Nanoparticle Photoresists: Highly Sensitive EUV Resists with a New Patterning Mechanism

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Currently, extreme ultraviolet (EUV) lithography despite its potential for high resolution, high throughput production is limited by many factors including the poor sensitivity of many potential photoresists. As a result, improved photoresists for EUV patterning technology are an important goal in the ITRS roadmap.

In this study we present a new photoresist material based on hybrid organic/inorganic nanoparticles. The nanoparticles are composed of a hafnium oxide or zirconium oxide core that is surrounded by organic ligands. Previous work at Cornell University has studied the application of these inorganic photoresists in DUV, 193 and e-beam lithography [1]. These studies also revealed that the nanoparticle films exhibit exceptionally high etch resistance due to their thermal and chemical stability [2]. Additionally, the hybrid nature of the nanoparticle films enables the control of the film absorbance in order to optimize their lithographic performance. By controlling the ratio of the organic and inorganic content of the films it is possible to regulate the film density and therefore its absorbance.

Hafnium or zirconium oxide nanoparticles were synthesized in the presence of selected organic ligands, but generally made using methacrylic acid. The resulting nanoparticles have a diameter of ~1 to 3 nm. These nanoparticle are soluble in a variety of solvents such as PGMEA and easily produce uniform, glassy films with added photoactive compound. When patterned using EUV radiation, exposure doses of ~ 5 mJ/cm^2 were needed. Selection of ligand plays an important role in determining the patterning behavior of the photoresist and combined with the choice of photoactive compound (photoacid generator or photoradical generator) we can produce either positive or negative tone patterns. A post-exposure bake (PEB) step is needed for positive tone development. If isobutyric acid is used as ligand, similar patterns can still be produced and this reveals that there is no crosslinking mechanism involved in the patterning step. These and other studies have shown that the photoresists are not chemically amplified. This presentation will report these and more recent results that better describe the patterning mechanism in more detail and discuss how further resolution, sensitivity and image improvement may be achieved.

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[1] Trikeriotis, M., Bae, W. J., Schwartz, E., Krysak, M., Lafferty, N., Xie, P., Smith, B., Zimmerman, P. A., Ober, C. K. and Giannelis, E. P., *Proc. SPIE 7639*, 76390E/1 (2010).
[2] Krysak, M., Trikeriotis, M., Schwartz, E., Lafferty, N., Xie, P., Smith, B., Zimmerman, P. A., Montgomery, W., Giannelis, E. P. and Ober, C. K., *Proc. SPIE 7972*, 79721C (2011).

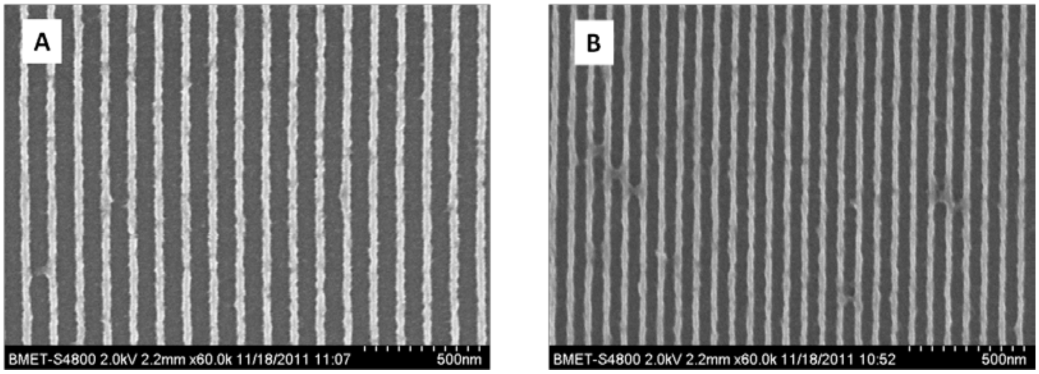

Figure 1. Negative tone patterns after EUV exposure of the ZrMAA photoresist with a PAG additive: A) 32 nm lines at 5.6 mJ/cm^2 and B) 26 nm lines at 4.2 mJ/cm^2.