International Journal of Environmental Sustainability and Green Technologies
Volume 12 • Issue 1 • January-June 2021

Copper Black Coatings for the Absorption of Solar Concentration With an APPJ SiO2 Super-Hydrophobic Protection:
Selective Copper Black Coatings for Solar Power

Jose de Jesus Perez Bueno, CIDETEQ S.C., Mexico
https://orcid.org/0000-0002-7775-405X

Esmeralda Reséndiz Rojas, Universidad Tecnológica de San Juan del Río, Mexico

Jorge Morales Hernandez, CIDETEQ S.C., Mexico
https://orcid.org/0000-0002-8892-128X

Maria Luisa Mendoza López, Instituto Tecnológico de Querétaro, Tecnológico Nacional de México, Mexico

Rufino Alberto Chávez Esquivel, Universidad Tecnológica de San Juan del Río, Mexico

ABSTRACT

Solar thermal energy can be captured on absorbent surfaces, but coatings tend to deteriorate, due to changes in hue, thermal shocks, or detachment of all layers. There is a great challenge in reducing the deterioration because of environmental factors such as corrosion, impact, and dust control, among others. The absorbent coatings interact with the incident solar radiation transforming it as heat energy, and selectivity allows a low emissivity. In this work, a three-layer system on copper is proposed. An anodized CuO or black copper layer as an absorbent with high absorptance is proposed. A protective layer was added to extend the lifetime of use while preserving the functional characteristics of the absorbent black layer by using SiO2 deposited by atmospheric pressure plasma jet (APPJ) using hexamethyldisiloxane. A selective layer of aluminum was deposited by physical vapor deposition (PVD). Thermal shocks were applied by concentrated solar power with a Fresnel lens to represent sudden temperature changes in the radiation absorbent when the weather changes.

KEYWORDS

Aluminum, Anodization, Black Copper, Central Tower, Concentrated Solar Power, CuO, Parabolic Trough, PVD, Selective Layer

INTRODUCTION

For many years, our consumer society globalization has contributed to intensifying, has demanded products in quantity, quality, and variety, accelerating both a state of dissatisfaction, health concerns, and environmental pollution with no thought given to improving living conditions. There has been

DOI: 10.4018/IJESGT.20210101.oa1

a formidable industrial development, which has been growing in installed facilities for the synthesis and manufacture of products that meet various needs. Today, new processes and new products are in the markets to satisfy new needs developed every day, which will test the creativity, innovation, science, and technology, but going to endanger ecosystems, human health, and doubtless going to stress every single person now and in each generation to come.

Given this perspective, in 1997 the governments agreed on the Kyoto Protocol to the UN Framework Convention on Climate Change (UNFCCC), which sets legally binding targets so that, during the 2008-2012 period, industrialized countries reduce 5.2%, on the 1990 levels, the emissions of the main greenhouse gases. There are alternative energy sources, such as sun, wind, wastes, etc., which are renewable every year, do not run out, and also do not pollute the environment, which means a double advantage.

Solar energy is very attractive because it is clean, renewable, affordable, and with lower impact on the environment (Liu, 2016; Carrillo, 2019). The reduction of gases is an advantage of using solar energy. Solar thermal collectors are environmentally friendly and do not pollute as a way to collect energy. The efficiencies of solar thermal collectors have been improved and its absorbent systems or coatings increased the operating and inactivation temperatures (Bagmanci, 2019; Wu, 2019).

Further development of collectors and new applications of solar energy, such as refrigeration and industrial solar heating, are raising the operating temperatures of absorbent materials even further. Since the first collectors, absorbing solar coatings actively have been developing, using advanced designs with improved efficiencies (Bagmanci, 2019).

The degradation processes in solar absorbers are caused by high temperatures, high humidity, water condensation, chlorine, and sulfide. In the case of moisture, corrosion mechanisms have been reported in absorbent coatings on aluminum substrates (Kotilainen, 2014).

The selective coatings are used on black absorbent surfaces to reduce radiative energy losses (Lizama-Tzec, 2019; Thappa, 2020). Such selective coatings require to have a low emittance ε (<0.2) of infrared wavelengths that, combined with the black surfaces that have high solar absorbance α (> 0.9) together, reach higher solar energy harvesting efficiencies. Super absorbent black coatings help us to have better absorption and concentration of solar energy for the different areas where it is intended to be used. The parabolic trough collectors are systems that require selective black absorbing surfaces that receive and transfer the energy (Tzivanidis, 2015).

BACKGROUND

A solar absorbent surface fulfills with requirements such as a high solar absorptance (α) and low thermal emittance (ε) to absorb the highest and re-radiate the lower amount of energy from the sun, respectively. Frequently, for materials such as metals, a high thermal emittance is directly related to high electrical conductivity, such as metals or graphene, but this characteristic is not necessary for this application.

Prasanth *et al.* (2019) reported CuO thin films deposited by Reactive Direct Current Magnetron Sputtering of a Cu target. Their optimized films were CuO with α and ε of 0.955 and 0.52, respectively. An additional useful finding was that the emissivity was increased to 0.78 after sandblasting of the substrate, which implies that a high roughness is related to both a higher diffuse reflectance and higher emittance that is undesirable. This is related to an increment in the area and an uneven reflection.

The short lifetime of absorbent surfaces is one of the difficulties in capturing solar energy for various applications. The deterioration of the multi-layer absorbent surfaces is observed as changes in hue or detachment of one or all layers. Among the causes of this and other difficulties are the environmental ones, such as corrosion, hail and rain impacts, dust, stress-strain caused by wind, etc. Another factor is the temperature since concentrated solar power (CSP) implies for parabolic trough about 250 °C and central tower above 500 °C. This causes thermal shock failures since, even