Nanofabrication of metasurface with gold polycyclic radial apertures for optical vortex by EBL

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Inhomogeneous spatial polarization status of vortex optical field is of great importance in multidimensional optical data storage, surface plasmon based photonic devices, etc.[1] To generate vortex optical field, metasurface with polycyclic radial apertures is one of the advanced approaches. When a circularly polarized beam traverses onto a gold film with radial apertures as schematically shown in Fig.1 (a), only the polarized light perpendicular to its long axis is transmitted due to the selective transmission of TM component and the extinction of TE part as showed in Fig.1 (b) [2]. To achieve high contrast vortex optical field, the width of aperture, the period in the whole metasurface must all be below the wavelength. Conventional fabrication method for such a metasurface is to employ electron beam lithography (EBL) in negative tone resist. However, there is always a problem in the lift off process because of the hardness in cured negative tone resists; moreover, it is also very time consuming and limited the use of metasurface in large area. To overcome these difficulties, a novel EBL process in a bilayer of PMMA/NEB has been developed, which combines the merits of both resists. PMMA is easy to be lift off; whilst NEB is a chemically amplified resist with high sensitivity can shorten the exposure time. Fig.2 is the contrast curves of PMMA and NEB.

Fig.3 illustrates the process flow. NEB lines can be independently replicated on PMMA after development since the developer for NEB is alkali TMAH, which doesn't attack PMMA. A subsequent reactive ion etch in O_2 plasma etched away the PMMA layer using NEB lines as mask. Fig.4 shows the section view of the PMMA/NEB lines. After evaporation 80nm gold and lift off, seven annulus radial gold apertures with subwavelength period are succeeded, as showed in Fig.5 and Fig.6. This process also can be used to fabricated ultra-fine lines efficiently; fig 7 shows the thinnest line (16nm) we can get by using this method.

In summary, a novel PMMA/NEB bilayer process by EBL has been developed for replicating nanosize apertures in gold film, which has been successfully applied to the fabrication of metasurface as a converter of optical vortex. The optical measurement of light field conversion by such a metasurface is under way and will be reported before long.

References:
[1] X. Li, T. H. Lan, C. H, Tien, Nature communication. 3, 998 (2012).
[2] Nanfang Yu, Federico Capasso, Nature Materials 13, 139 (2014).

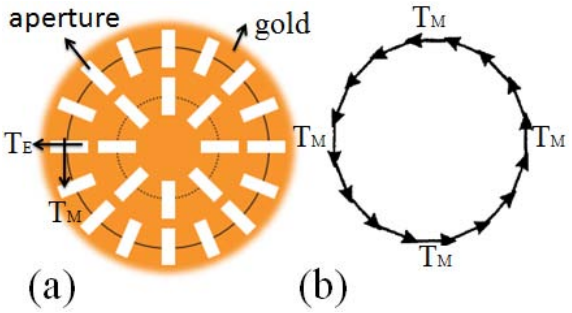

Fig.1 The schematic diagram showing the formation of rounded vector field.

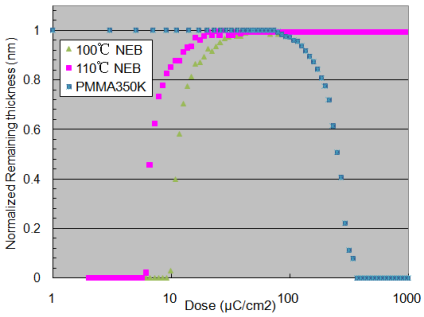

Fig.2 Contrast curves of PMMA and NEB

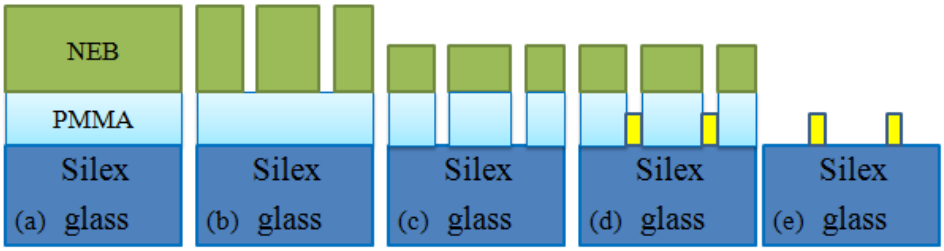

Fig.3 The process flow: (a) Layer stack; (b) Exposure and Development; (c) RIE; (d) Au evaporation; (e) Lift-off.

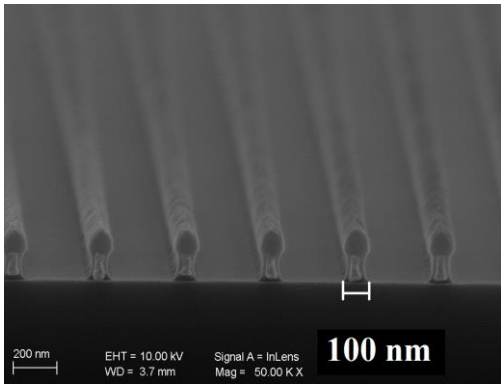

Fig.4 Section view of PMMA/NEB lines after RIE

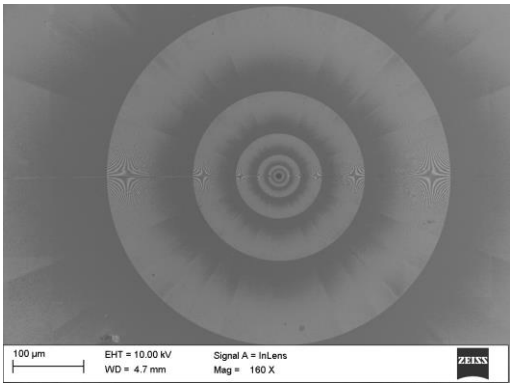

Fig.5 Global SEM image of the metasurface after metal evaporation and lift off

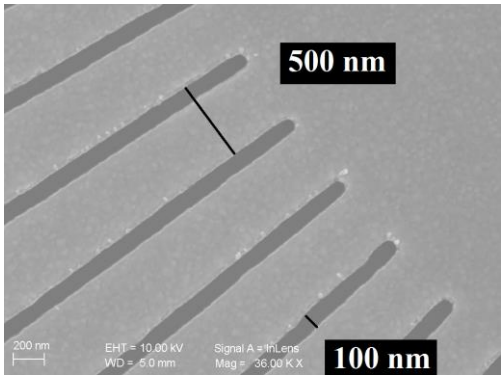

Fig.6 Enlarged details for the metasurface

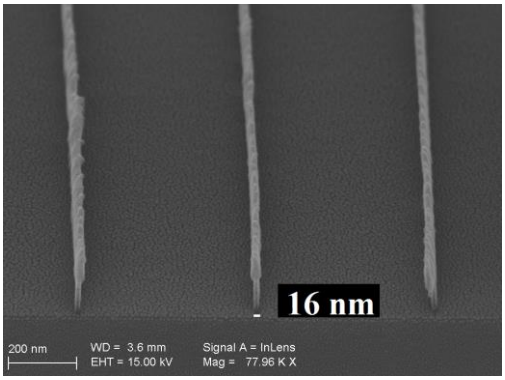

Fig.7 Ultra-fine resist lines fabricated by this bilayer process