

New High Resolution Resists for EUV Lithography

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Principal Investigator(s): Christopher Kemper Ober

User(s): Dr. Madan Rajendra Biradar, Dr. Gokhan Sagdic

Affiliation(s): Department of Materials Science and Engineering, Cornell University

Primary Source(s) of Research Funding: DuPont and SK hynix Inc.

Contact: cko3@cornell.edu, mrb348@cornell.edu, gs767@cornell.edu

Research Group Website: <https://ober.mse.cornell.edu/index.html>

Primary CNF Tools Used: ASML PAS 5500/300C DUV Wafer Stepper, JEOL 6300 E-Beam Lithography, P10 Profilometer, Optical Microscope, Veeco Icon Atomic Force Microscope

Abstract:

The semiconductor industry relies heavily on photoresists for fabricating advanced chips. With the growing need for higher resolution and pattern fidelity, EUV lithography presents unique challenges due to the limited number of EUV photons. This necessitates the use of highly sensitive resists such as chemically amplified resists (CAR) and novel double amplification resists (DAR). In DAR systems, ionizing radiation activates photoacid generators (PAGs), which produce acids that depolymerize the polymer backbone into monomers. Each acid can trigger multiple depolymerization events, enabling a double amplification effect. Due to their higher sensitivity of DAR resists compared to CAR, DAR systems require precisely tuned PAGs to control depolymerization kinetics. To address this, we designed and synthesized non-ionic PAGs to be utilized with Br-PPA polymer. This report details the design and synthesis of these PAGs and demonstrates their performance with Br-PPA polymer using DUV lithography. The resulting patterns were characterized by AFM microscopy.

providing an efficient amplification mechanism, as illustrated in Figure 1. However, the higher sensitivity of DAR systems demands the use of optimized PAGs. Non-ionic PAGs have gained importance due to their improved solubility in organic solvents, superior thermal stability during pre- and post-exposure bake steps, and reduced dark loss. By advancing both Br-PPA polymers and non-ionic PAG formulations, it is possible to achieve significant improvements in the performance of next-generation EUV photoresists.

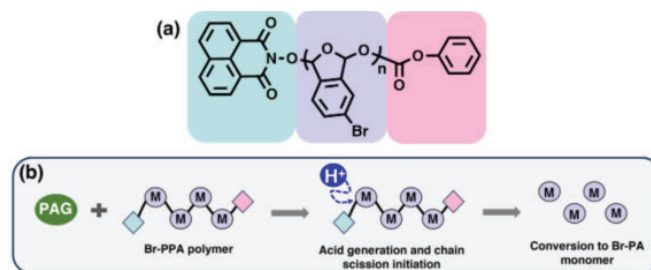


Figure 1: (a) Molecular design of Br-PPA polymer; (b) depolymerization mechanism of Br-PPA resist.

Summary of Research:

To fabricate high-performance integrated circuits, the semiconductor industry relies heavily on chemically amplified resists (CARs), which typically comprise a polymer resin, a photoacid generator (PAG), a quencher, and various additives. Most commercial CAR formulations use ionic PAGs because of their high sensitivity and efficient acid generation.²⁻³ However, to meet the evolving demands for finer resolution and greater pattern fidelity, there is a growing need to develop next-generation high-performance resist systems. Polyphthalaldehyde (PPA) based resists belong to the class of double amplification resists (DARs), having self-immolative nature.⁴⁻⁵ Upon acid activation, the polymer undergoes complete depolymerization into monomers, enabling sharp pattern formation and

Results and Discussion:

Different functionalized non-ionic PAGs were designed using computational chemistry, synthesized, and characterized by ¹H and ¹³C NMR spectroscopy. Br-PPA polymer was also synthesized and confirmed by ¹H NMR. Gel permeation chromatography was used to determine the molecular weight of polymer. A resist formulation, consisting the Br-PPA polymer and 20 wt% PAG in cyclohexanone, was spin-coated onto silicon wafers (2000 rpm, 60 s). These wafers were exposed to DUV radiation using an ASML PAS 5500/300C DUV wafer stepper. Further, pre- and post-exposure baking (90°C), followed by development in isopropyl alcohol (60 s) yielded line-space patterns, which were analysed by using atomic force microscopy as shown in Figure 2. The initial testing of a non-ionic PAG and Br-PPA as DAR resist yielded promising results, demonstrating

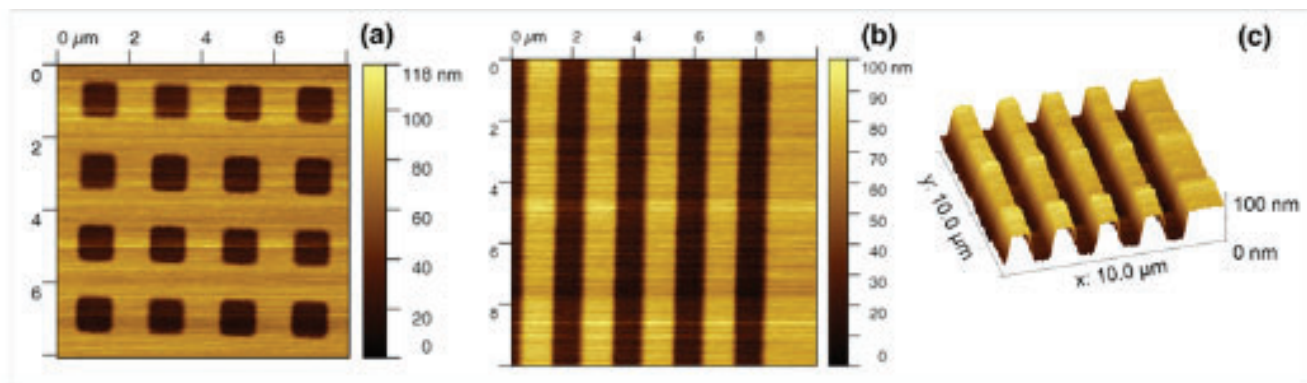


Figure 2: AFM images of $1\ \mu\text{m} \times 1\ \mu\text{m}$ square hole pattern for DAR resist (a); $1\ \mu\text{m}$ line patterns for DAR resist (b); (c) 3D height image of (b).

the fabrication of $1\ \mu\text{m} \times 1\ \mu\text{m}$ square hole and line patterns.

Conclusions and Future Steps:

In this work, we developed a series of non-ionic PAGs incorporating various functional groups to evaluate their acid generation efficiency, sensitivity, and acid diffusion behavior, which are key factors affecting overall resist performance. DUV lithography experiments were conducted to evaluate the patterning performance of the DAR resists, and characterized by using AFM and SEM imaging. Further optimization studies, along with E-beam and EUV lithography evaluations, are currently in progress.

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