Performing E-Beam induced Gas Assisted Etching with a Dual-Beam-FIB

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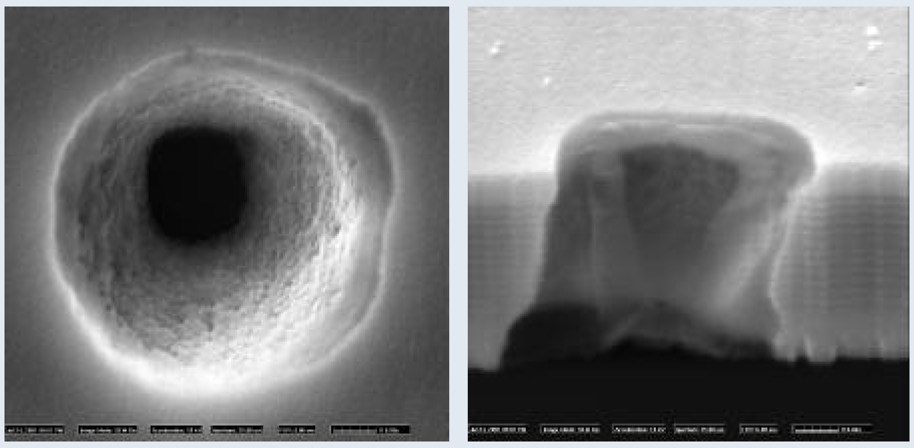
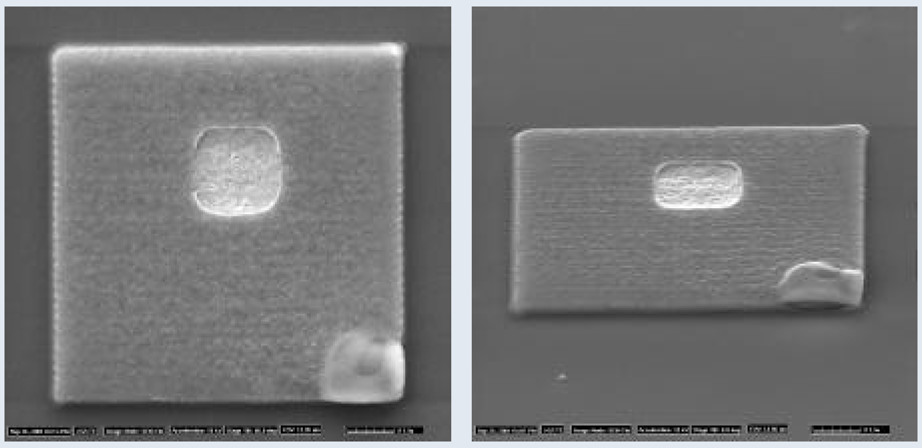
FIB induced gas reactions are commonly used in the industry. But for some special applications like repairing phaseshift masks (DUV) the Ga-staining incorporated in ion beam processes is critical. A method to overcome this problem is to stimulate the gas reaction with the electron beam available in dual-beam-systems.



opening in a Si stencil mask (thickness 3µm)
produced by e-beam GAE
(V_{acc}=5kV; I_{Beam}=214pA; t=30min)



box in a layer of silicon oxide (FIBCVD)
produced by e-beam GAE (V_{acc}=5kV;
I_{Beam}=280pA; t=20min; depth d=190nm)

The micrographs show results of electron induced gas assisted etching with XeF_2 on silicon and silicon oxide surfaces. The achieved etching rates are 40- 50µm^3/µC for silicon and 4µm^3/µC for oxide surfaces (V_{acc}=5kV) which is about 50 times (Si) resp. 600 times (SiO_2) lower than that of a comparable ion beam process. Nevertheless, these values are high enough to do real work as demonstrated by the opening in the stencil mask.

The mechanism causing EB-GAE is of special interest. Typically the yield of e-beam induced reactions is controlled by the ratio of secondary electrons to primary electrons . This means that for a low acceleration voltage of the primary beam with a lot of available secondary electrons the reaction works better than for high acceleration voltages. This effect can also be seen in EB-GAE of Si with XeF_2. Experiments on EB-GAE of SiO_2 with XeF_2 however did not reveal this characteristic. This is caused by the fact that in order to form the volatile reaction products (SiF_4), first bonds in the SiO_2 molecule have to be cracked. Here the primary electron beam itself seems to play a major role.

As indicated by the low etching rates, EB-induced GAE is especially useful for the removal of small volumes of material. The minimum possible structure size is influenced by the profile of the e-beam (e.g. the gas nozzles interfering with the e-beam especially at very low acceleration voltages make it hard to get sharp edges). Another issue is that XeF_2 reacts spontaneously with silicon-surfaces. This also blurs the etching profile.

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