Workshop »Coatings for Energy Technologies«

Solar thermal energy applications - state of the art and current challenges

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Solar thermal energy is the only form of renewable energy with an intrinsic storage capacity in the form of heat. Based on flat plate and evacuated tube collectors, approx. 520 GW power have been installed worldwide for domestic hot water supply boiling and heating so far. For concentrated solar power (CSP), the solar flux from solar concentrators is transformed into heat at a solar receiver, and either immediately converted into electricity by a downstream turbine power generator unit or stored as disposable heat energy in storage tanks. Starting from its today's 7 GW installed peak power, CSP has a huge growth potential in the next decades for electricity generation, industrial heat production, decentralized district heating and thermal building management. Its further progress depends mainly on two crucial factors: i) the increase of energy conversion efficiency and ii) the reduction of installation and service costs.

In this talk, an overview of the state of the art and the current challenges for solar thermal energy applications will be given. It will start with few remarks about recent approaches to improve the performance and stability of flat plate and tube collectors. The main part of the talk will focus on recent materials science efforts devoted to increase the CSP plant efficiency by implementing higher operation temperatures and reducing the levelized costs of electricity. An overview about current and ongoing plant installations as well as on results for conventional absorber paints is provided. Based on the identified limitations of these approaches, the concept of solar selective coatings (SSCs) is introduced. Using realistic operational parameters of CSP plants, its potential and its limitations are discussed and graphically illustrated [1]. Examples from our own research on design, characterization and thermal testing of SSCs will be given with emphasis on their optical efficiency and thermal stability up to temperatures of 800 °C [2, 3]. Finally, volumetric receivers are introduced as another alternative concept to advance CSP technology. These solar absorbers consist of regular, porous metal or dielectric frameworks. The porous structure mutually affects radiation, convection, and conductive transport of thermal energy. At high temperature, the porous absorber matrix is expected to have a higher efficiency than a "standard" tubular receiver, because the volumetric effect leads to a low temperature at the front of the absorber, reducing the radiative emission losses.

[1] R. Escobar-Galindo, M. Krause, K. Niranjan and H. Barshilia, Solar selective coatings and materials for high-temperature solar thermal applications, Chapter 13 in "Sustainable Material Solutions for Solar Energy Technologies", Elsevier, 2021

[2] F. Lungwitz et al., Transparent conductive tantalum doped tin oxide as selectively solar-transmitting coating for high temperature solar thermal applications, Solar Energy Materials and Solar Cells 196, 84-93 (2019)

[3] K. Niranjan et al., WAlSiN-based solar-selective coating stability-study under heating and cooling cycles in vacuum up to 800 °C using in situ Rutherford backscattering spectrometry and spectroscopic ellipsometry, Solar Energy Materials and Solar Cells 255, 112305 (2023)