Contact Model for a Pad Asperity and a Wafer Surface in the Presence of Abrasive Particles for Chemical Mechanical Polishing

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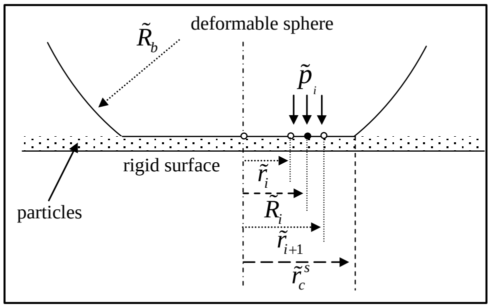

In CMP the interface of the polishing-pad and the wafer is filled with liquid slurry and abrasive particles. The average surface roughness R_a of the pad is much larger than the typical particle diameter. The majority of material removal in CMP is due to the abrasion of the particles trapped between the pad asperites and the wafer. Therefore, it is necessary to understand the relative contributions of pad-to-wafer (2-body) contacts and pad-to-abrasive-to-wafer (3-body) contacts. The Greenwood and Williamson (GW) multiasperity model is widely used to simulate the contact of a rough-pad with a smooth-wafer. This model is based on the Hertz contact theory for modeling the interaction of surface asperities. This approach assumes that only wafer and the pad make contact, and the effect of the particles on the contact pressure distribution and the contact area is neglected.

The objective of this study was to develop a contact model for a single (pad) asperity and a flat (wafer) surface, with an interface filled with spherical (abrasive) particles. The model considers the effects of particle concentration, non-linear material behavior of the pad; and, assumes that the abrasives are rigid and abrasive diameters have a normal distribution.

Finite element method is used to determine the deformation characteristics of a single rigid-sphere indenting a hyper-elastic material. Relations are developed to predict pad-to-particle-to-wafer contact in two distinct regimes, where a) pad and the wafer are

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separated by the particle; and b) all three bodies come in contact simultaneously. Greenwood and Tripp (GT) model, which is widely used for the contact of rough spheres forms the basis of the current model. Greenwood and Williamson (GW) multi-asperity model is utilized to characterize the local contact of the rough surfaces in GT model.

The presence of the abrasive particles in the (pad) asperity-wafer interface caused the contact to be distributed over a larger area as compared to the Hertz model, while the maximum contact pressure became relatively lower. It was found that the contact region can be divided into 3 different sub-regions: At the outside edge of contact, pure 3-body contact was the responsible mechanism for the contact pressure. On the other hand, 2-body contact was the dominant mechanism near the center of contact as the particles became embedded in the elastic surface. There was a transition region between these two regions where the effects of 3-body and 2-body contact were comparable. The deviation of the contact pressure distribution from Hertz contact became smaller for large contact force as the extent of the 2-body contact dominant region covered almost the whole contact zone. This model is then used to explain experimentally observed material removal behavior in CMP.