Fabrication of Silver Nano Slit Chain Waveguides for Surface Enhanced Raman Scattering

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Scattering of light from small metal particles or surfaces with an appropriate geometry gives rise to surface enhanced Raman scattering (SERS). Study has shown that closed and open rectangular cavities, formed by a metal, provide a very large average field in the cavity due to resonance of a waveguide mode, hence a very large SERS effect. This led to a new type of nano-slit chain waveguide mechanism based on resonant inter-particle gaps (or slits) [1].

One of the main problems of fabricating metal nanostructures is the control of surface roughness, as most metals, especially silver, do not wet the dielectric surface and tend to form metal nanoparticles. Recently, Nagpal, *et al* explored a method of combining template stripping with precisely patterned silicon substrates to achieve ultra-smooth pure metal films [2]. They have demonstrated smooth metal films at feature sizes range from microns down to hundreds of nanometers. Here, we adopt this method to work on precise fabrication of chain waveguide with gap sizes range from tens of nanometers or even smaller.

Silicon molds are prepared on 110 silicon wafers. Gratings in 50-nm thick negative e-beam resist Hydrogen Silsesquioxane resist (HSQ) are patterned with e-beam lithography (Vistec Leica VB6). We have demonstrated 20nm pitches using a double patterning process (Fig. 1a). Rapid thermal annealing is followed to further cross-linking HSQ, converting it to SiO2. Using HSQ as a hard mask, orientation-dependant potassium hydroxide (KOH) wet etching was used to obtain atomically smooth side wall gratings. Fig. 1b shows one of our wet etching results in 200 nm pitch.

Figure 2 illustrates the schematic of process flow for transfer the smooth grating pattern to the metal layer. After achieving silicon mold, e-beam evaporation of 250 nm thick silver is followed. On top of it, additional metal layer is electroplated or a thick layer of epoxy is spun coat. The last step is to apply the concept of template stripping. Because of the adhesion between silver and epoxy is stronger than that between silver and silicon, when peeling off, silver is going to stick to epoxy, leaving the mold behind. In this way, a pure metal chain waveguide can be formed, and the silicon mold could be reused as well.

Since the silicon mold is very smooth, the surface of silver chain would be smooth as well. AFM and SEM will be conducted to detect the surface smoothness.

References:

[1] K. J. Webb and J. Li, "Resonant Slot Optical Guiding in Metallic Nanoparticle Chains," *Phys. Rev. B* **72**, 201402R (2005).
[2] Nagpal, P., et al., "Ultrasmooth Patterned Metals for Plasmonics and Metamaterials", *Science*, **325** 594-597, (2009).

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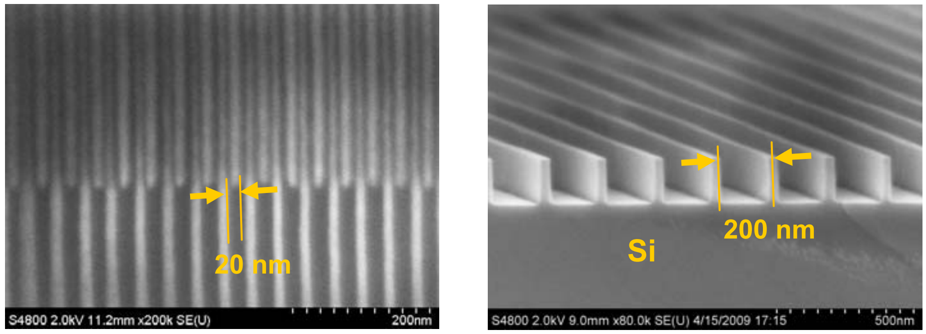

(a) (b)

Fig. 1: (a) 20nm pitch gratings exposed in HSQ with double patterning. (b) Silicon grating mold with atomically smooth side walls with 200 nm pitch.

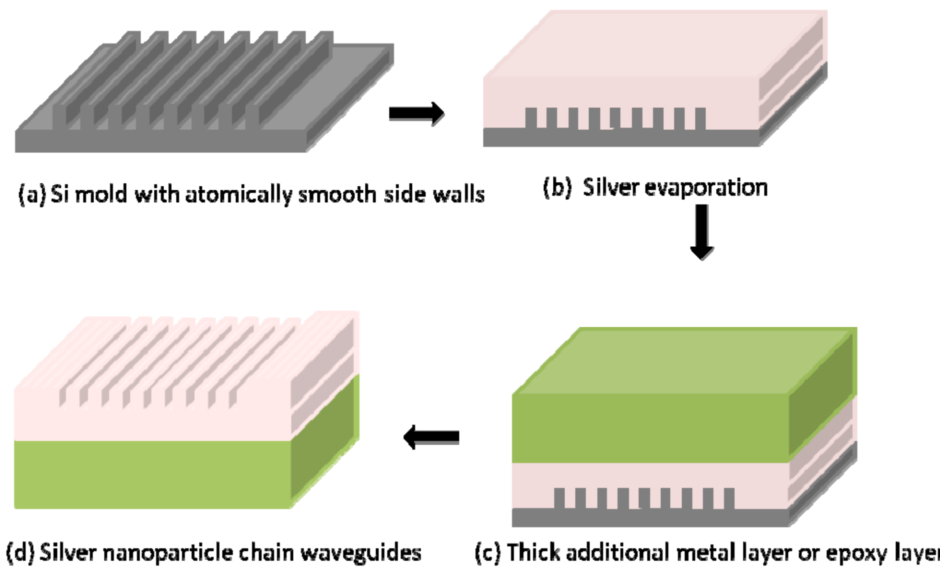

Fig. 2: Schematic of a process to transfer the grating chains from silicon mold to silver. (a) Silicon mold with atomically smooth side walls is obtained via KOH wet etching. (b) Deposition of around 250 nm thick silver. (c) Additional metal layer by electroplating or a thick layer of epoxy via spin coating. (d) Template stripping by direct peeling off to reveal nano-slit silver chain.