Fabrication of metallic nano-slit waveguides with sharp bends

M. Lu[1], L. E. Ocola, S. K. Gray and G. Wiederrecht
Center for Nanoscale Materials, Argonne National Laboratory,
Argonne, IL 60439

Metallic nano-slit waveguides are promising new technologies for ultra-high-density optical interconnections. Theoretical investigations show that deep sub-wavelength metallic slit waveguides with sharp inner corners bend light with a very low transmission loss [1]. While several experiments have demonstrated the light bending behavior in nano-slits [2], none work with in-plane geometry at the 100-nm scale. This is due to the difficulty in patterning high resolution, high aspect ratio structures in metal thin films. Up to now, all the reported devices were made by using focused ion beam milling technology and therefore not compatible with volume semiconductor manufacturing process. In this article, we present a new process using traditional semiconductor fabrication techniques such as mix-and-match lithography and electroplating, which is suitable for production manufacturing.

The waveguide assembly demonstrated here is composed of traditional waveguides, taper couplers and metallic nano-slit waveguides, as shown in Fig. 1. The process starts from patterning and embedding a gold plating base into a silicon oxide wafer using photolithography, reactive ion etch (RIE) and lift-off technologies. A photolithography step is then applied to pattern a one-micron-thick negative photoresist SU-8 to form three-micron-wide waveguides, which will bridge the light from the light source to the taper couplers. Then a thick HSQ e-beam resist layer is coated and patterned with 100-keV e-beam lithography to form the cores for taper couplers and sub-100-nm-wide nano-slit waveguides. After resist development, a RIE process is performed to remove the titanium adhesion promoter, followed by gold electroplating process to finalized the metallic nano-slit waveguides.

HSQ is also a high-resolution resist in EUV (extreme ultraviolet) lithography. Therefore this process can be extended to volume production manufacture when replacing the e-beam lithography with EUV lithography.

References:
[1] T. -W. Lee and S. K. Gray, *Opt. Express* **13**, 9652 (2005).
[2] J. A. Dionne, H. J. Lezec, and H. A. Atwater, *Nano Lett.* **6**, 1928 (2006).
[3] Y. Ekinci, H. H. Solak, C. Padeste, J. Gobrecht, M. P. Stoykovich and P. F. Nealey, *Microelectron. Eng.* **84**, 700 (2007)

---

[1] Email address: mlu@anl.gov

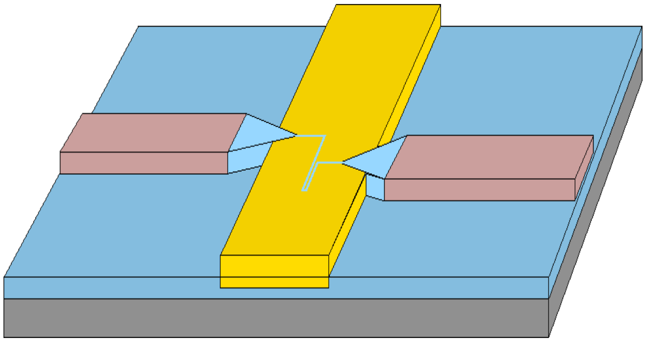

Fig. 1. A waveguide assembly composed of traditional waveguides, taper couplers and a nano-slit waveguide with right angle bend and U-turn structures.

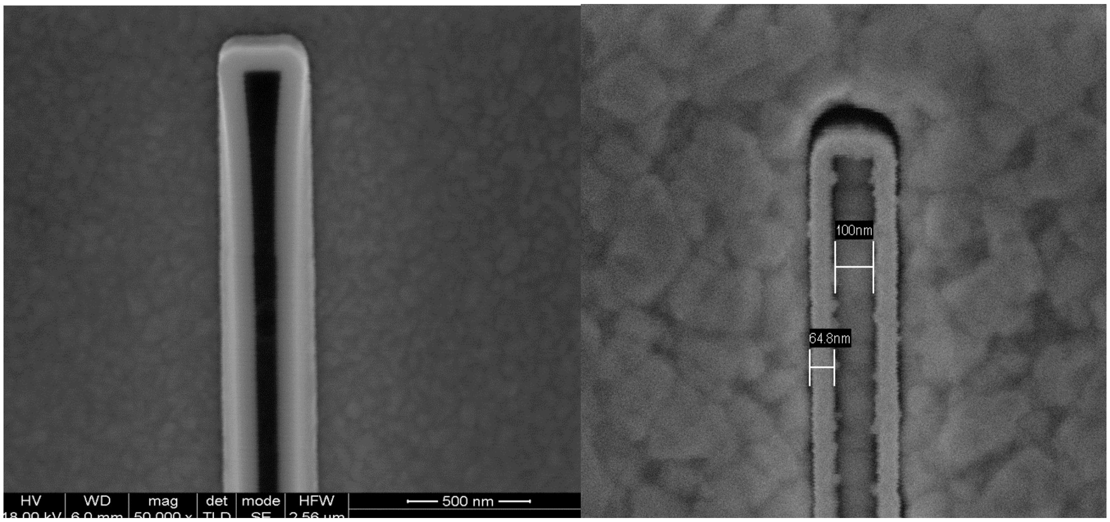

Fig. 2. SEM micrographs of 950-nm-thick HSQ waveguide cores patterned by 100-keV e-beam lithography. Left: after development. Right: after electroplating of 700-nm-gold.