Design, Synthesis, and Characterization of an Aqueous Alkaline Developable Molecular Resist for EUV Lithography

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Over the past 50 years, advancements in semiconductor fabrication technology, particularly in the scaling of device feature size, has enabled the production of microprocessors with a high density of circuit components, resulting in incredible processing power. Moore's Law suggests that the density of components will continue to double every two years, and a modern integrated circuit device contains features that are on the order of 30 nm in size (by comparison, a human hair is 50,000 nm and an *E.coli* bacterium is 2,000 nm). Features of this size are possible due to advancements in the lithographic technologies used to the print the circuit features during semiconductor device fabrication, however current methods have been unable to continue the trend observed in Moore's Law. Current lithography methods involve coating a substrate with a photosensitive material, and specified areas of the resist are exposed to radiation using a mask. The radiation exposure induces a solubility change in the material, and the differences in solubility between the exposed and unexposed regions of the resist allows for selective removal of portions of the resist in a developer to form a relief image. Following exposure, development in solvent, and drying, the substrate is etched using this relief image mask to form the desired device features. In order to maintain Moore's Law, lithography must overcome several challenges for producing sub-30nm features including: (1) development of resists that function at next-generation exposure wavelengths (i.e. EUV at ~13nm), (2) collapse of nanometer scale patterns due to capillary force during development and drying, and (3) decay in mechanical properties of molecular and polymeric resist materials as a function of dimension due to confinement and high surface-to-volume effects. In order to combat these challenges, this work focuses on the design, synthesis, and characterization of a negative tone resist based on a photo-induced cross-linking material. This particular resist was designed to include an environmentally friendly processing method as well as the ability to produce mechanically robust nanometer scale features. In order to maintain safe processing methods, the resist was designed so that aqueous alkaline developers could be used to develop the material in replacement of organic solvents. The resist is comprised of an aromatic core that is functionalized with epoxide and a phenolic groups. The phenolic groups render the resist soluble in an aqueous alkaline developer. The epoxide groups act as a site for cross-linking, and upon initiation with a photoacid, undergo robust polymerization. The epoxides in the exposed resist also react with the phenolic groups, greatly reducing the functional groups that contribute to the aqueous solubility of the exposed region. This polarity change, combined with the increased molecular weight resulting from polymerization of the resist, result in a large imaging contrast between exposed and unexposed regions of the resist. This presentation will review the design methods, the synthesis techniques, and the basic characterization and lithographic evaluation of this new resist.