Lightpipe Proximity Effects on Si Wafer Temperature in Rapid Thermal Processing Tools

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Accurate temperature measurements are critical in rapid thermal processing (RTP) of silicon wafers for thermal oxidation and dopant anneals. Many RTP tools use lightpipe radiation thermometers (LPRTs) to measure the wafer temperatures during processing. These LPRTs can yield accurate temperature measurements when they are properly calibrated and used with a suitable model to correct for surface emissivity and chamber irradiation effects. The LPRTs are used primarily because they cause less disturbance to the wafer temperatures than contact thermometers or lens-type radiometers, which generally require larger viewing apertures. Wafer temperature measurements are frequently performed in a highly reflecting chamber to obtain a near-unity effective emissivity of the wafer. The sapphire lightpipe has a relatively low reflectivity (0.1) and therefore reduces the temperature of the wafer in proportion to its proximity to the wafer or view factor. This study was undertaken to measure and model the effect of LPRT proximity on the wafer temperature.

Our experiments were performed in the NIST RTP test bed using a NIST thin-film thermocouple (TFTC) calibration wafer. We measured the spectral radiance temperature with the center lightpipe and compared these with the TFTC junctions and with the three LPRTs at the midradius of the wafer. We measured LPRT outputs from a position flush with the reflecting plate to within 2 mm of the stationary wafer under steady-state conditions with wafer-to-cold plate separation distances of 4 mm and 10 mm. Depressions in the wafer temperature up to 20 °C were observed. In addition to the cooling effect caused by the close proximity of the light pipe, the LPRT response is influenced by the lightpipe self emission and scattered chamber irradiation. The experimental results are compared with those from a model that accounts for lightpipe geometry and radiative properties, wafer emissivity and chamber cold plate reflectivity.