

## Etching of Silicon Native Oxide Using Ultra Slow Multicharged Ar<sup>q+</sup> Ions

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Removal of native/chemical oxide is a key step in the conditioning of silicon surfaces in a variety of processes in silicon device manufacturing. Several methods of native oxide etching are available. Wet cleaning using dilute HF has been used for many years in this application, but the trend toward process integration calls for improved methods of native oxide control using gas-phase processing. Each of the currently available dry methods of native oxide etching has some limitations. Purely chemical methods, such as anhydrous HF/methanol processes may leave excess fluorine on the surface while purely physical methods, such as ion sputtering using single-charge Ar<sup>1+</sup> ions tend to damage the surface. The hydrogen reduction process on the other hand requires a temperature of 900 °C to be effective.

In this study the use of multicharged argon ions (Ar<sup>q+</sup>, q>1) for the purpose of native oxide etching is explored. In contrast to singly charged ions, the interaction of slow multicharged or highly charged ions (MCI or HCI) with a surface is dominated not by the ion's kinetic energy but by its potential energy (i.e. the energy needed to go from the ground state to the atom's ionized state). The way this potential energy is released over the surface is related to a new type of sputtering or desorption process referred to as "potential sputtering" Study of the various processes and phenomena involved along with more fundamental aspects are described in details elsewhere<sup>1</sup> and other applications beside etching are currently under development<sup>2</sup>. One of the most striking features of this new type of sputtering is that it is strongly selective regarding the nature of the surface. Specifically, potential sputtering is solely observed above dielectric surfaces and not above metallic surface. While keeping advantage of singly charged ions the use of multicharged ions adds selectivity to the process. In addition, this type of etching does not require kinetic energy. Therefore, by using a beam of fully decelerated ions one can avoid surface roughening

In the experiment presented here we demonstrate etching of silicon native oxide using multicharged argon ions Ar<sup>q+</sup>. Multicharged argon ions beams were produced with an ECR type ion source with charge state up to Ar<sup>11+</sup>. After extraction and charge selection, the ions were directed toward silicon wafers covered with a thin layer (10 to 12 Å) of native silicon oxide. Before reaching the wafer, ions are decelerated to a kinetic energy close to 1 eV/q.

Etch rates were compared for various charge states of argon ions using an in-situ Auger spectrometer. In overall etch rates in the order of 0.5 Å/min were obtained. Though the ion dose necessary to fully etched the native Silicon oxide layer is observed to decrease as the ion charge state is increased, the ion current is

higher for lower charge states giving a relatively similar etch rate for Ar<sup>8+</sup> and Ar<sup>11+</sup>. Such etch rates are expected even for 300 mm wafer with improved E.C.R ion source and ion transport system. As Auger spectra taken before and after MCI irradiation demonstrate (Fig.1) complete removal of native oxide was accomplished. AFM characterization did show that the oxide etching process in this case occurs without any meaningful damage to the etched surface.

1. J.-P.Briand et al., *Phys. Rev. Lett.* **77**, 1452 (1996)
2. G. Borsoni et al., *J. Vac. Sc. Tech. B Vol.* **18**, 3535 (2000).

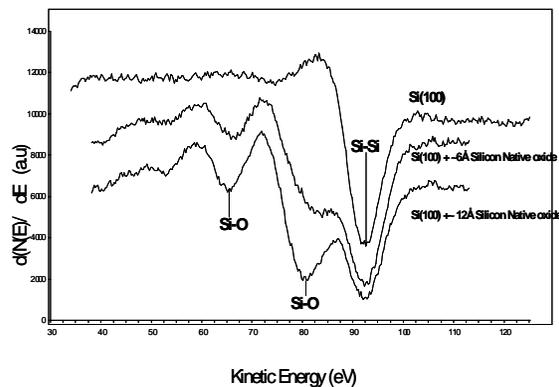


Fig 1. Auger Spectra showing native silicon oxide removal using Ultra Slow Multicharged Ions (USMCI) : before processing (Bottom), half removed (Middle), complete removal (Top)