MAP-fis Essay Proposal, 2015-2016

(*please write in English*)

Supervisor

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Title

Solar selective absorber for high temperature applications

Area

(*Materials, Optics, Condensed Theory, High Energy Theory,....*);

Materials

Summary of Proposal

Solar thermal technology is already being used for electricity production. This is done in large-scale power plants and this technology has an important advantage over some other forms of renewable energy, such as photovoltaic or wind energy, in that thermal energy can be stored more cost-effectively and efficiently than electricity. This technology uses parabolic-trough solar systems, which concentrate sunlight 80 times onto an evacuated receiver tube. The energy is absorbed in the solar selective coating deposited in the absorption pipe, which reaches high temperatures (up to 400 ºC), so that the energy can be subsequently used in steam turbines to produce electricity. The relative cost of electricity obtained with this technology still needs to be reduced, this can be achieved with improvements in the optical and thermal properties of selective coatings and with the increase of the operating temperature (>450°C). To reach these requirements, it is important to minimize emissivity, as well as, improvements in the durability and oxidation resistance of the solar selective coating. Current solar-selective coatings do not have the stability and performance necessary to work at aforementioned operating temperatures, hence new materials/solutions are necessary.

The objective of this proposal is to develop solar selective coatings having simultaneously high solar absorptance ($\alpha > 0.95$) and low emissivity ($\varepsilon < 0.07$ at 450°C) together with high thermal stability above 450°C, ideally in air, with improved durability.

Multilayer absorbers or multilayer interference stacks will be designed and deposited to obtain the desired optical properties. The multilayer structure will have four layers, where the first layer will be a back reflector tungsten layer with high electrical conductivity (stainless steel it is not a good infrared reflector). For the remaining stack will comprise a double film structure for phase interference and finally an antireflection layer. Several potential materials will be tested as high-temperature solar selective coatings. For these double film structures, solutions based on high and low volume fraction cermets will be used. Extra diffusion barrier layers introduced before of after the back reflector can be also tested. The cermets will be prepared via two different methods. In the first they will be obtained by the co-deposition of the two materials in same magnetron sputtering chamber. With this method, a structure based on Al_2O_3:Ta and $(Al,Si)O_x$:W cermets, will be studied using this first method. In the second method, nanoparticles will be first nucleated in a supersaturated gas using a magnetron sputter source operating at a primary vacuum in an auxiliary chamber, and then will be ejected to a main chamber using a differential pumping system, where the ceramic matrix is being deposited. Al_2O_3:Ni and $(Al,Si)O_x$:W cermets will be tested with this second method.

The first step will be deposition of the individual layers on glass with subsequent measurement of the optical properties. The optical constants of the individual layers will be calculated using optical modelling software, which makes the theoretical analysis of transmittance and reflectance data of films deposited on glass. Those optical constants, together with those of the stainless steel substrate and of the infrared reflector, will be then used to design the optical stacks for a solar selective absorber. The functionality of the multilayer structures will be verified through the solar absorptance and emissivity measurements and the coating performance and durability will be evaluated with thermal annealing in air and in vacuum.

Several characterization techniques, namely, Scanning Electron Microscopy (SEM), X-ray Photoelectron Spectroscopy (XPS), X-Ray Diffraction (XRD), Transmission Electron Microscopy (TEM), micro-Raman spectroscopy, Rutherford Backscattering Spectrometry (RBS) and Elastic Recoil Detection Analyzes (ERDA) will be used to characterize the morphological, compositional, structural and chemical properties of the films.

References

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