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Cryo-ALE of Si based on SF_6 physisorption

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Abstract content

Cryogenic Atomic Layer Etching (Cryo-ALE) has been presented in the previous PLATHINIUM conference (2019) as a different approach to achieve ALE of SiO_2. In this process, C_4F_8 is used as a precursor in the "modification" step in order to physisorb on a cooled SiO_2 surface between -120°C and -90°C [1,2]. The "etching" step is then achieved by using an Ar plasma with a low energy ion bombardment. However, C_4F_8 injection at cryogenic temperatures does not allow high etching selectivity of SiO_2 over Si and Si_3N_4 as the deposited CF_x passivation layer is not thick enough to efficiently passivate Si and Si_3N_4 surfaces. Nevertheless, self-limiting etching was achieved and a very stable process of SiO_2 etching was obtained.

In 1996, Royer *et al.* studied the chemisorption of fluorine and sulfur on Si during a simultaneous exposure to SF_6 gas and Ne^+ ion beam. In this study, they showed by XPS measurements that the fluorine amount at the Si surface increases as the temperature decreases in a process window between 20°C and -130°C [3]. Moreover, SF_6 is a well-known gas used in Si plasma etching. Therefore, cryo-ALE based on SF_6 physisorption was studied to extend the use of this new type of process to other materials and to characterize its etching properties.

This work was carried out using a cryogenic ICP reactor equipped with in-situ diagnostics. Mass spectrometry measurements enabled to characterize the SF_6 physisorption and its surface residence time at different temperatures. Spectroscopic ellipsometry was used to monitor the etching rate and to characterize the sample surface at the nanoscale during the three process steps: SF_6 physisorption, pumping and Ar plasma etching. Tests were performed on SiO_2, Si_3N_4 and p-Si coupons glued on SiO_2 6" carrier wafers.

SF_6 physisorption experiments will first be studied and presented notably to find the optimal temperature and purging time for the process. Then, cryo-ALE test results on Si, SiO_2 and Si_3N_4 will be shown. These results will finally be compared to the ones obtained using C_4F_8 physisorption.

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