TEL AVIV UNIVERSITY

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Measurement of Emissivity at high temperature

A thesis submitted toward the degree of
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by

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Abstract

Spectral emissivity of materials and coatings is a very important property in various applications, and specifically in solar energy. The knowledge of emissivity at high temperatures is crucial in designing and analyzing the performance of solar thermal receivers. However, it is a very difficult property to measure or predict due to the intricate nature of the physical phenomena involved. The available data for emissivity at high temperatures is very limited and often shows great variance between measurements done at different conditions, preparation etc.

Spectral emissivity measurement techniques can be divided into direct measurements of emitted radiation and indirect measurements by measuring reflectivity and/or transmissivity and applying Kirchhoff's law. Direct measurements include measurement of emitted radiation at a desired spectral band from a heated surface and comparison to a pre calibrated reference blackbody.

The aim of the current work was to develop a spectral emissivity measurement system for the infrared, capable of measuring solar receivers' constituent materials and coatings at working temperatures. Since the emission in the infrared at these temperatures is strong, a direct measurement approach has been employed. The developed system uses back heating in air atmosphere. While suitable for measuring only non oxidizable samples, these are the vast majority of materials that are used in the solar industry, and this makes the system robust and capable of measuring most of the materials of interest for solar applications. This is achieved while using affordable off-the-shelf components.

A novel type of CERMET selective coatings that are stable at high temperatures were prepared at the Hebrew University using sol-gel methods. Infrared emissivity measurements and characterization were performed by the developed system and the contributions of the different components of the CERMET to the spectral emissivity/absorptivity were analyzed.

The use of a gold IR reflecting layer on the substrate reduces IR emissivity from around 0.2 to a negligible value. The matrix material and morphology also have a significant impact on the IR emission, and matrix contribution of 0.2-0.4 to emissivity in the 2-4μm region can be observed for porous matrices such as the polysiloxane. The matrix contribution to emissivity is dependent on its thickness as well and coating thickness of
below 2µm is beneficial for reduced infrared emissivity. Sandblasting with 30µm grains also increases emissivity across the measured spectrum.

The main aspect of the coatings that needs to be improved is the fact the pigments contribute too much to the total emission. It was suggested that the emission is increased by agglomeration of the pigment particles in the coatings and the existence of agglomerates was confirmed by SEM pictures. Other routes for improvement include fine grain sandblasting with grains in the range of 1-2µm in order to avoid contribution to infrared emissivity whilst improving adhesion and solar absorption.

Measurements of solar thermal air receiver constituents were also performed using this system. The absorber element alumina shows low emissivity/absorptivity at wavelengths up to 4µm. applying a black paint on the alumina induces very high emissivity/absorptivity at all measured wavelengths, highlighting the importance of the paint. The window quartz shows abnormal low emissivity in the long wavelengths and further refinement of the quartz measurement procedure should be done in the future.

The emissivity measurement system may serve now as a general analysis tool in the lab for a variety of scientific and industrial applications.