Aerospace Engineering Doctoral Defense

Spectral Control of Thermal Radiation with Porous Metafilm for Enhancing Thermophotovoltaic Energy Conversion

School for Engineering of Matter, Transport and Energy

Rajagopalan Ramesh

Advisor: Liping Wang, and Bruno Azeredo

Abstract

The objective of this dissertation is to study the use of isotropic and uniaxial metamaterials as spectrally selective filters and broadband selective absorbers for solar thermal and opto-thermal energy conversion. In the ongoing search for new materials with tunable absorption, transmission and radiation characteristics, porous metals, and nanowires (NW) provides an extensive design space to engineer its optical response based on the morphology-dependent phenomena. This tunable optical characteristic can be used to improve energy conversion device performance.

This dissertation firstly discusses the use of aluminum nanopillar (AlNP) array on a quartz substrate as spectrally selective optical filter with narrowband transmission for Thermophotovoltaic (TPV) systems. An investigation into the physics indicated that the narrow-band transmission enhancement is attributed to the magnetic polariton (MP) resonance between neighboring Al nanopillars. Tuning of the resonance wavelengths for selective filters could be achieved by changing the nanopillar geometry.

Next, isotropic nanoporous gold (NPG) films is investigated for applications in energy conversion and 3D laser printing. The fabricated NPG samples are characterized by scanning electron microscopy (SEM), and the spectral hemispherical reflectance is measured with an integrating sphere. The effective isotropic optical constants of NPG with varying pore volume fraction (PVF) are modeled using the Bruggeman effective medium theory.

NPG are metastable and structurally densify upon annealing. Hence, for its deployment in high temperature applications such as solar thermal energy harvesting and optothermal conversion, it requires understanding of its temperature dependent optical properties. For this purpose, a lab-scale fiber-based optical spectrometer setup is developed to characterize the in-situ specular reflectance of nanoporous gold thin films in the wavelength range between 400 and 1000 nm at temperatures ranging from 25 to 500 oC. The in-situ measurements suggest that the specular reflectance does not change up to 125 oC highlighting its stability and it progressively decreases particularly in the range of 600-1000 nm between 125-400 oC beyond which it becomes invariant to temperature.

The dissertation continues with modeling & measurements of the optical behavior in porous powders with improved absorptance. This is important from the viewpoint of scalability, to get end products such as sheets and tubes with the requirement of high absorptance that can be produced through 3D printing.

Finally, the dissertation concludes with recommendations on the methods to fabricate the suggested optical filters to improve TPV system efficiencies. The results presented in this dissertation will facilitate not only the manufacturing of materials but also the promising applications in solar thermal energy and optical systems.

July 11, 2022; 4 PM; ERC 593;

Zoom Link: https://asu.zoom.us/j/2047543925