Damage-Free Photoresist Cross Sections via Dual-Beam FIB: Improving Information Turns During Lithography Development

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For emerging lithography technologies such as high-NA Immersion or EUV, rapid screening of resist profiles for photoresist libraries is required to optimize the patterning process. Cross section images through focus and exposure requires 10's of individual SEM samples. The slow turnaround time of lab cross sections can limit the number of information turns in a development cycle or the number of variables explored within one information turn. In-fab FIB-SEM platforms can greatly improve throughput time for taking cross sectional images. However, ion-beam assisted coating and milling can cause severe damage to photoresist (Figure 1), thereby limiting its utility for lithography development.

In this paper, CD-AFM is used to first characterize 193nm photoresist patterned in a 50nm:200nm line/space structure. The use of CD-AFM has two advantages as a calibration method for this application. It is traceable to the SI unit (*Système International d'Unités* or International System of Units) of length and it avoids convoluting the measurement with an electron beam which is known to cause damage (i.e. measurement bias) in photoresists. After linewidth calibration (shown in Figure 2), a variety of different site protection schemes are explored to investigate resist damage. The traditional use of ion-assisted metallo-organic precursor decomposition results in a substantial change to resist height and CD . Ex-situ sample preparation methods that utilized sputtered Ni showed little damage. This work lead to an optimization of a gentle in-situ Cr sputter method where the ion beam sputters Cr from a target to a localized region of the wafer. After depositing Cr to a depth of ~25nm in order to protect the photoresist, W is deposited to depth of >400nm to allow an even mill by the ion-beam (Figure 3). Results show that in-situ sputtering of Cr for FIB-SEM site preparation leads to CD measurements that are damage free and in statistical agreement with CD-AFM

The Cr sputtering approach has been optimized to take less than 10 minutes per sample (site registration to image) without damage. Recipes are fully automated and a 5x5 Focus/Exposure matrix can be measured in a matter of a few hours. To date, this approach has been used to characterize structures as small as 50nm 1:1 line/space arrays in EUV photoresist.

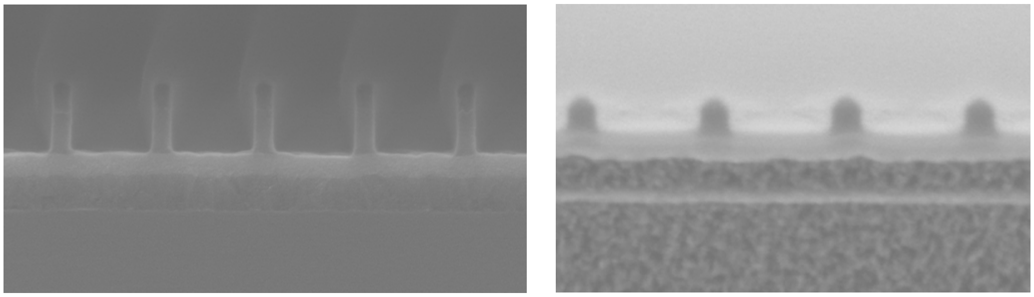

Figure 1: A cleaved sample of 193nm photoresist (left) is compared to a sample prepared in a FIB-SEM (right). Image magnifications are not the same. The FIB-SEM sample is coated via ion-assisted tungsten deposition as part of site preparation and shows substantial damage to resist height and CD.

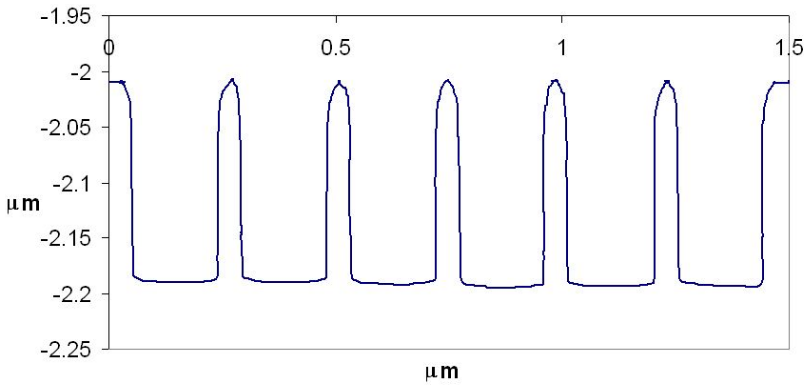

Figure 2: CD-AFM micrograph of a 50nm line, 200nm space array of 193nm photoresist. The effect of the AFM tip has been removed.

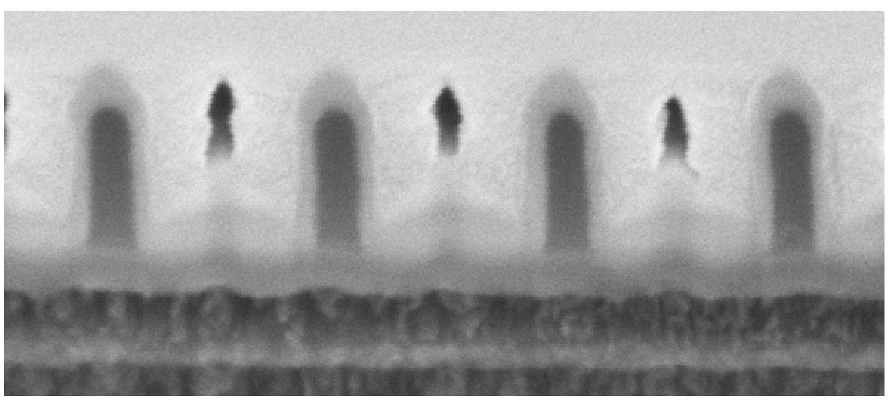

Figure 3:   FIB-SEM image prepared using Cr sputtering. Resist lines are coated with a conformal layer of Cr (light gray). Ion assisted tungsten is deposited on top to allow for uniform FIB milling. The line CD are statistically matched to CD-AFM measurements.