Cleaning of Fragile Fine Structures with Cryogenic Nitrogen Aerosols

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Introduction
As semiconductor device architectures continue to shrink, small-feature/high-aspect ratio structures have become common in the devices. These structures are formed in close proximity to each other and can become stuck together due to the high surface tension of water in the cleaning solution during the wetting and subsequent drying of the structures in an aqueous cleaning. Therefore, dry cleaning techniques that avoid this problem are required. Cryogenic aerosol-based wafer cleaning is one of the most promising dry cleaning techniques that can remove particles and process residues from silicon wafers without wet chemical solutions [1, 2].

In the aerosol cleaning, conventionally used argon aerosols, however, can cause the destruction of fragile fine structures, such as cantilevers and beams both in stencil masks for electron beam lithography and in mobile components for MEMS devices.

In this paper, we have demonstrated the cleaning of high aspect-ratio fragile fine structures without their destruction by employing nitrogen as a source of aerosols, whose force of impact against the structures is smaller than argon due to its smaller molecular weight.

Experimental
Figure 1 illustrates the aerosol cleaning system used in this study [1]. Gaseous nitrogen and/or argon preliminary pressurized and cooled at a cryogenic refrigerator is injected into the vacuum process chamber through jet nozzles to generate nitrogen or argon aerosol clusters. The cantilevers made of 300nm-thick silicon nitride on silicon wafers were processed with nitrogen or argon aerosols at various nozzle pressures. After processing, the cantilevers were inspected by SEM in terms of their sticktion and destruction. Their aspect ratios (length/width) are varied from 10 up to 200.

Results and Discussion
Figure 2 shows that maximum aspect ratios of sustainable cantilevers with a width of 80 nm and particle removal efficiency as a function of nozzle pressure in nitrogen aerosol cleaning. The nitrogen aerosols can remove particles though the force of the impacting nitrogen aerosols is small. Possible mechanisms of particle removal for cryogenic nitrogen aerosols are considered. Our simulation based on molecular dynamics shows that the pressure and temperature of impacting nitrogen aerosols against the surface reach the critical point of nitrogen. Hence, resultant supercritical nitrogen fluid will be considered to generate relatively large shear force to remove particles on silicon wafers even when the force of the impacting nitrogen aerosols is small.

Conclusion
Cryogenic aerosol cleaning to employ nitrogen as a source of the aerosols has successfully removed particles on the fragile fine structures by optimizing the nozzle pressure.

REFERENCES