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A review on thermal stability and high temperature induced ageing mechanisms of solar absorber coatings

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ABSTRACT

Many novel, efficient solar absorber coatings are developed in recent decades. However, the methods of qualification tests, such as test of thermal stability, corrosion resistance and prediction of service life that have important engineering significance for solar absorbers to be large-scale applications, are still lacking. Currently, European standard (EN 12975-3-1) and International standard (ISO/CD 12592, 2) are usually applied in conventional situations, such as low- to mid- temperature, slight moisture and sulphur dioxide. However, many other developing industrial countries may face a tougher circumstance, for instance, acid rain, salt mist, sandstorm, smog etc. Therefore, resulting in more complicated ageing mechanisms that the European standard and International standard are no longer well suited. As for the current thermal stability test methods. The customized test method are usually adopted to evaluate the coatings durability during research stage. And the standard test method mainly used to predict the service lifetime for low- to mid- temperature applications. The current problem is how to make up the scarcity of standard test procedure for performance evaluation of high-temperature solar absorber coatings. As for the ageing mechanisms, the most common ageing mechanisms under high temperature are diffusion and oxidation of elements. But, more details on the thermal stability and micro behaviours including element diffusion and distribution, chemical interaction, crystal transition, the surface and cross section ageing morphology of different solar absorber coatings, are still worthy of in-depth study. This paper reviews various solar absorber coatings and thermal stability test methods, evaluates the temperature induced ageing mechanisms, and discusses several commercial applications and challenges in protect the solar absorber coatings. The purpose of this review is to discuss the thermal stability and underlying ageing process of some popular coatings, and the scope for performance improvement. In addition, this paper addresses the new concept of graphene solar absorber coatings.

Contents

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1. Introduction

In recent years, Due to energy crisis, solar energy, as an inexhaustible and clean energy, is widely utilized in the world. One of the most popular utilization is to convert solar energy into heat. This is because solar energy is a type of clean energy, during the process of utilization, it does not produce waste water, waste gas and even without any noise, more importantly, it will not disturb the ecological balance. Another reason is that the earth receives abundant solar radiation. The global solar resource distribution is shown in Fig. 1. At present, the Germany, United States, Spain, Italy, Japan and so forth are at the forefront of solar thermal utilization. This may be attributed to that they have advanced science and technology and a large energy demands as well as an abundant solar energy resource.

In1950s, Israel physicist Tabor [1] came up with the concept of solar selective absorbing coatings. This is a significant breakthrough of solar thermal utilization for it opened a new era of high performance of solar absorber coatings. In recent years, a great efforts have been doing to develop and prepare novel, efficient and excellent weather resistance coatings by researchers all over world. Now it is a completed science branching of solar thermal utilization from theoretical foundation to applications.

Concentrating solar power plants (CSP) are widely used in high temperature solar thermal conversion [2]. One of the advantages of the CSP plants is that they can store thermal energy for later electricity generation. That is to say, after several hours' full-capacity operation, CSP plants can continue to generate electricity when clouds block the solar radiation even at night [3]. Among these solar thermal conversion systems, solar energy is transferred into heated working fluids to drive turbines. The heated working fluids can also be used as domestic hot water for bath, heaters and so on [4,5]. The schematic diagram of solar thermal utilization is shown in Fig. 2.

CSP power plants experience fast development over the past decades. The first commercialized 11 MW CSP power plant was installed in Spain, which was designed to generate 23 GW h of electricity per year. By 2005, the global solar thermal utilization total installed power amounted to 120 GW, and 600 TW h electricity was generated [4]. As for solar water heating (SWH) systems, the global usage amount grew from 160 GW (2010) to 185 GW (2011) [11,12]. Ivanpah solar power plant, presented in Fig. 3, is the world largest solar power station located at the junction of California and Nevada in the Mojave Desert. This solar plant covers an area of about 14.2

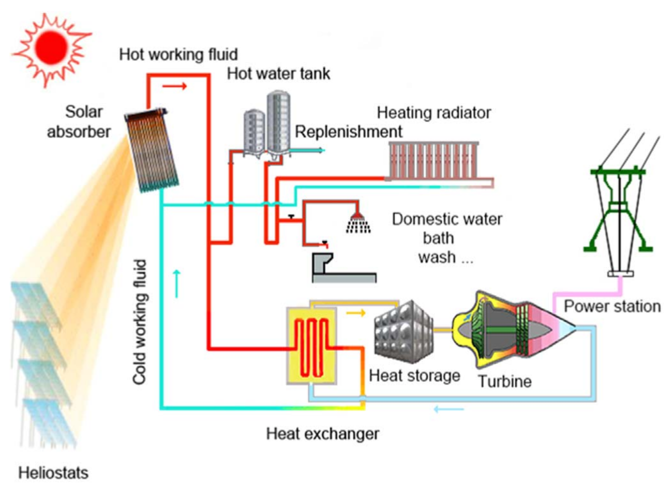

Fig. 2. Abridged general view of solar thermal utilization (summarized from [5,7–11]).

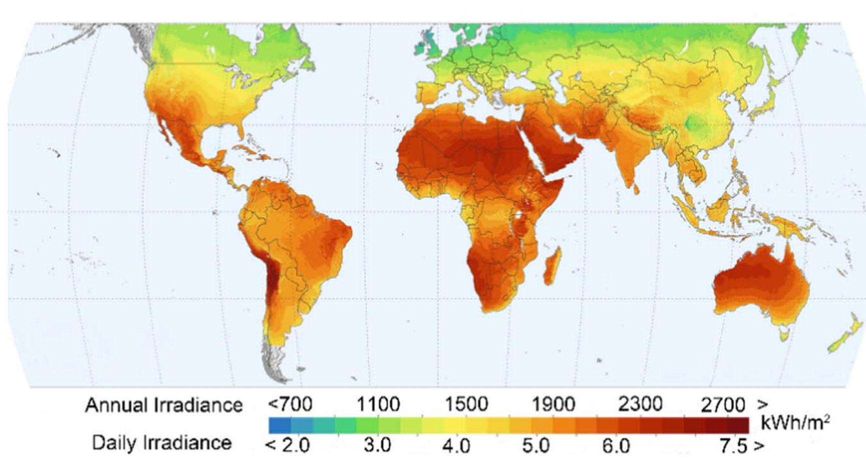

Fig. 1. The horizontal distribution of global solar irradiation (Modified based on Ref. [6]).