Using EUV Photoacoustics for Nanometrology of Ultrathin Films

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Inventive material development and device design require reliable characterization tools to understand the benefits and drawbacks of new nanomanufacturing ideas. In the semiconductor industry in particular, Moore's Law scaling has pushed the frontiers of nanofabrication so far that the thinnest films and smallest nanostructures being made today cannot easily be measured using current metrology techniques. To overcome these limitations, we implement a non-destructive photoacoustic technique that uses coherent extreme ultraviolet (EUV) light and nanoscale acoustic waves to probe the material properties of nanostructured systems on extremely short length scales. We excite periodic metallic nano-gratings on the surface of low-k dielectric thin films with a femtosecond 800nm laser pump pulse to launch acoustic waves: longitudinal waves (LAWs) within the nanostructures, LAWs traveling down into the film and transverse surface acoustic waves (SAWs) with a wavelength set by the grating period. Because SAWs penetrate only as deep as a fraction of their wavelength, their sensitivity can be isolated to ~10nm films by shrinking their wavelength with shorter grating periods. Wave dynamics are monitored by diffracting 30nm EUV probe light from the surface. Such short wavelength light obtained via tabletop high harmonic generation offers exceptional sensitivity down to picometer surface displacements caused by the nanoscale acoustic waves. Previously we used this technique to characterize a series of 50-100nm thin dielectric films, demonstrating selective sensitivity to the film properties without contribution from the substrate beneath. Here we extend that work to sub-50nm thin film samples where we begin to address how thickness alone may affect the nanoscale elastic properties of a material. Also, we examine softer, highly hydrogenated SiC:H films in which we can explore important trends or thresholds in the relationship between Poisson's ratio and the decreasing bond coordination that contributes to film softness.