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Carbon and particle removal from EUV reticles by shielded microwave induced remote plasma

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For EUVL to be successful it is essential that reticles can be made without defects and that they can be cleaned without causing any damage. Contamination of reticles can be in two ways: particles due to handling can cause printable defects and carbon contamination due to residual hydrocarbons can cause change in CD and loss of throughput. We have shown in previous work that our Shielded Microwave Induced Remote Plasma (SMIRP) is excellent for cleaning EUV multilayer mirrors without any damage. In this presentation we show that SMIRP also can be used to clean EUVL reticles.

In our latest research we focused on cleaning of reticles, especially on the removal of contamination in the trenches of the mask. Because of the nature of the EUVL masks with the absorber on top of the reflective mirror it is of importance that the trenches of the mask are perfectly clean. The sidewalls of the trenches receive a double dose of EUV light causing increased carbon growth on the sidewalls. This will give a change in CD because the carbon acts as an absorber and thereby reduces the printed line width. It is very likely that wet cleaning techniques may not reach the bottom of the trenches because of bubble formation and capillary action. Plasma cleaning can be a very good, environmentally friendly, alternative for wet cleaning or be an add-on the wet cleaning process.
For our research we used a dummy reticle which consists of a TaN absorber, a SiO_2 buffer layer on a ULE substrate (see figure 1).

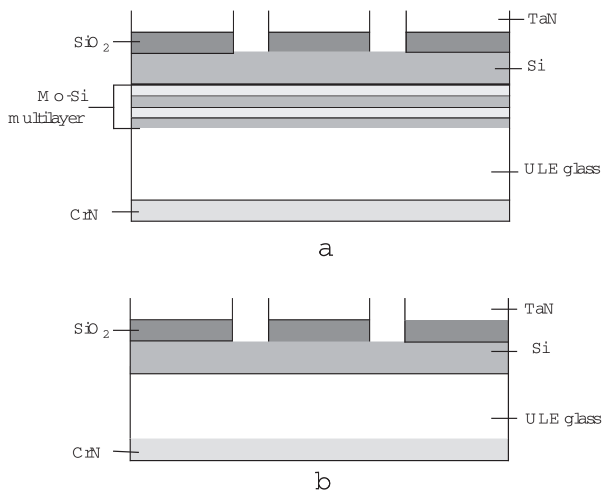

Figure 1: schematic layout of dummy reticle

The reticle did not have a EUV reflective multilayer coating, as we already have shown that multilayer mirrors are not affected by the plasma cleaning process. As the reticle was quite old we started with imaging the old reticle with our Helium Ion Microscope (HIM) to see what the present condition was. Immediately after the first image we treated the reticle for 1 hour with our plasma process. From figure 2 it can be clearly seen that most of the carbon contamination has been removed from the surface.

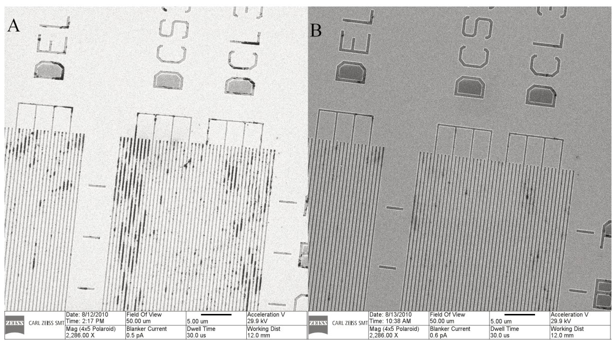

Figure 2: a) HIM image of old reticle before and b) after first 1 hour cleaning step

Figure 3 shows the result on single lines and spaces on the same reticle.

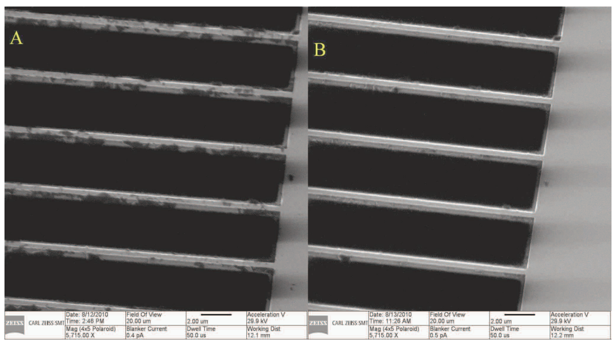

Figure 3: a) HIM image of single lines and spaces before and b) after first 1 hour cleaning step

In order to verify if the reticle was not damaged we analyzed the absorber layer and the bottom of the trench with SEM EDX micro analysis. Results show that the material is not modified by the plasma. As a result of the micro analysis some carbon contamination with an approximate thickness of 2 nm was deposited on the reticle. To investigate the cleaning rate we exposed the reticle for 10 min to the plasma and imaged the reticle with HIM. The results of this cleaning action can be seen in figure 4 and 5.

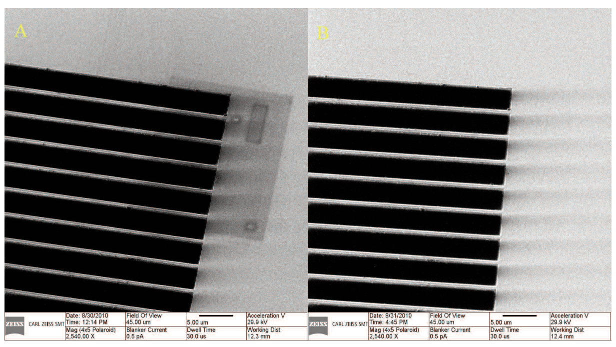

Figure 4: a) HIM image of single lines and spaces before and b) after first 10 min of cleaning

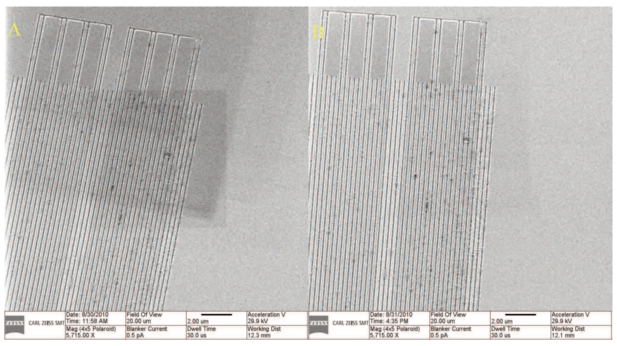

Figure 5: a) HIM image of SEM deposited carbon and b) the same image after 10 min plasma treatment

We removed almost al the carbon except for 1 area, which shows some slight signs of carbon contamination. After one additional treatment for 10 min with plasma the area has no traces of carbon left.
Finally we coated the reticle with 50 nm PSL sphere. Again the reticle was exposed to plasma for 10 min and re-imaged. From figure 6 it can be seen that some particles completely disappeared and some particles have become a lot smaller. This clearly shows that organic particles can be removed using our plasma process.

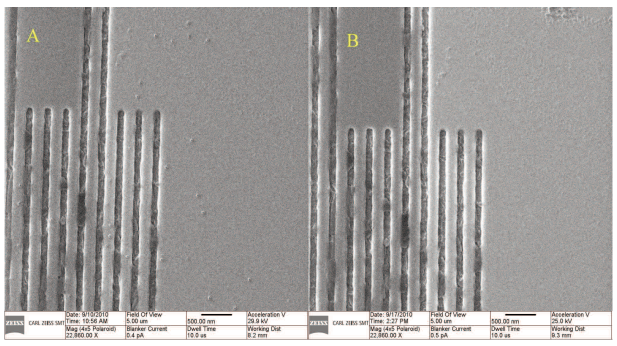

Figure 6: a) HIM image of reticle with 50 nm PSL spheres before and b) after 10 min plasma treatment

Conclusion

We have shown that it is possible to clean carbon contamination inside the trenches and on top of the absorber in reasonable short times. We estimate the cleaning rate for molecular contamination to be about 0.2 nm/min. In case of organic particles we have shown that they can be removed or reduced in size in a very short time. We have not observed any damage to the reticle.
This work was performed at the Van Leeuwenhoek Laboratory in Delft, the Netherlands.