Characterization of Single-Particle Scattering Properties Using a Laser Scatterometer

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Solar thermal energy storage using particles as a storage medium have been investigated for extending electricity production via concentrated solar power applications to periods when sunlight is unavailable. Understanding the scattering behavior of the particles is critically important for radiative heat transfer analysis. Two different measurement configurations are employed that are coupled to a laser scatterometer to measure angular scattering: (1) a falling particle curtain and (2) taped particles. The falling particle curtain is formed with a one-particle nominal thickness so that the scattered signals from particles are obtained directly. However, the flowing nature of particles may result in noises. The taped particles are used to provide a constant particle areal fraction throughout the measurement, which requires additional analysis to correct for effects of the tape on the measurements. Scattered signals from a particle curtain/layer with a single particle thickness enable the determination of mean particle scattering properties without multiple scattering that occurs in a particle bed. A three-axis automated scatterometer operating at a wavelength of 635 nm is used to detect scattered signals from the particle samples. Measurements are performed on ceramic particles which exhibit strong solar absorption and good thermal stability. Semi-transparent silica particle measurements are also conducted for comparison. Scattering cross section and scattering phase function are determined for each both particle types. A Monte Carlo ray-tracing model is developed to estimate particle scattering behavior and compare with measured results. This study enables the measurements of single-particle scattering properties and facilitates the understanding of the scattering behavior of particles with different optical properties.