High Dose Implant Ash using a Medium-Pressure, High Power Plasma Jet

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This paper describes the application of a novel medium-pressure plasma (MPP) ash tool to stripping high-energy, high-dose, ion implanted (HDI) photoresist. As described in a companion paper, the plasma jet, formed by a surface wave discharge, impinges on the wafer mounted to a rastering vacuum chuck. A typical process recipe uses a 9:1 ratio of O_2 to N_2 and a total reactant flow of 3 sccm at 2.5kW microwave power and a pressure between 50 and 80 Torr. Due to the dynamic thermal characteristics of the jet, extremely efficient HDI crust removal is achieved with no evidence of post-implant ash residues. Charge damage, measured using surface photo-voltage, on 45Å and 1 kÅ oxide wafers was shown to be at or below values for the other commercial tools, which are known to provide damage-free ash solutions. A conservative estimate of time-to-clear for a 300mm, 2-jet system is about 80 seconds for HDI ash, compared to 10 seconds for blanket and LDI ash (see companion paper).

Introduction

The complete, damage-free and efficient removal of high dose implanted (HDI) photoresist is one of the most challenging front-end-of-line issues in integrated circuit manufacturing. The problem arises because the crust of implanted metal ions and vitrified carbon is much less reactive to plasma strip chemistries than unimplanted bulk resist. This is compounded for typical plasma ash tools because popping, the explosive ejection of macroscopic crust particles due to thermally induced bulk resist volatilization, limits the wafer temperature and, hence, the ash rate. This rate can be enhanced with RF-bias[1],[2] and/or fluorine chemistry[3] but this causes erosion and oxidation of unprotected surfaces.

Our approach to ashing implanted resist is to maintain the bulk wafer temperature below the hard-bake temperature while providing localized heating only to the area of the wafer which is being stripped. This dynamic temperature control can, as we will show, prevent the bulk resist from volatilizing, while thermalizing the crust above its activation temperature.

This paper discusses the application of the Medium Pressure Plasma (MPP) source, described in a companion paper, to HDI ash. Studies of charged particle and ultraviolet damage are discussed. Silicon loss studies, in progress, will be reported at the conference.

Finally, throughput implications based on times-to-clear for 300mm wafers are discussed.

Experimental

Test wafers (200 mm) were coated with 1.0 μm thick I-line resist and implanted with an arsenic dose of $5\times10^{15}/cm^2$ at 40 keV and baked at 120 ^oC.

Figure 1 shows the MPP ash tool (the chuck assembly is not to scale). Reactant gas (typically O_2:N_2=9:1) flowing in a quartz tube is activated by a high power, 2.45 GHz surface wave discharge at pressures between 50 and 80 Torr. The directional flow (3slm) of process gas, in conjunction with the downstream surface wave, produces a plasma jet that emerges from the end of the discharge tube and impinges on the wafer. The wafers are held by a vacuum chuck below the jet and rastered by an in-vacuum motor assembly at speeds up to 105 cm/s. The chuck temperature was typically maintained at about 100 ^oC to prevent global popping. The jet is about 1 cm in diameter and its thermal power is about 500 W/cm^2.

Results and discussion

Figure 2 shows the remarkable ability to selectively remove the crust prior to base resist etching. This prevents the crust from ever contacting the wafer, where it would form an unetchable residue.[4] Once the crust is removed, the base resist can be rapidly removed by a bulk resist process using a reduced scanning speed.

Figure 3 shows a picture of half a 200mm wafer that was ashed on the MPP tool. XPS analysis shows that the light haze is due to atmospheric water vapor adsorbed on the As_2O_3 particles which form during the ash process. This can be completely removed with a DI water rinse, after which, SEM analysis indicates no ash residues.

Figure 4 compares the plasma-damage-monitoring voltage (V_{pdm}) as measured using the surface photo-voltage (SPV) technique for the MPP tool, to a typical remote plasma ashing system. The SPV measurements for MPP are seen to be below the values for the commercial tools which is known to provide damage-free ash solutions.

Similarly, interface trap density was measured on thin oxide wafers using the COCOS technique. Again, the MPP results indicated no significant difference with the commercial tools when the plasma exposed wafers were compared to control wafers (no plasma exposure).

Stress induced leakage current measurements on the MPP also showed no significant departure from the results of commercial ash tools, thereby signifying an essentially charge-damage-free process on the MPP system.

Extrapolating from experiments on the single-jet 200 mm system yields a conservative time-to-clear estimate of 80 seconds for a 2-jet, 300 mm tool.

Conclusions

A novel mechanism for high-dose implant ash has been developed using a medium-pressure plasma jet above a rastering wafer. The results indicate no charge or UV damage during ash. Implant ash is done without creating residues, thereby eliminating the requirement of post-implant wet cleans, other than DI rinse. A conservative estimate of time-to-clear for a 300mm, 2-jet system is about 80 seconds for HDI ash.

Acknowledgements

Partially supported by the Texas Center for Superconductivity at the University of Houston.

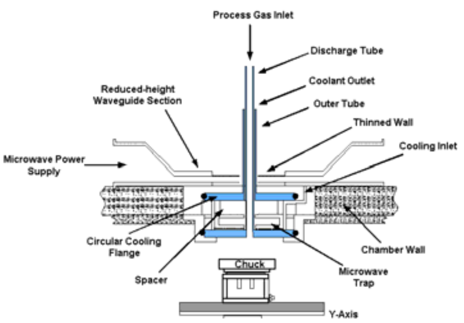

Figure 1. A schematic of the plasma jet resist ashing system including a plasma applicator and a high speed wafer scanning stage.

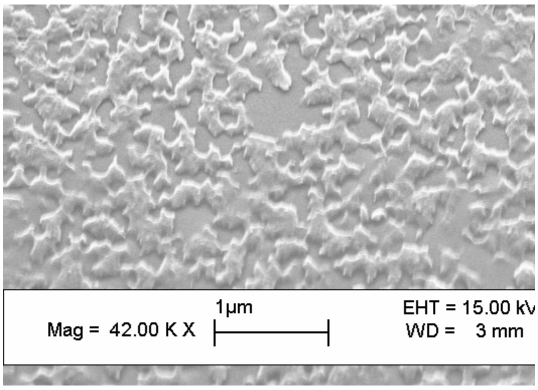

Figure 2: Surface of a partially ashed HDI wafer showing the ability to selectively remove the implanted crust from the base resist.

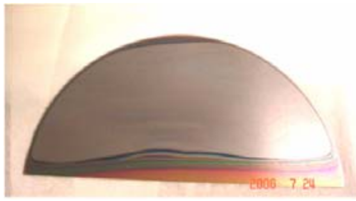

Figure 3. 200mm wafer ashed on the MPP – 5E15, 40KeV As implant on blanket I-line 1.0 micron coated wafer

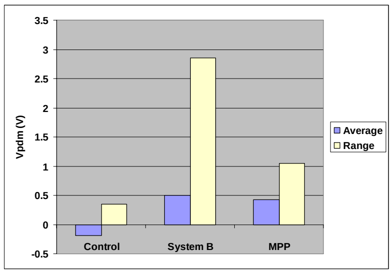

Figure 4. Plasma damage monitoring voltage (V_{pdm}) for the MPP as compared to a commercial ash tool, and control (no plasma).

References

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