Non-fluorine plasma strip of HDI resist for 45nm node

K Han[1], S. Luo[1], P. Geissbühler[1], Q. Han[1], I. Berry[1], R. Sonnemans[1],
V. Grimm[2] and C. Krueger[2]

[1]*Axcelis Technologies, Inc., Beverly, MA 01915, USA*
[2]*AMD Fab36 LLC & Co. KG, D-01109 Dresden, Germany*
Email: keping.han@axcelis.com

Non-fluorine plasma chemistries were developed in this work for high dose implant (HDI) resist removal to minimize substrate loss. The metrics of dry strip process development includes crust breakthrough, resist removal, surface cleanliness, substrate loss and dopant retention.

Introduction

The most demanding aspects of HDI resist strip process for 45nm technology node are complete resist and residual removal with near-zero substrate loss [1]. To meet the substrate loss requirement, non-fluorine plasma chemistry needs to be developed. This paper discusses HDI resist strip process development based on (O_2 + N_2H_2) plasma chemistries without the use of fluorine-containing gases. The metrics of process development includes crust breakthrough, resist removal, surface cleanliness, substrate loss and dopant retention.

Experimental

The HDI resist strip experiments were conducted in an Axcelis RpS320 tool with various plasma chemistries along with other parameters. The RpS320 system is a 300mm, dual-chamber, chuck based, downstream microwave plasma dry strip and residue removal tool which offers high throughput and process flexibility with low cost.

Endpoint detection for crust breakthrough and bulk resist removal (time-to-clear) was carried out with optical emission spectroscopy. Surface cleanliness was inspected by optical microscope and SEM. Substrate losses were determined by film thickness measurements before and after plasma strip. For dopant loss tests As and B implanted silicon wafers were exposed to different plasma strip conditions and evaluated by Rs measurement.

Results and discussion

The effectiveness of crust breakthrough and bulk resist removal was tested with varying the O_2 / N_2H_2 ratio in the plasma gas mixture. As seen in Fig. 1, higher content of O_2 in O_2 + N_2H_2 helps both crust breakthrough and bulk resist removal. However, it is known that O_2 plasma also enhances the oxidation of the silicon surface hence causes more silicon consumption. Process optimization should have both crust removal and substrate loss considered. Fig. 2 shows substrate loss data with different plasma chemistries. It is clear that fluorine-containing chemistry caused much more substrate losses than the non-fluorine chemistry conditions. Rs shift as a function of B implant energies for both reducing and oxidizing chemistries is shown in Fig.3. Oxidizing chemistries convert the sub-oxide into a slightly thicker dioxide that can consume some dopant but can effectively cap the out-diffusion of B and As during the anneal. These two effects explain the results in Fig. 3. At high energies, the dopants are deep in the silicon, and the strip chemistries have little effect, as the energy decreases, the dopant consumption due to oxidation take effect first – causing the reducing plasmas to have lower dopant loss, as the implant energy drops further, the oxide capping effects dominate – making the oxidizing plasmas retain more dopant.

Conclusions

Non-fluorine plasma chemistry for HDI resist strip was developed in a Rps320 system. Optimized O_2 / N_2H_2 ratio yielded fast crust breakthrough and resist removal with clean wafer surface and minimum substrate loss. This non-fluorine strip process has been qualified for 45nm production.

References

[1] ITRS 2005

Figures

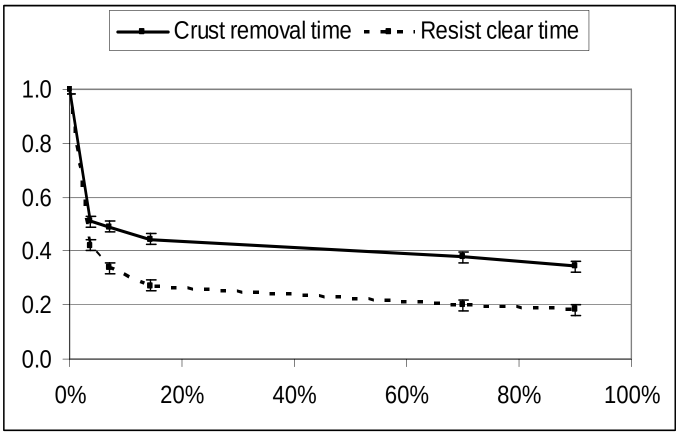

Fig. 1 Time to breakthrough the crust and to completely remove the as a function of O_2 content in $O_2 + N_2H_2$ gas mixture (normalized).

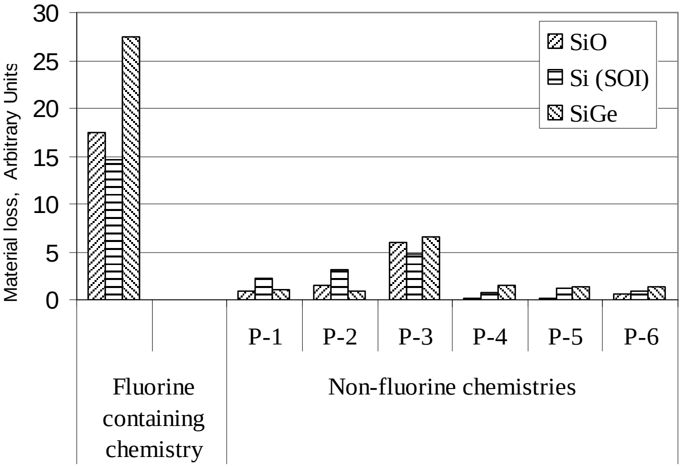

Fig. 2 Substrate (SiO, Si and SiGe) loss per cleaning cycle for different chemistries.

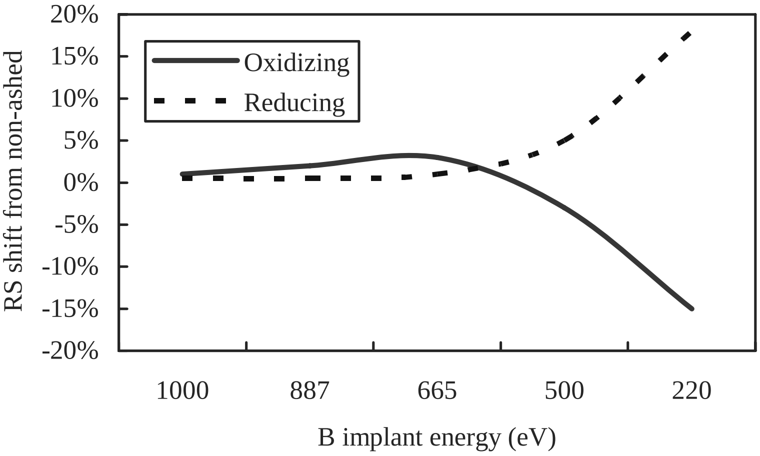

Fig. 3 Rs shift as a function of B implant energies for both reducing and oxidizing chemistries.