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ScienceDirect

Energy Procedia 49 (2014) 30 – 39

Energy Procedia

SolarPACES 2013

Selective coatings for new concepts of parabolic trough collectors

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Abstract

The CSP technology based on parabolic trough solar collector for large electricity generation purposes is currently the most mature of all CSP designs in terms of previous operation experience and scientific and technical research and development. The current parabolic trough design deals with a maximum operating temperature around 400ºC in the absorber collector tube but some recent designs are planned to increase the working temperature to 600ºC increasing the performance by 5-10% to attain the improved productivity that the market demands .These systems are expected to be working during 20-25 years.

One of the key points of the receiver is the stack of layers forming the selective absorber coating. Typical optical values for this coating are >95% of absorbance and 10% of emittance at 400ºC. In the HITECO EU funded project a new modular concept of collector is being tested. With this new design the coating has to fulfill new requirements as the collector will be working at 600ºC and in a low vacuum of 10^{-2} mbar. The authors from IK4-Tekniker have collaborated in the HITECO project building a sputtering system to upscale these new coatings to 4 meters long tubes for the application in a set of experimental collectors, being the project coordination done by ARIES Ingeniería y sistemas S.A.

However, there is a great lack of knowledge about the performance of the absorber coatings during the whole life of the receiver. So, it is necessary to establish characterization methods and standards to guarantee the performance, durability and quality control of high temperature coatings. For this purpose, a new EU funded project called NECSO, aims to design accelerated ageing protocols to test the evolution of these coatings under more aggressive conditions in the new designs.

Selection and peer review by the scientific conference committee of SolarPACES 2013 under responsibility of PSE AG.
Final manuscript published as received without editorial corrections.

Keywords: Selective absorbers; Concentrating Solar Power; Parabollic Through; Solar absorber tube.

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Selection and peer review by the scientific conference committee of SolarPACES 2013 under responsibility of PSE AG.
Final manuscript published as received without editorial corrections.
doi:10.1016/j.egypro.2014.03.004

Nomenclature

AM Air Mass
CSP Concentrating Solar Power
FESEM Field Emission Scanning Electron Microscope
IR Infrared
PVD Physical Vapour Deposition

1. Introduction

According to the EC's Strategic Energy Technology Plan (SET-Plan), no single measure or technology will be sufficient to achieve the 2020 objectives and as such there are several pathways towards a low carbon economy. Solar energy, and concentrated solar power (CSP) in specific, is on the verge of becoming more competitive and gaining mass market appeal.

The CSP technology based on parabolic trough solar collector for large electricity generation purposes is currently the most mature of all CSP designs in terms of previous operation experience and scientific and technical research and development. As a result, this technology has led the way to a world-wide extended implementation of CSP technologies: more than 2800MW are currently operating and more than 6 GW are estimated to be commissioned in the next 5 years. This means to have around 12000-16000 km of solar receivers. The current parabolic trough design deals with a maximum operating temperature around 400ºC in the absorber collector tube but some recent designs are planned to increase the working temperature to 600ºC increasing the performance by 5-10% [1] (on the classical plants performance around 12-14%) as this is considered to be the only way to attain the improved productivity that the market demands [2][3][4]. These systems are expected to be working during 20-25 years.

One of the elements governing the parabolic through performance is the solar selective coating which is responsible of the solar radiation absorption. For efficient photothermal conversion solar absorber surfaces must have high solar absorbance and a low thermal emittance at the operational temperature, typical values for efficient technologies are: absorbance >0.95 and emittance around 0.1 at 400ºC [5]. Current technology is limited to 400ºC by the oil used as heat transfer fluid. In new concepts (molten salts or water vapor) higher temperatures could be reached, which can improve the overall solar to electric efficiency [6]. As a consequence, new selective coatings have to be designed for higher temperatures.

There are 3 main types of approaches which potentially could fulfill the requirements of stable performance for solar absorber at temperatures >400ºC: Semiconductor-metal tandems, multilayer spectral selective absorbers (MSSA) and metal-dielectric composite coatings (cermets). Although, the research on semiconductor-metal tandems and MSSA showed promising results in terms of optical properties their stability at high temperatures is still to be determined. Thus, cermets are currently viewed as the most realistic alternative to be used as solar selective coatings [7]. The highly absorbing cermets are dielectric or ceramic matrices containing micro or nano metal particles or a porous oxide impregnated with the metal. Typical solar selective coatings for mid-high temperatures comprise solar absorbent alloys (AlNx, MoOx, WOx, TiAlN, ZrCNx, Mo, W, Ni, Co, Si, Ge) in combination with transparent dielectrics (SiO_2, TiO_2, Al_2O_3) having different coating structures as single and multiple cermet [8] and graded layers [4][9]. The basic structure of a cermet-based absorber from bottom to top, consists on a SS substrate, a diffusion barrier layer, an IR reflection layer to reflect back IR irradiance from the substrate minimizing losses, a cermet absorber layer and a top antireflection layer.

1.1. New designs for higher temperatures: the HITECO project

To overcome the current limitations in the technology HITECO project [10] (New solar collector concept for high temperature operations in CSP applications", funded by the European Commission under the 7th Framework Programme develops a new solar receiver [2] with the aim to increase the parabolic-trough efficiency, reaching the