Scissionable Polymer Photoresist for Extreme Ultraviolet Lithography

Abstract:

Extreme ultraviolet (EUV) is one of the most promising methods to create nano-size patterns below 10 nm. Numerous EUV resists have been developed in last decades to accommodate EUV lithography. The main challenge of EUV lithography lies in RLS tradeoff, which specify the tradeoff among resolution (R), line edge roughness (L) and sensitivity (S). In addition, EUV lithography suffers from low photon numbers, which may cause stochastic issues. In this work, we developed chemically amplified chain scissionable polymers to tackle these issues. Polyphthalaldehyde (PPA) based photoresists have been synthesized and their lithographic performance have been investigated.

Summary of Research:

Scissionable polymers are polymers that will depolymerize under different stimuli including acid, base, and free radicals [1]. These polymers have been investigated in the development of photoresists and other degradable materials. This work focuses on the poly(phthalaldehyde), PPA, family of scissionable polymers. The PPA backbone consists of acetal linkages that are very sensitive to acids. Upon exposure to acids, the polymer chain depolymerizes to its corresponding monomers.

This depolymerization behavior makes PPAs excellent candidates as photoresist materials. Several new architectures are being explored. For example, PPAs with tethered photoacid generators (PAG)s, which release acid upon irradiation, depolymerize upon exposure followed by a post exposure bake step. The depolymerized monomers in exposed areas could be easily removed using appropriate organic solvents while the unexposed areas remain unchanged. Therefore, both unsubstituted and substituted PPAs may equally serve as a positive tone photoresist.

This study focuses on the development of low exposure dose, sensitive PPA photoresists, which do not suffer from materials stochastic issues related to non-uniformities at nanoscale present in multi-component systems for EUV lithography.

In order to improve the lithographic performance of the PPA photoresists, the structure of the polymer backbone as well as photoacid generators (PAG)s are being investigated and tailored for EUV lithography. Aryl sulfonates were prepared as non-ionic PAGs for PPA photoresists [2]. The steric and electronic nature of the aryl sulfonate PAGs can be easily tuned to optimize acid generation efficiency and their compatibility with a polymer photoresist matrix.

The homogenous solution of PPA polymers and PAGs were prepared and spin coated on a silicon wafer. The coated silicon wafers were then exposed using ASML 300C DUV stepper. After exposure, the exposed film was baked and developed.
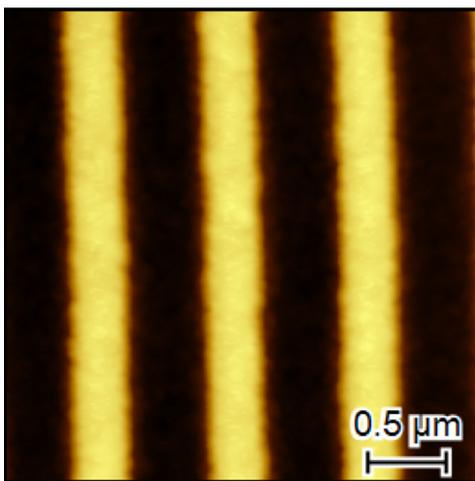
Figure 1. 1:1 Line space pattern with feature size 512 nm observed under AFM after exposure of 100mJ/cm² deep UV exposure.
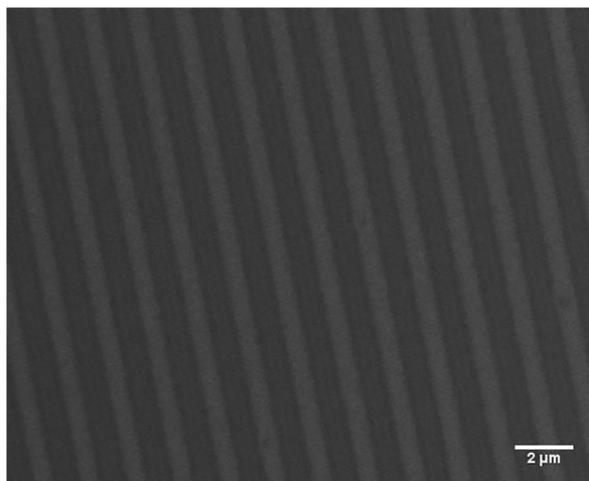

Figure 2. 1:1 Line space pattern with feature size 512 nm observed under SEM after exposure of 100mJ/cm² deep UV exposure.

Results and Discussions:

The resulting line-space patterns were characterized using AFM and SEM. The images are shown in Figure 1 and 2, respectively.

As seen from these figures, the relatively rough line edge roughness was caused by the acid diffusion, which could be alleviated by changing the chemical structure of the photoacid generator.

Next, we plan to explore the resolution limit of these photoresists with different photoacid generators using e-beam and EUV. These samples are currently under preparation.

Summary:

In summary, preliminary results were obtained with chain scissionable photoresists. With these results in hand, the lithographic performance of newly developed functionalized PPAs will be investigated under DUV, e-beam and EUV to pursue higher resolution and improved LER.

References:

[1] Yardley, R. E.; Kenaree, A. R.; Gillies, E. R. Macromolecules 2019, 52, 6342.

[2] Sulc, R.; Blackwell, J. M.; Younkin, T. R.; Putna, E. S.; Esswein, K.; DiPasquale, A. G.; Callahan, R.; Tsubaki, H.; Tsuchihashi, T. Proc. SPIE, 2009; 7273, 72733.

MATERIALS