A novel PMMA/NEB bilayer process for sub-20 nm metallic nanoslits by electron beam lithography and dry etch

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Metallic nanoslits in the order of sub-20 nm is increasingly demanded by the applications of both local surface plasmonic resonators (LSPRs) and surface enhanced Raman scatterings (SERs) as high sensitive sensors in bioscience, environmental monitoring, food safety, and optical devices, etc. To improve the sensitivity, narrower slits in thicker gold such as sub 20 nm in width and 100 nm in height are desirable. So far, one of the most efficient methods for nanoslits is to use PMMA/HSQ bilayer technique by electron beam lithography (EBL), followed by a plasma etch. [1] This raises two technical issues, one is it's hard to remove the HSQ lines after being cured in both e-beam exposure and the plasma process, and the other is HSQ requires very high exposure dose, which can cause PMMA underneath is exposed.

In this work, we propose to replace the HSQ top layer by a highly sensitive NEB resist which is a chemically amplified resist (CAR) with negative tone, delivered by Sumitomo Ltd in Japan. Figure 1a presents the contrast curves of the two resists, PMMA and NEB, respectively. From the contrast curves, the sensitivity of NEB resist is typically in the order of 44μC/cm2, which is far below that of PMMA (280 μC/cm2), i.e. when NEB is fully exposed, PMMA still remains unexposed. Furthermore, the developer for NEB is alkali, which does not attack PMMA. The light dose is beneficial not only for large area patterning, but also to the removal of PMMA after the formation of nanowires. Therefore, the overlap region of the two contrast defines the dose latitude, as depicted by the green area in the curve. Figure 1b presents the process flow for the fabrication of nanoslits. Both lines and mesh structures of NEB on PMMA are first formed by EBL. The subsequent RIE process in fluorine based plasma etches the PMMA, using the patterned NEB as etch mask. As narrow as 10 nm PMMA/NEB lines/meshes are successfully replicated as shown in figure 2.A layer of 10 nm Cr /100 nm Au is then deposited by heating evaporation in vacuum. Figure 3 show both line trenches and mesh trenches after lift-off in acetone. As narrow as sub 20 nm trenches in 100 nm Au can be observed. Because the dose range for replicating PMMA/NEB lines is 10 – 200 μC/cm2, which is very broad, indicating that this novel process is very reliable.

By summary, we have developed a novel PMMA/NEB process for the fabrications of sub-20 nm nanoslits in 100 nm thick Au film. This success enables us to produce highly sensitive sensors with either LSPRs or SERS configurations. With this process, it is now also possible to manufacture optical components for the manipulation of lights as metal materials and nanophotonicstructures.

[1]AE Grigorescu, CW Hagen, Resists for sub-20-nm electron beam lithography with a focus on HSQ: state of the art, Nanotechnology, 2009.

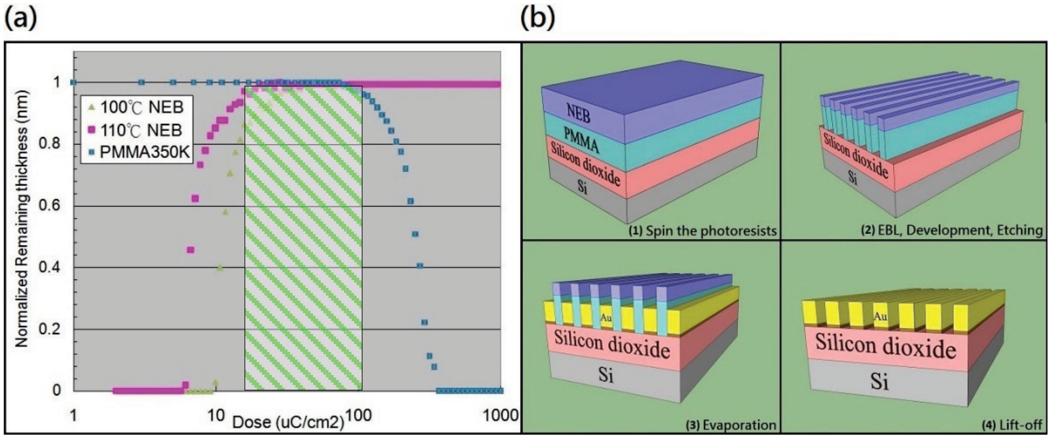

Figure 1.(a)Contrast curves of NEB: at two different post exposure bake (PEB) temperatures 100 ℃/ 110 ℃ and contrast Curve of PMMA350K obtained at the developing temperature of room temperature, showing the processing window for the dose.*(b)Processing flow*.

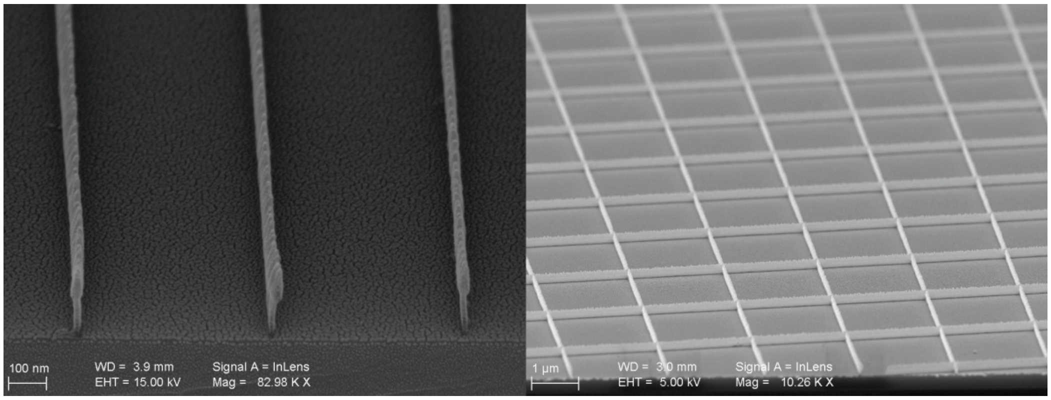

Figure 2. As narrow as 10 nm PMMA/NEB lines/meshes

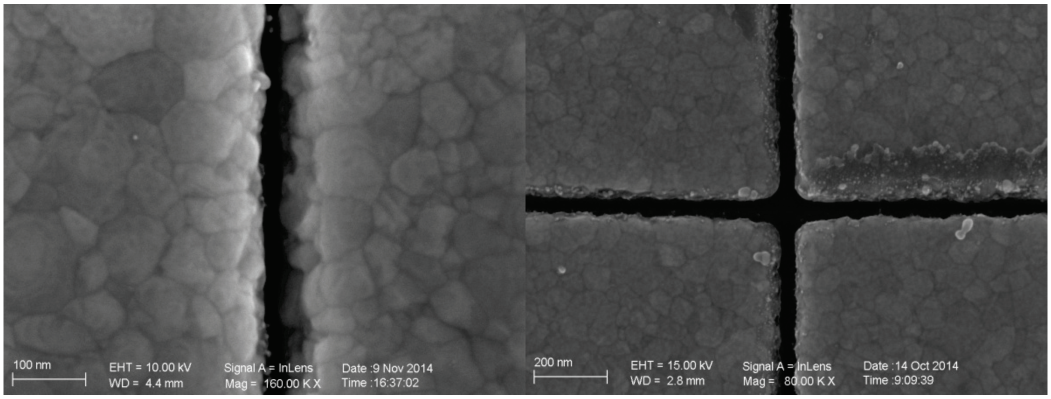

Figure 3. Line trenches and mesh trenches after lift-off