

# Laser-assisted Silicon Substrate Cleaning for UHV Systems

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With continuous downscaling of the dimensions of MOSFETs the cleaning of silicon (Si) surfaces becomes more and more sophisticated – effects like organic contamination, silicon surface roughness or out-diffusion of dopants (especially boron) gain in importance [1]. Therefore all processing temperatures will have to be lowered to about 700 °C. This requires a method to also remove the two main contaminants, organic impurities and the native oxide, at these temperatures.

One reasonable approach to lower the thermal budget was the introduction of plasma-enhanced processes, which are already used in VLSI production. But recent research shows that plasma-enhanced cleaning processes roughen the Si surface, leaving the interface unsuitable for the production of a 10 nm-feature size MOSFET. The aim to prevent high energy ions, which are likely to be the reason for surface roughness, by using a DC or remote plasma source failed to prove reproducible effectivity [2].

Another possibility to provide the necessary energy for the chemical reactions without using high temperatures is the application of lasers. It is well known, that radiation perpendicular to the substrate can lead to very high temperatures or even melting of the substrate [3]. Therefore this is no solution of the above mentioned thermal problems. We combined an excimer laser (ArF,  $\lambda = 193$  nm, max. energy  $W = 150$  mJ/pulse) and a UHV system, guiding the laser beam parallel to the substrate surface. Our goal was to decouple laser energy and temperature in order to be able to excite different gaseous precursors for cleaning and deposition. A schematic view of the complete system is shown in figure 1.

It is well known that photodissociation of O<sub>2</sub> produces ozone and O\*-radicals, which both can be used to reduce organic impurities [4]. Figure 2 shows the SIMS analysis of a RCA cleaned substrate after “Laser-assisted carbon-burning” and thermal removal of the oxide layer. The laser processing time was only 10 s at room temperature and as is shown, the organic contamination is below the detection limit. This affects the device characteristics of a MOSFET

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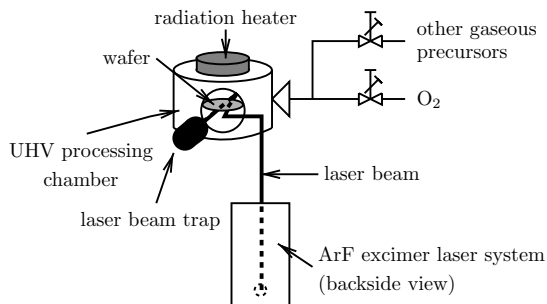


Figure 1: Integration of an ArF excimer laser into a UHV system.

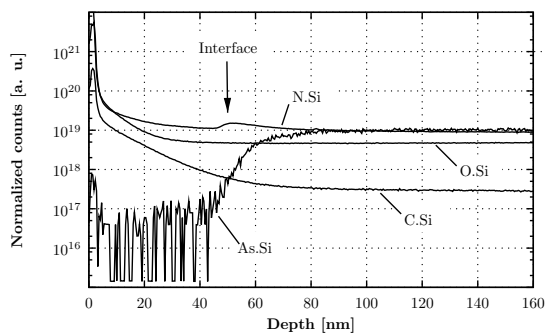


Figure 2: SIMS analysis after laser treatment in oxygen ambient. No visible peak in the C.Si line at the interface indicates carbon concentration below the SIMS detection limit.

in a positive way: break through voltage can be increased and at the same time leakage currents are reduced significantly. Additional cleaning experiments using SiH<sub>4</sub> and GeH<sub>4</sub> showed the desorption of the SiO<sub>2</sub> layer starting at temperatures below 700 °C even without using the laser.

It will be shown that at temperatures below 700 °C a complete removal of organic impurities as well as the SiO<sub>2</sub> layer is possible by using laser excited gaseous species. Furthermore the corresponding chemical reactions at the interface and the influence of these cleaning methods on surface roughness and device characteristics will be discussed.

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