High Resolution Organic Resist Materials for EUV and E-beam Lithography Based on Molecular Glasses: A Comparison of Negative Tone and Positive Tone Approaches to Form Robust Cross-linked Polymer Nanopatterns

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ABSTRACT

Developing resist materials that can robustly produce sub-20nm feature sizes using EUV and/or E-beam exposure tools is a significant challenge. There are many factors to consider and many trade-offs that often must be made. Generally speaking, there is a trade-off between resist sensitivity, resolution, and pattern roughness. Organic resist materials are attractive for a number of reasons including the ability to tune the properties of such materials through the wide variety of chemistries and synthetic methods available, the inherent etch contrast with common inorganic materials employed in nanofabrication, and the relative ease with which the resist can be removed without damaging the underlying structure. Chemically amplified positive tone polymeric resists have been the workhorse for the semiconductor industry for more than two decades now. Both chemically amplified and non-chemically amplified polymeric resist technologies have been instrumental in enabling e-beam patterning in applications such as photomask manufacturing. However, as feature sizes are pushed into the sub-40 nm regime, pattern collapse of organic resist materials becomes a significant problem. In addition, at these size scales, methods for enhancing resist sensitivity such as the use of chemical amplification in positive-tone polymeric resists can lead to resolution limitations due to various chemical blur effects. In order to overcome many of the issues with current polymeric resist designs while retaining their attractive features, we have explored a number of alternative organic resist designs based on use of organic molecular glasses. In particular, we have shown in recent years that negative tone resists based on cross-linking of functionalized molecular glass cores can yield very high resolution, high sensitivity resists that could be useful in both e-beam and EUV lithography. One very attractive feature of such cross-linking resists that was rigorously characterized in our work was their good mechanical properties and resistance to pattern collapse during development and drying. Based on that work, we have explored new organic resist designs that are highly sensitive, have high contrast, and which function by producing densely cross-linked polymer networks in the final patterned features that are resistant to pattern collapse. In this paper, we will compare the best current positive tone and negative tone designs from this family of molecular glass resists. In the case of negative tone resists, new single component molecular glass resists that contain both cross-linkable groups (e.g. glycidyl ethers) and photoacid generator functionality into a single molecular glass core will be presented. It will be shown that high sensitivity, high resolution resists can be produced using this design approach. For positive tone resists, we will discuss and present imaging results from a new class of positive tone molecular glass resists that function by depolymerization.

Keywords: photoresist, molecular glass, cross-link, depolymerization, positive tone, negative tone