Metal-Organic Complex Photoresists

CNF Project Number: 386-90

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Primary CNF Tools Used: Zeiss Supra SEM, ASML 300C DUV Stepper, ABM Contact Aligner

Abstract:

The most advanced microelectronics are made by using 193 nm immersion lithography systems, but it is difficult to follow the rapid development of semiconductors due to approaching its physical limits. Extreme ultraviolet (EUV) lithography, which use shorter wavelength (i.e., 13.5 nm), can offer the way to print under 40 nm lines and spaces. EUV lithography requires photoresist to utilize EUV photons because photons generated by EUV exposure are fewer than photons generated by 193 nm light exposure. One of the approaching for utilizing fewer EUV photons is using higher EUV absorption elements such as transition metals. We have continuously developed metal-oxide nanoparticles resists since we reported our first example of hafnium oxide nanoparticle resist [1]. In this report, our recent progress in metal oxide nanoparticle photoresist research will be described.

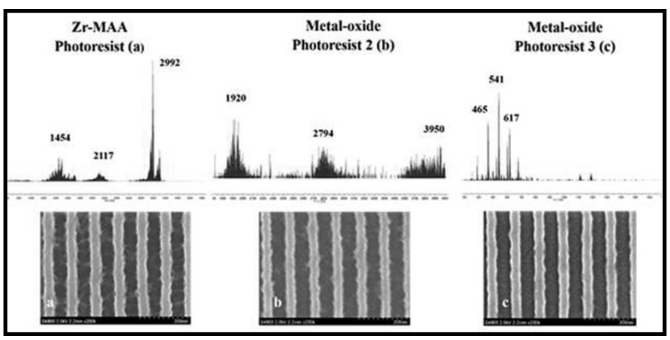

Figure 1: ESI-MS and SEM images after development of different metal oxide photoresists.

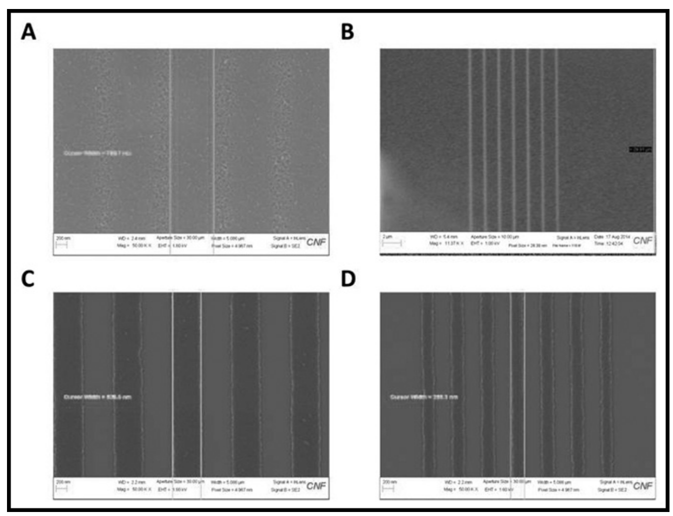

Figure 2: SEM images of DUV exposure results. (A) Zirconium nanoparticle (Zr-NP) 500 nm line-and-space (LS). (B) Zr-NP 250 nm LS. (C) Mono-crystal zirconium (MC-Zr) 500 nm LS. (D) MC-Zr 250 nm.

Summary of Research:

After we have developed hafnium oxide nanoparticle resist, we have also reported zirconium oxide nanoparticle resist. The features of these materials are very fast sensitivity with severe bridging and scumming. In order to elucidate what induced severe bridging and scumming, analysis with electron spray ionization mass spectrometry (ESI-MS) was investigated [2]. ESI-MS spectra and scanning electron microscope (SEM) images of three different resists are summarized in Figure 1. There is a connection between molecular weight and bridging and scumming. This result indicates that metal oxide resist should be smaller molecular weight and narrower size dispersion to print patterns without bridging and scumming. With this hypothesis, we have developed two new materials; one is mono-crystal zirconium resist and the other are metal oxide nanoclusters with a controlled size distribution. The mono-crystal zirconium resist results are summarized in Figure 2. While large amounts of residues can be easily found at unexposed areas in the case of zirconium nanoparticle, mono-crystal zirconium resist demonstrate good 1:1 line-and-space patterns with a feature size from 500 nm to 250 nm.

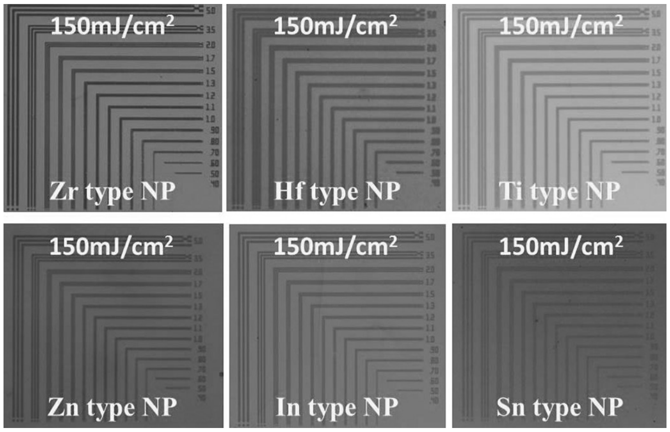

Figure 3: Optical microscope images of micro-scale patterning using the ABM contact aligner.

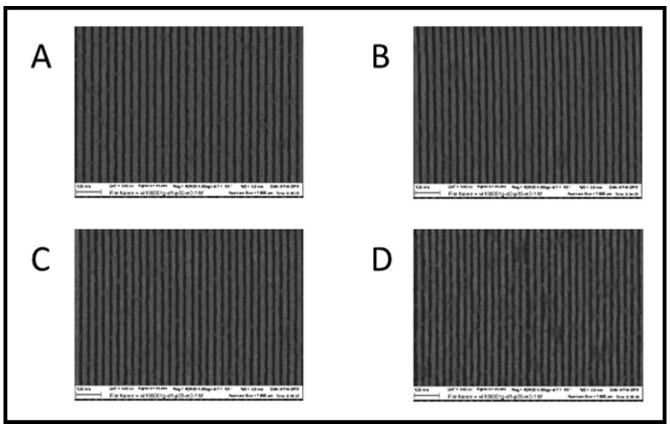

Figure 4: SEM of EUV exposure results with zinc nano-cluster resist. (A) 16 nmLS with 45 mJ/cm^2. (B) 15 nmLS with 47 mJ/cm^2. (C) 14 nmLS with 36 mJ/cm^2. (D) 13 nmLS with 35 mJ/cm^2.

We have synthesized zirconium, hafnium, titanium, zinc, indium and tin nanocluster and obtained microscale patterning result with 150 mJ/cm^2 exposure dose, a typical value at 248 nm exposure are summarized in Figure 3.

The zinc nanocluster is expected to absorb more EUV light than the zirconium nanocluster and we have evaluated zinc nanocluster with EUV light. SEM images are summarized in Figure 4 and demonstrates good 1:1 line-and-space patterns with the feature size of 16 nm, 15 nm, 14 nm and 13 nm, with a dose of 45, 47, 36 and 35 mJ/cm^2, respectively [3].

In this report, we described our recent progress in metal oxide nanoparticle photoresist. Currently we are performing further investigations to improve our material's lithography performance.

References:

[1] Ober, C. K., Xu, H., Kosma, V., Sakai, K., Giannelis, E. P., EUV Photolithography: Resist Progress and Challenges. Proc. SPIE 2018, 10583, 1058306.

[2] Kosma, V., Kasahara, K., Xu, H., Odent, J., Ober, C. K., Giannelis, E. P. Elucidating the patterning mechanism of zirconium-based hybrid photoresists. J. Micro/Nanolithography, MEMS, and MOEMS 2017, 16, (4), 041007.

[3] Xu, H., Sakai, K., Kasahara, K., Yang, K., Herbol, H. C., Odent, J., Clancy, P., Giannelis, E. P., Ober, C. K., MOF-inspired metal-containing building units for high resolution patterning, Chem. Mater. accepted.