Wafer Emissivity Effects on Light Pipe Radiometry in RTP Tools

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The knowledge of wafer temperature during rapid thermal processing (RTP) of semiconductors for implant anneal and gate oxide formation is critical. Light pipe radiation thermometers (LPRTs) are frequently used to monitor wafer temperatures during rapid thermal processing for semiconductor fabrication. However, additional information about the test wafer radiative properties and chamber effects are required to establish confidence in the LPRT calibration for use with production wafers having an emissivity different from that of the test wafer. Test wafers with thermocouples provide a convenient method for in-tool calibration of LPRTs against the ITS-90. This method overcomes the difficulties of sorting out influences of chamber stray radiation and wafer-chamber interactions. In this paper we will report on the results of changing the wafer emissivity on the LPRT calibration in the NIST RTP Test Bed.

NIST test wafers (200 mm dia.) instrumented with wire and thin-film thermocouples were used for measuring temperatures at three locations in close proximity to the LPRT target areas: a 25-mm diameter spot at the center, and two locations at the wafer mid-radius. The central target spot was bare or sputter deposited with platinum or gold providing spectral emissivities of 0.21 and 0.03, respectively. The wafers were thermally oxidized to thicknesses of 0.31 m and 0.85 m providing for spectral emissivities of 0.65 and 0.86, respectively. These combinations of spot and wafer emissivities permitted making six different spectral radiance temperature measurements against a single wafer TFTC temperature. The LPRTs were calibrated at NIST using a sodium heat-pipe blackbody. The emissivities of the wafer and the target were inferred from directional hemispherical reflectance measurements in the NIST Spectral Tri-Function Automated Reference Reflectometer facility.

For each wafer-target spot combination, measurements were made of three spectral radiance temperatures (on the center spot, and on the oxidized wafer at the two mid-radii locations) and of comparative wire- TFTC temperatures. Using radiative models appropriate for each of the LPRT target viewing conditions considering the surface emissivities and wafer-chamber geometry, model-corrected estimates for the wafer temperature were generated and compared with the wire-TFTC measurements. Significant spectral radiance temperature changes (10 C to 20 C) were measured with the Pt and Au targets in the NIST test bed which has a highly reflective cold shield parallel to and in close proximity to the wafer.