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Study of Spin-coated Resist Coverage on Nanoscale Topography Using Spectroscopic Ellipsometry

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The spin-coating process is used extensively as a conformal technique for coating on planar substrates, however, there are several applications where spin-coating on a topography is required. For example, in the "reverse-tone" process, a silicon-rich, etch resistant material such as HSQ is first spin-coated on an imprinted resist pattern and then etched back through multi-step RIE to form a negative tone replica of the original pattern.[1,2]

To precisely control the etch-back in the reverse-tone process, it is critical to determine the spin-coated resist thickness on the pattern as well as in the non-patterned area (FIG.1). However, a general answer regarding the effect of underlying topography on spin-coating is difficult because of the physical and mathematical complexity of the problem. Experimentally, systematic characterization of resist coverage on a topography using conventional techniques such as AFM or SEM is hindered by their small sampling size, destructive sample preparation techniques, and limited sensitivities.

Being highly sensitive and nondestructive, spectroscopic ellipsometry optical critical dimension (SE-OCD) analysis is especially suited for this application. SE-OCD collects the light signal reflected from periodic structures, and the measured spectra are analyzed to extract pattern profile information.[3] In this study, we apply SE-OCD to the characterization of spin-coated resist on high-density line-and-space patterns used in discreet track recording (DTR). From the measured spectra, critical coverage information can be extracted using rigorous coupled wave analysis (RCWA). The results are also in good agreement with cross-sectional SEM (FIG.2).

Further analysis of resist coverage on patterns of various dimensions indicates that the effective resist thickness (defined as the resist volume divided by the area, as shown in FIG.1) on the pattern is slightly thicker than the film coated on the non-patterned area, and it shows a slight dependence on pattern depth. The observed phenomena can be explained by assuming no-slip condition on the pattern surface and by dividing the spin-coating process into two stages.[4] In the first the film remains fluid and the resist thinning is dominated by radial outflow driven by the centrifugal force. As the resist thins, evaporation of the solvent causes the resist to "gel" due to the increase in its viscosity and the resist no longer flows. The subsequent thinning is then dominated by solvent evaporation until the resist film reaches its final thickness. SE-OCD study reveals when that transition occurs and how much thinning afterwards is caused by solvent evaporation.

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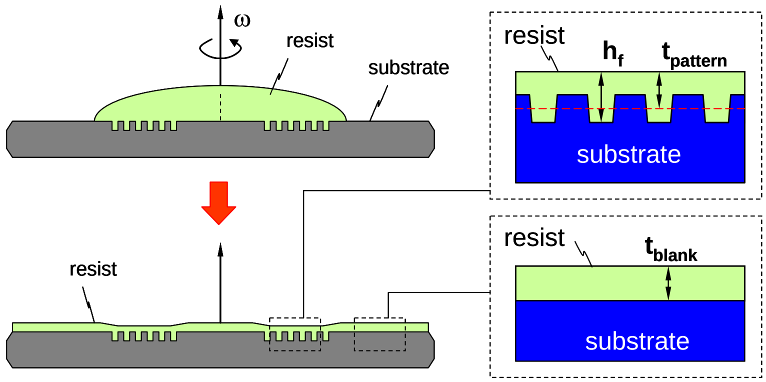

FIG.1 Schematic of the experiment: resist was spin-coated on a patterned 6-inch silicon wafer, we measured the effective resist thickness in both the patterned ($t_{pattern}$) and non-patterned area (t_{blank}) using spectroscopic ellipsometry and rigorous coupled wave analysis. Note that the effective film thickness is defined as the remaining resist volume divided by the area. Thus, in the patterned area, $t_{pattern}$ is slightly smaller than the resist filling height h_f, defined as the distance from the bottom of the pattern to the top surface of the spin-coated resist film.

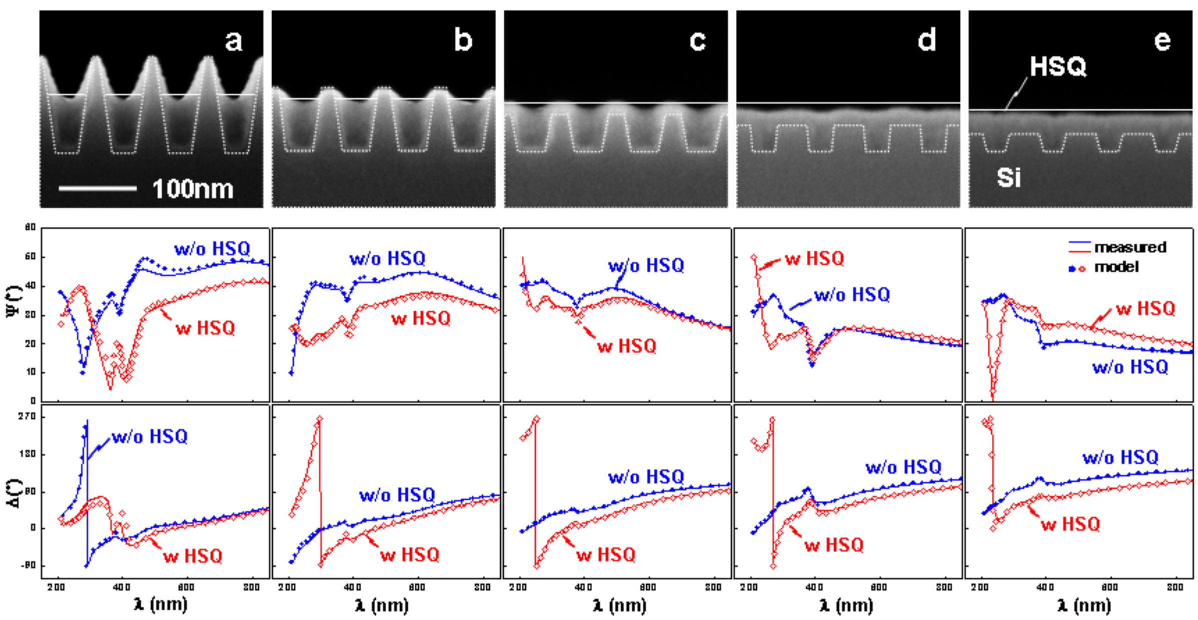

FIG.2 SEM images of 72.6nm pitch HSQ-coated silicon line-and-space patterns of different depths and their SE spectra, with and without the spin-coated HSQ. Outlines of the SE-OCD best fit models are superimposed on the SEM images for comparison. Both measured (lines) and calculated (dots) spectra are presented. The HSQ was spin-coated using the same conditions. The SE-OCD best fit models are in good agreement with the cross-sectional SEM.