Modeling and Measurements of Spectral Radiative Properties of Solid Particles, Particle Beds, and Inhomogeneous Layers

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Solid particle receivers are considered as the next generation of concentrated solar power that operates at higher temperatures with reduced overall cost. The solid particles with diameters ranging from 0.1 to 1 mm serve as direct solar absorber, heat transfer fluid, and thermal storage materials. Measurement techniques have been developed to measure the light scattering from a single particle layer and spectral radiative properties of particle beds. Spectrometers are used with different integrating spheres and detectors to measure the directional-hemispherical reflectance of the bauxite-based and silicon dioxide particles sandwiched between transparent plates at room temperature at wavelengths from 0.38 μm to 15 μm. The solar absorptance and total emittance are calculated by integration over the measured spectral properties. The Monte Carlo method is used to model the particle radiative properties and the results are compared with the experiments to shed light on the effects of particle size, wavelength, and refractive index. A high-temperature emissometer is developed to measure the infrared (2 – 15 μm) emittance of particle beds and plate samples up to 700 °C. Angular dependent light scattering experiments are also performed with a laser scatterometer to obtain the scattering phase function and scattering and absorption efficiency factors of individual particles. In a different application such as daylight radiative cooling, highly solar reflective materials with a large infrared emittance are desired. PTFE films and dual-layer PTFE-Ag structures are investigated considering both surface reflectance and volume scattering. The dual-layer structure has been demonstrated to achieve a solar reflectance greater than 0.99 with a high infrared emittance exceeding 0.9. This presentation will discuss the instrumentation, modeling, and measurement results for particles, particle beds, and inhomogeneous layered materials.

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