A New Approach for Study of Particle Adhesion and Removal Relevant to Post CMP Cleaning

Su-Youn Lee, Sang-Ho Lee, Hyung-Soo Song* and Jin-Goo Park
Department of Metallurgy and Materials Engineering, Hanyang University, Ansan, 425-791, Korea
* Dongwoo Fine Chem, R&D Center, Iksan, Korea

Chemical Mechanical Planarization(CMP) has become widely used in the semiconductor industry due to its ability to provide a global planarization and novel interconnect process for a wide range of sub-micron device manufacturing. As device features continue shrinking and metal surfaces appear to be planerized, post CMP cleaning for removing the sub-micron particles become more and more important. In order to develop effective cleaning in CMP process, it is necessary to understand particle adhesion and removal mechanisms during CMP [1]. The purpose of this study was to investigate the interaction force between slurry particles and wafer surfaces for the development of effective post CMP cleaning process.

The mechanism of post CMP cleaning was understood from the calculation and measurements of the interaction force between slurry abrasives and wafer surfaces used in CMP. Usually, silica and alumina slurries have been most widely used in oxide and metal CMP. Two-step polishing is the most common method used for copper CMP. Because of many scratches, large dishing and easy corrosion, the 2nd step of Cu CMP has been applied in alkaline pH region [2].

DLVO theory [3] was used to calculate the interaction force between the slurry particle and the wafer by measuring zeta potentials of particles and surfaces. Figure 1 shows the interaction force between a silica particle and wafers as a function of pH. The stronger attractive force was calculated for silica particles and wafers in acidic than in alkaline solution. In acidic and alkaline solution, attractive interaction force between silica particle and Cu wafer was the strongest; attractive interaction force between silica particle and Si wafer was the strongest in neutral solution.

The interaction force was directly obtained by measuring the force on the cantilever as a function of distance between the particle and surface using Atomic Force Microscope (Autoprobe CP, Park Scientific Co.). Figure 2 shows the optical micrograph of a silica particle on a tipless cantilever. The change of interaction force between the particles and surface was measured as the cantilever approached to the substrate [4]. Figure 3 shows interaction forces between wafers and silica particles by using AFM. The strongest interaction force on Cu wafers and the weakest force on silicon were measured. Even though the clear changes of forces were not observed in liquid of pH 11 as observed in air, they were very reproducible. The interaction force was also measured in solution of the range of all pHs Adhesion force measurements by AFM showed the same results as the theoretical calculation. Relatively, stronger attractive energy was calculated for colloidal silica particles in acidic than alkaline solution. In order to remove particles effectively in Cu CMP, it might be more desirable to use alkaline slurry.

In order to measure how much the interaction force is important in the development of post CMP cleaning process, the wafers were polished with silica particles on a polisher. The polished wafers were rinsed in DI water and N_2 dried. Then, these wafers were observed by FESEM. The least number of particles were found on the silicon surface and the greatest on Cu. It indicates that the interaction force plays a major role in determining the level of contamination on wafer surfaces during CMP.

Reference

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[3] D. J. Shaw :Introduction to Colloid and Surface Chemistry, p.174-200, Butterworth-Heinemann Ltd., oxford, (1992)
[4] T. J. Senden : Surface Chemistry and Tip–Sample Interactions in Atomic Force Microscope, Colloids and Surfaces, p.29-51, A: Physicochemical and Engineering Aspects, **94** (1995)

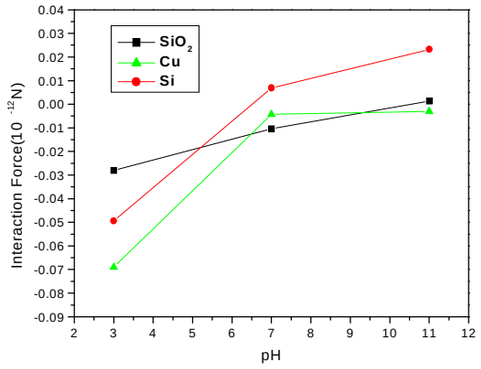

Figure1. DLVO total interaction force as a function of pH in 25A of inter particle-wafer distance

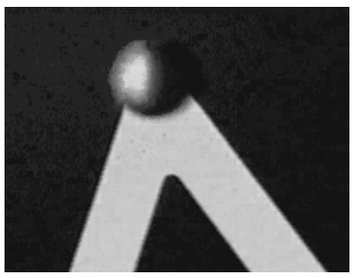

Figure2. The optical micrograph of a silica particle on a tipless cantilever

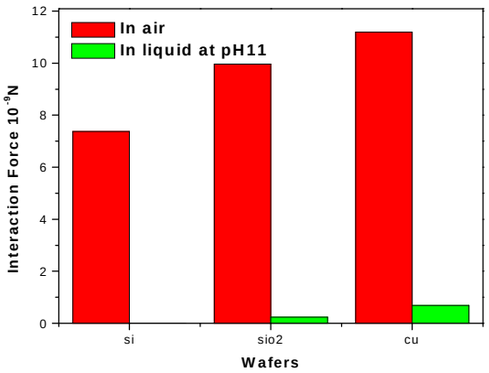

Figure3. Interaction force measured by AFM in air and liquid