Fabrication of Thin Metallic Nanostructures Using Atomic Layer Deposition

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Atomic layer deposition (ALD) is an effective method to apply new materials with better structural properties to complex nanostructures [1,2]. Various research groups have employed ALD process after the fabrication of their unique nanostructures, such as nanosprings, nanotubes, and nanolattices [3-5]. Different materials, including ZnO, TiO_2, and TiN, were used for their ALD process, so better optical properties and mechanical stability can be achieved. However, in previous implementation of ALD process the final products are brittle and fragile by the nature of their materials; therefore the achievements have been limited.

In this work, we report the fabrication of thin metallic nanostructures by conformal ALD coating on one-dimensional (1D) grating layer patterned by interference lithography (IL). Figure 1 shows a proposed fabrication process, which includes IL for a periodic photoresist 1D structure, ALD for a conformal metal layer deposition and a subsequent burning process using a convection oven for removing the sacrificial resist structure. A negative-tone photoresist (SU-8) was selected as a platform due to its high glass transition temperature (> 200°C), which is required for metal ALD processes. A buffer layer with a fully crosslinked SU-8 was prepared for a better adhesion and stability of 1D grating layer. After lithography, a hard bake process with a temperature higher than the one for the following metal ALD process was performed to prevent any crosslinking of photoresist during the metal deposition process.

Initial fabrication results are shown in the cross-sectional SEM images of the fabricated 1D periodic structure after platinum (Pt) ALD process (Figure 2(a)-(b)). The thickness of SU-8 including the buffer layer is about 1 μm and the period of 1D grating is 1 μm in this experiment. Subsequently, 30 nm of Pt film was deposited over the photoresist 1D grating structures using ALD at 200°C. Figure 2(c) and 2(d) illustrate the thin Pt nanostructures after the burning process, indicating that the sacrificial photoresist layer was removed completely during the final process. The thickness of the metal layer will be experimentally optimized to confirm a uniform and durable structure. Using an analytical method, we will confirm the burning condition for the sacrificial template without any loss or defect of the metal layer. Detailed optical, electrical, and mechanical characterizations of the thin metallic nanostructure will be performed using different substrate materials and grating geometries.

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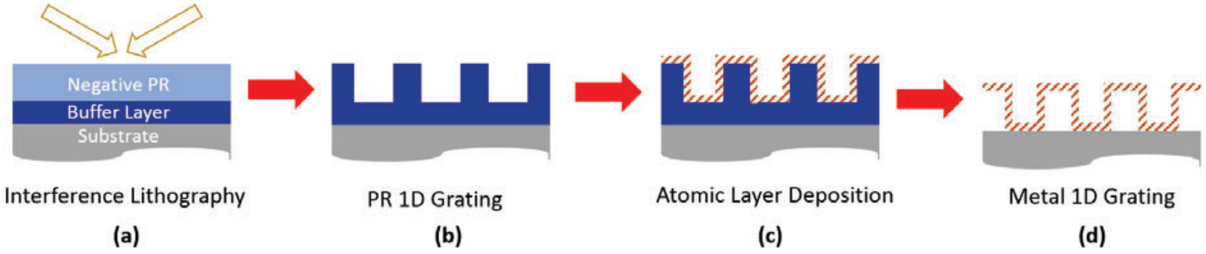

Figure 1. Fabrication process for thin metallic nanostructures. (a) Prepare buffer layer and a photoresist on silicon substrate, (b) interference lithography to pattern grating structure, (c) atomic layer deposition of metal over photoresist structure, (d) removing the sacrificial layer using a temperature process.

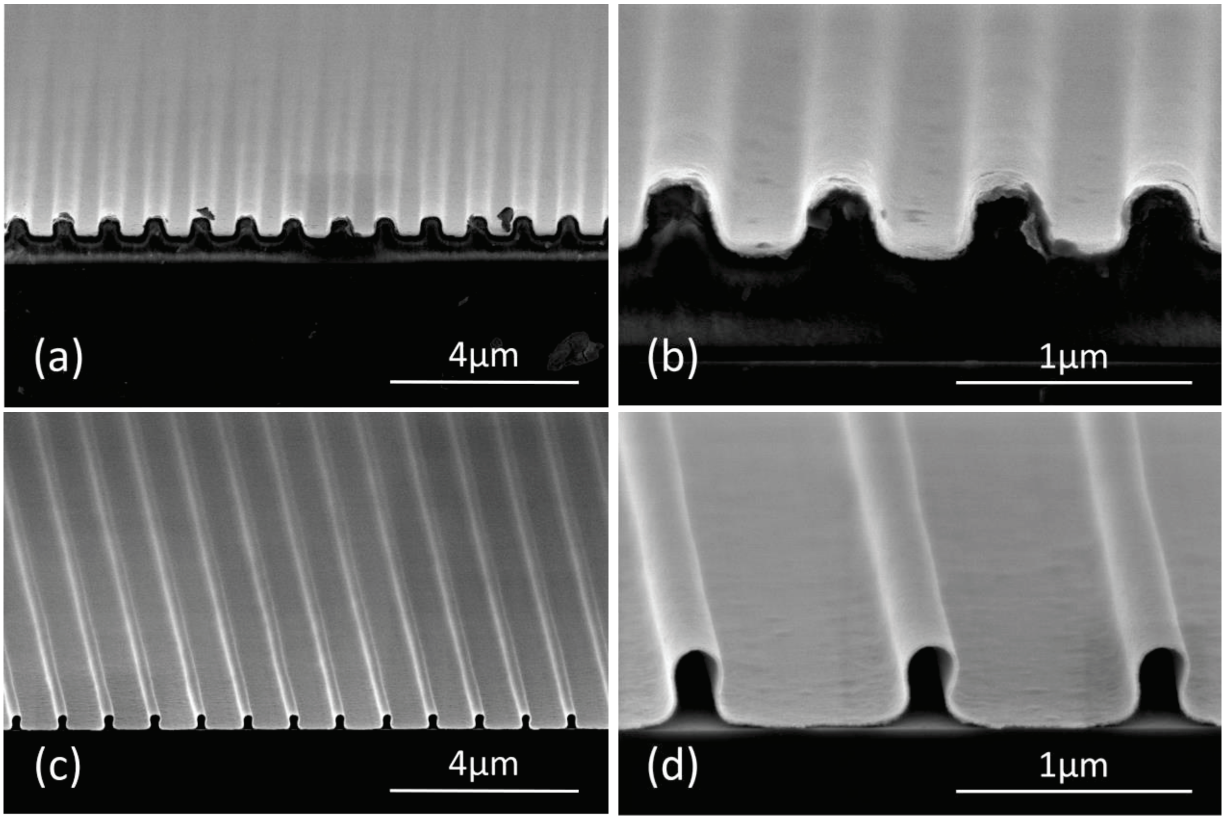

Figure 2. Cross-sectional SEM images of (a)-(b) 1D grating structure after interference lithography of SU-8 and atomic layer deposition of 30nm platinum. (c)-(d) Periodic platinum 3D nanostructure on silicon substrate after burning process

References:
[1] *M. Knez et al., Advanced Materials, 2007,* ***19****, 3425-3438*
[2] *H. Kim et al., Thin Solid Films, 2009,* ***517****, 2563-2580*
[3] *A. Bagal et al, EIPBN 2014, Washington D.C.*
[4] *D. Jang et al., Nature Materials, 2013,* ***12****, 893-898.*
[5] *S. Park et al., Journal of Material Chemistry C, 2014,* ***2****, 1957-1961.*