INVERSE MICROLOADING EFFECT IN REACTIVE ION ETCHING OF SILICON

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We have characterized microloading effects in reactive ion etching of silicon and found an inverse microloading effect—an increased etch rate at increased local pattern densities—which is likely caused by an increased sputtering by silicon ions. At reduced gas flows, we have also seen a normal loading effect.

Areas of varying sizes and pattern densities were made on silicon wafers using standard photolithography in 1.5 µm resist. The wafers were then etched at different orientations in an STS reactive ion etcher to a depth of about 2.5 µm. The etch took place in a SF_6/O_2 plasma at a pressure of 80 mTorr and with an RF power of 30 W. Two batches of wafers were run at gas flows of 32 sccm/8 sccm and 16 sccm/4 sccm. Finally, the resist was removed, and the etch depths of 15 µm wide trenches were measured using a Tencor profiler.

The results obtained at the higher gas flows are shown in figure 2. There are no microloading effects in the 3 mm cells, but in the 10 mm cells, we see an inverse microloading effect—the etch rate increases as the pattern density increases. We believe that this is a result of an increased sputtering by silicon ions in the plasma, and that this shows up because the etch is in a regime where sputter-induced desorption limits the etch rate.

The gas flow was reduced in order to force the etch into a radical-limited regime, where the supply of flourine radicals would limit the etch. The results are shown in figure 3. There is no visible microloading effect in the 3 mm cells, but in the 10 mm cells, there is a clear normal microloading effect—the etch rate decreases as the pattern density increases. We interpret this as a result of a depletion of flourine radicals in areas of high pattern density. The cells close to the center of the wafer obviously behave differently. This is a result of a lower overall flourine concentration and a more effective ion bombardment in the center. The center cells are thus depleted faster, but the more efficient center ions are able to keep up the etch rate at 25% pattern density.

In the experiments, we have seen both an inverse and a normal microloading effect. The two effects seem to be of the same magnitude, leading to about a 5% change in the etch depth as the local pattern density is changed from 5% to 35%. Both the inverse and the normal microloading effects are local effects with a characteristic distance. In the case of the normal loading effect it is the depletion radius—the range from which the radicals that contribute to the etch of a point originate—and in the case of the inverse loading effect it is the range of the silicon ions originating from a point. In both cases, the characteristic distance is estimated to be between 5 mm and 10 mm.

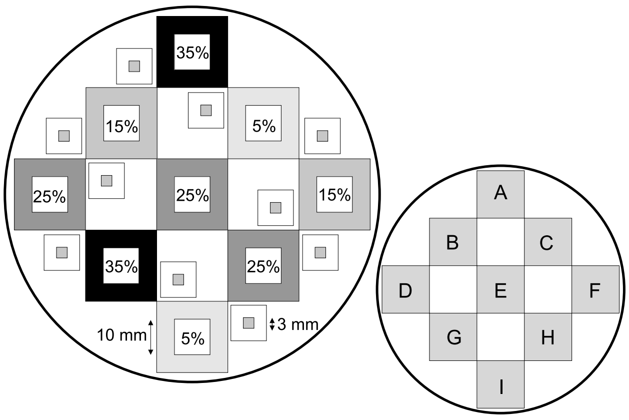

Figure 1: *Overview of patterned wafer. There are nine 10 × 10 mm and ten 3 × 3 mm cells with pattern densities varying from 5% to 35%. Around each cell there is an area with the same load, and around the 3 mm cells, there are also additional areas that make sure that the cells have the same load if the characteristic distance of the microloading effect is 10 mm.*

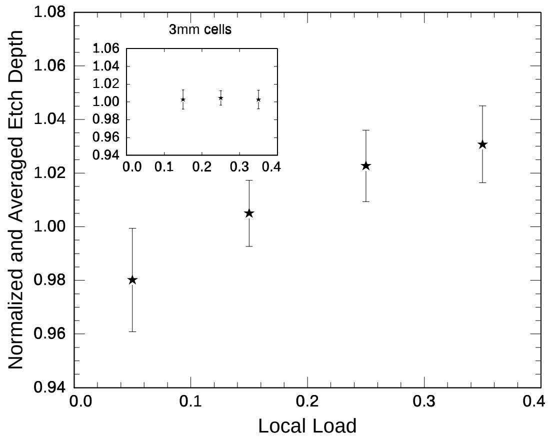

Figure 2: *Normalized etch depths in 10 mm cells at 32 sccm SF_6 and 8 sccm O_2, showing an inverse microloading effect. The large error comes from a reproducible etch rate variation across the wafer.*

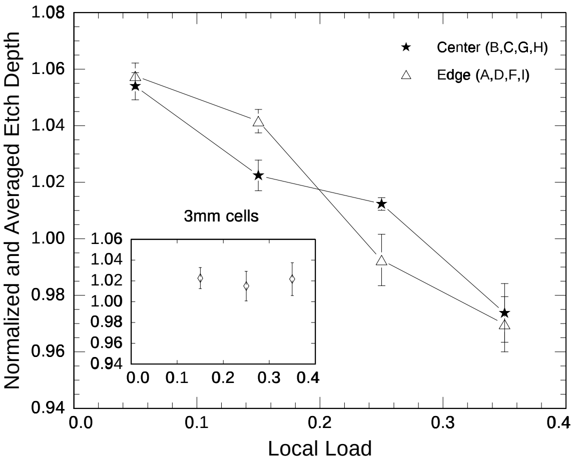

Figure 3: *Normalized etch depths in 10 mm cells at 16 sccm SF_6 and 4 sccm O_2, showing a normal microloading effect.*

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