Measurement of the Emittance of Silicon Wafers with Anisotropic Roughness and Thin-Film Coatings

H.J.L. Lee, A.C. Bryson,[S] Y.B. Chen, and Z.M. Zhang[C]
George W. Woodruff School of Mechanical Engineering, Georgia Institute of Technology, Atlanta, GA, U.S.A.
zzhang@me.gatech.edu

Understanding the emittance of rough silicon surfaces is critical for the determination of wafer temperature using radiation thermometers during short-time thermal processing [1]. Many studies dealing with rough surfaces have assumed that the roughness is completely random and can be described by Gaussian statistics. On the contrary, the unpolished surface of crystalline silicon wafers often exhibits non-Gaussian roughness characteristics, as evidenced by the side peaks in the slope distribution [2]. Previous theoretical and experimental studies showed that anisotropy can significantly affect the bidirectional reflectance for coated and uncoated rough silicon surfaces [3,4]. However, the effects of anisotropic roughness on the emittance have not been fully investigated. While the emittance can be predicted from the Monte Carlo simulation by integrating the modeled bidirectional reflectance, it is impractical to obtain the emittance by summing the bidirectional reflectance measured with the laser scatterometer over a very large number of angular positions around the hemisphere. In the present work, a center-mount integrating sphere will be employed to measure the directional-hemispherical reflectance in the wavelength region from 400 to 1000 nm using a monochromatic light source and a silicon photodiode detector. The emittance can be obtained from the measured reflectance based on Kirchhoff's law, since the silicon wafer is opaque in the measured spectral region. Sample rotation allows measurements of the reference signal (without reflection from the sample) and the signal reflected by the sample at different angles of incidence for each polarization. Calibration of the instrument will be made using standard reference samples with known reflectance. Thermoelectrically cooled laser diodes at 635 nm and 795 nm will also be used for grazing angle measurements. The measured emittance of silicon wafers with or without thin-film coatings will be compared with the predicted emittance to investigate the effects of anisotropic roughness. This research will provide accurate and much needed directional emittance data of anisotropic silicon surfaces with various coatings, such as gold and silicon dioxide.

[1] P.J. Timans, *The Thermal Radiative Properties of Semiconductors*, in: Advances in Rapid Thermal and Integrated Processing, F. Roozeboom, Ed. Dordrecht, Netherlands: Academic Publishers, 1996, pp. 35-102.
[2] Q.Z. Zhu and Z.M. Zhang, *J. Heat Transfer* **126**, 985 (2004).
[3] H.J. Lee, Y.B. Chen, and Z.M. Zhang, "Directional Radiative Properties of Anisotropic Rough Silicon and Gold Surfaces," *Int. J. Heat Mass Transfer*, submitted (2005).
[4] H.J. Lee and Z.M. Zhang, "Measurement and Modeling of the Bidirectional Reflectance of SiO2 Coated Si Surfaces," *Int. J. Thermophys.,* submitted (2005).