Dimension-Dependent Mechanical Properties of Pure and Antiplasticized Polymer Nanostructures

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Preventing the collapse of high aspect ratio photoresist nanostructures during lithographic processes is an emerging difficulty in the fabrication of integrated circuits. Photoresist collapse leads to unwanted masking and defects in the etching profile of lithographic patterns.

The International Technology Roadmap for Semiconductors stipulates that integrated circuit design will require resist half-pitches as small as 35 nm by the year 2010. This half-pitch will decrease to less than 18 nm by 2016. The height of resist structures will also decrease such that there will be a consistent need for dense photoresist patterns of aspect ratio 3 to 5.

As the spacing between photoresist patterns decreases, the magnitude of capillary forces acting on the patterns during rinse drying will increase, thereby increasing the probability of collapse. It follows that there is a considerable interest in understanding the mechanical behavior of sub-100 nm polymer structures.

Our research group has developed a method for applying precisely-defined capillary forces on three-dimensional polymer nanostructures fabricated through electron-beam and extreme ultraviolet interferometric lithography techniques. By coupling the collapse data collected through this method with continuum models, mechanical properties such as the elastic modulus and yield stress can be determined. Evidence exists that higher capillary forces are not the sole contributor to increased photoresist collapse at sub-100 nm length scales. The elastic moduli of confined polymer structures have been observed to decrease with critical dimension.

In this work we present how a special class of polymer additives known as antiplasticizers can counteract confinement softening and increase the elastic moduli of polymer nanostructures, thereby reducing structure collapse and providing a means to extend current semiconductor manufacturing techniques.

References: