FULL 300mm WAFER SPATIALLY RESOLVED MECHANICAL PROPERTY AND ADHESION MAPPING OF ULK-FILMS WITHOUT SAMPLE PREPARATION

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Introduction-

Successful implementation of ultra low-κ (ULK) dielectric films are required for the continual downward scaling of microelectronic devices. ULK films incorporate nanometer sized pores to minimize κ, but this porosity typically results in significantly decreased strength, stiffness, and adhesion properties of the deposited films. Films are believed to behave sufficiently uniform throughout the entire wafer. The assumption was not confirmed by actual testing and it is therefore realized that the deposited films are far less homogenous than originally expected. Nanomechanical Metrology techniques are able to reliably probe thin film behavior with high spatial resolution to identify film variability and process instabilities.

Experimental-

Nanoindentation and nanoscratch testing was performed using an ATI 8800 Nanomechanical Metrology Tool (Hysitron, USA). An evenly spaced array of 1884 nanoindentation and nanoscratch tests were performed on a 200nm thick ULK film deposited on a 300mm wafer to measure spatially resolved variability. Nanoindentation measurements were performed using a cube corner indenter to a force just large enough to penetrate the stiff surface region present on the majority of ULK films to probe the 'bulk' film response. Ramped force nanoscratch was performed utilizing a 1μm conical scratch probe to continuously increase stress applied to the ULK/Si interface until the critical load, C_L, of interfacial adhesion was achieved.

Figure 1. ATI 8800 Nanomechanical Metrology Tool providing full 300mm wafer testing capabilities with X-Y position accuracy up to ±100nm and robotic substrate handling allows fast feedback to identify structure-processing variability and drift.

Results-

Adhesion Mapping:

Adhesion mapping showed a significant critical load variability of approximately 14%. The onset of delamination was identified by the first excursion in the lateral force and normal displacement scratch data and spatially plotted to map adhesion variability.

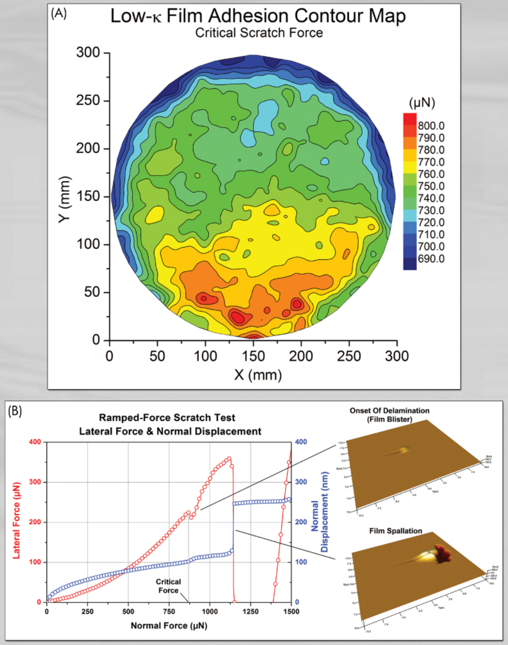

Figure 2. (A) ULK adhesion Map showing adhesion variability due to non-uniform processing conditions. (B) Representative data from a nanoscratch test showing how the critical load was determined.

The large adhesion variability can be attributed to wafer cleaning processes and/or plasma instabilities during initial ULK deposition, which warrants further investigation. The measured gradient cannot be due to a systematic measurement errors (i.e. probe blunting, contamination), as a 90° wafer rotation produces the same gradient profile.

Mechanical Property Mapping:

Hardness (H) and modulus (E_r) maps also showed relatively large spatial variability trends of 9% and 13%, respectively. The lack of gradient correlation between H&E_r and C_L indicates the mechanical property variation of these films do not influence critical load measurements and vice versa. H and E_r variations can be attributed to highly localized ULK chemistry, porosity, pore shape, and/or crosslinking variability during film processing.

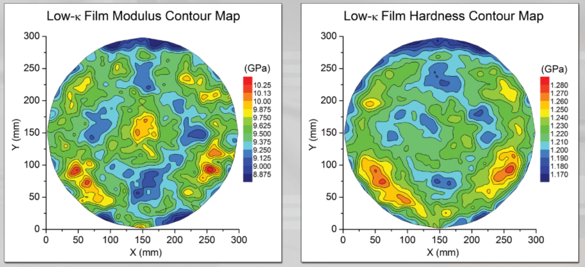

Figure 3. Mechanical property maps comprised of 1884 nanoindentation tests on a 200nm thick ULK film showing significant spatial variability in film properties.

Conclusion-

Nanomechanical metrology is a valuable method for process monitoring to identify spatially resolved variation in the deposited ULK thin films. 200nm thick ULK films were found to be much less homogeneous than originally thought with Hardness, Modulus, and Adhesion values varying by 9 to 14% over the full 300mm wafer range; but the localized variation (~10μm²) is approximately 1%.

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