc. of SPIE -The International Society for Optical Engineering 74, 5220 (2003).
2. T.W. Ebbesen *et. al.* , Nature, 391, 667–669 (1998).

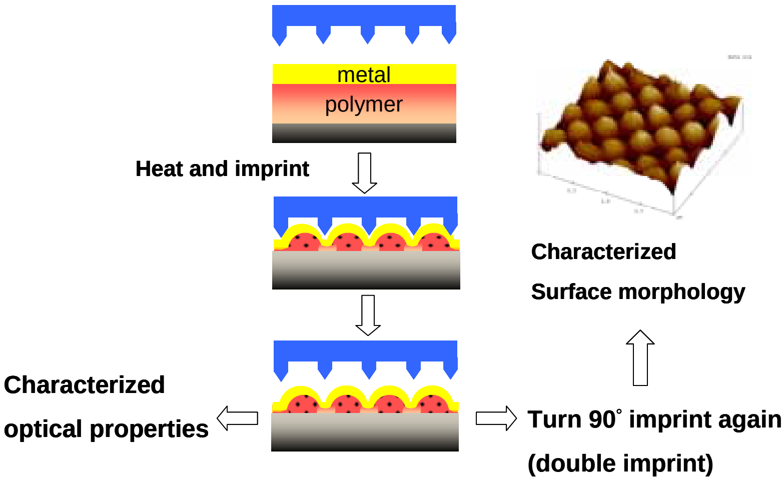


Figure 1 Schematic diagrams of nanoimprint in metal / polymer bi-layer.

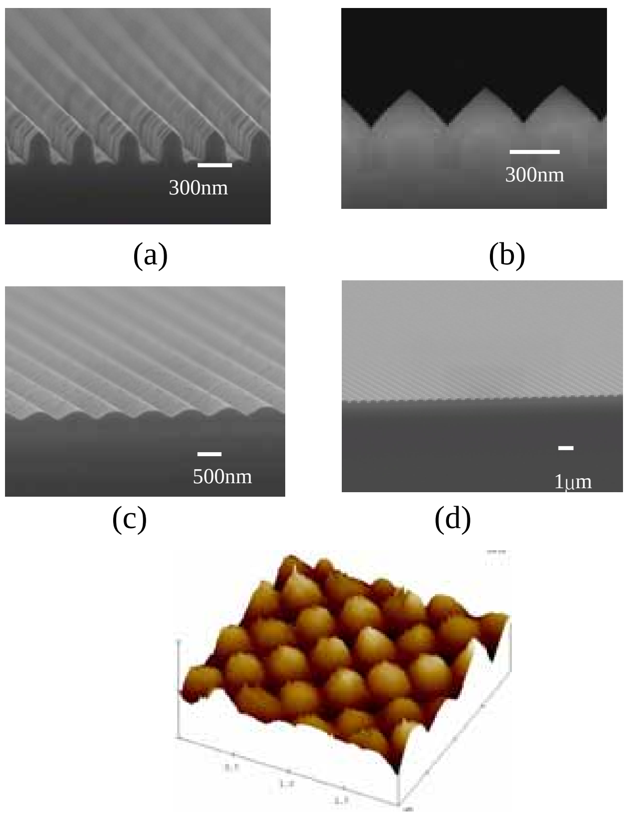


Figure 2 Microscope images of (a), (b) the sharp mold (c), (d) wavy gold films (e) two-dimensional wavy gold structure patterned by using direct imprint method.

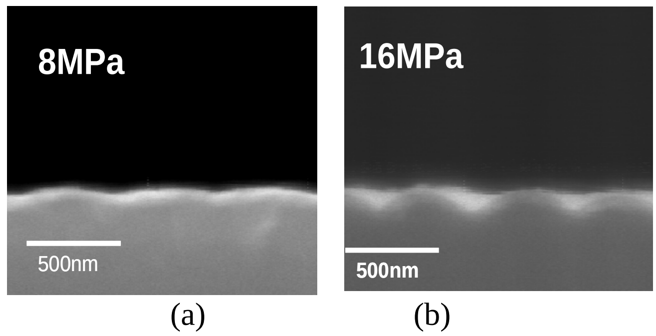
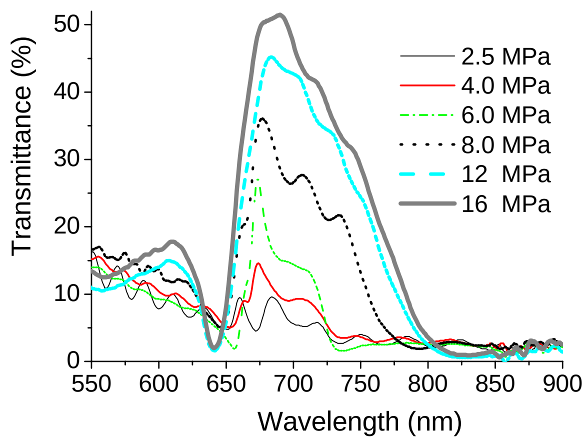


Figure 3 The depth of surface-profile in metal films can be changed by using different imprint pressure (a) 8MPa (b) 16MPa



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