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# Plasma-assisted Atomic Layer Etching (PE-ALE) of $SiO_2$ via surface fluorination and argon bombardment

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Silicon dioxide ($SiO_2$) is crucial in the semiconductor industry, acting as an insulating layer, providing passivation, and serving as a gate dielectric material. [1,2] As its use expands in advanced devices and design structures become more complex, plasma-assisted atomic layer etching (PE-ALE) process for $SiO_2$ continues to be extensively studied for multiple applications.

Given its importance, this work presents a two-step approach that involves low-pressure sulfur hexafluoride ($SF_6$) remote plasma modification followed by argon (Ar) ion bombardment. Understanding the nature of surface fluorination is critical, as it significantly impacts the efficiency and precision of the etching process. In-situ characterization using Attenuated Total Reflectance - Fourier Transform Infrared Spectroscopy (ATR - FTIR) was used to analyze surface bonding during the half-reaction steps, offering real-time insights into the chemical modifications at the surface. The FTIR data for $SiO_2$ reveals that the terminal -OH groups are removed during fluorination. This removal was observed to reach saturation after 30 seconds of exposure. Conversely, a reduction in the asymmetric Si-O-Si peak during ion bombardment indicated the removal of the modified layer following Ar irradiation.

Furthermore, spectroscopic ellipsometry data showed variations in thickness and indicated an incubation period before a steady etch rate per cycle was established. The unsaturated mixing layer is strongly linked to ion bombardment energy, which is crucial in creating adsorption sites for fluorine radicals on the SiO2 surface. This connection leads to similar incubation periods regardless of the duration of fluorine exposure during the incubation phase. After the incubation period ends, the combined effect of fluorine radicals and ion bombardment becomes more pronounced, resulting in the creation of additional active sites. The etch profile of the trenched sample exhibited isotropic etching from the two- step process.

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References

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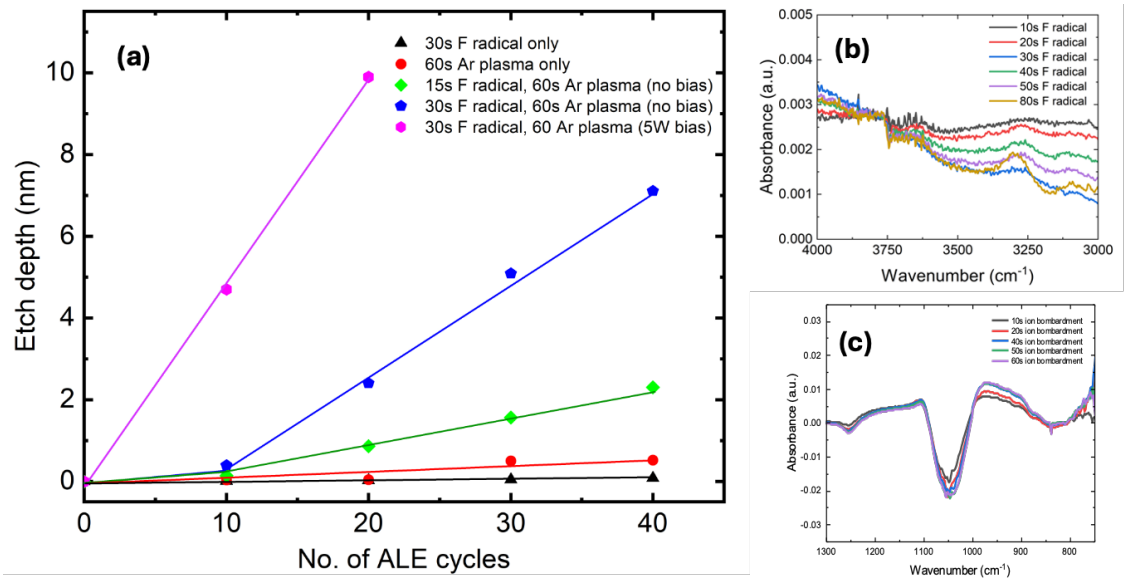


Figure 1. (a) Synergy of sequential fluorination and ion bombardment on $SiO_2$ surface and the FTIR-ATR data during half reactions (b) fluorination, and (c) Ar bombardment