ABSORBER COATINGS FOR PARABOLIC TROUGH COLLECTORS A REVIEW

Soteris A. Kalogirou, Pantelis C. Kelires

Department of Mechanical Engineering and Materials Sciences and Engineering, Cyprus University of Technology, P.O. Box 50329, Limassol 3603, Cyprus, Emails: soteris.kalogirou@cut.ac.cy, pantelis.kelires@cut.ac.cy

Abstract

Parabolic trough collectors are a special kind of concentrators that can be used for low to medium temperature applications, like water heating to steam for power generation. The greatest advantage of this and other type of concentrators is that the absorber/receiver area is much smaller than the collector aperture. This creates opportunities to develop and apply novel, high-technology coatings in order to improve the optical characteristics. The most important of such characteristics are the absorptance and the emittance. The former must be as close to unity and the latter as close to zero, as possible. In this way the overall performance of the system can be maximized, thus expanding the areas of applicability. Current materials used for selective absorbers are either very expensive or they loose their properties when stagnation conditions exists. These conditions are obtained when the flow in the collector is interrupted and the collector remains at the focus position. By doing so, very high temperatures on the order of 600-800°C can be developed depending on the magnitude of the available radiation and the collector geometric concentration ratio.

Generally, to maximize the energy collection, the absorber of a collector should have a coating that has high absorptance for solar radiation (short wavelength) and a low emittance for re-radiation (long wavelength). Such a surface is referred as selective surface. The absorptance of the collector surface for shortwave solar radiation depends on the nature and colour of the coating and on the incident angle.

By suitable electrolytic or chemical treatments, surfaces can be produced with high values of solar radiation absorptance (α) and low values of longwave emittance (ε). The parameter representing the quality of coating is called *selectivity* defined as the absorptance/emittance ratio (α/ε). Essentially, typical selective surfaces consist of a thin upper layer, which is highly absorbent to shortwave solar radiation but relatively transparent to longwave thermal radiation, deposited on a surface that has a high reflectance and a low emittance for longwave radiation. Selective surfaces are particularly important when the collector surface temperature is much higher than the ambient air temperature. The cheapest absorber coating is matt black paint however, this is not selective and the performance of a collector produced in this way is low especially for operating temperatures more than 40°C above ambient.

An energy efficient solar collector should absorb incident solar radiation, convert it to thermal energy and deliver the thermal energy to a heat transfer medium with minimum losses at each step. It is possible to use several different design principles and physical mechanisms in order to create a selective solar absorbing surface. Selective absorber surface coatings generally fall into six distinct categories (Kennedy, 2002) as shown schematically in *Figure 1*:

a) Intrinsic or mass absorbers. These absorbers use a material having intrinsic properties that result in the desired spectral selectivity.
b) Semiconductor-metal tandems. Semiconductor-metal tandems absorb short wavelength radiation because of the semiconductor bandgap and have low thermal emittance as a result of the metal layer.
c) Multilayer absorbers, which use multiple reflections between layers to absorb light.
d) Metal-dielectric composite coatings. Metal-dielectric composites—called cermets—consist of fine metal particles in a dielectric or ceramic host material.
e) Surface texturing. Textured surfaces can produce high solar absorptance by multiple reflections among needle-like, dendritic, or porous microstructure.
f) Selectively solar-transmitting coatings on a blackbody-like absorber. These are typically used in low-temperature applications.

These constructions are explained in some detail in this paper.

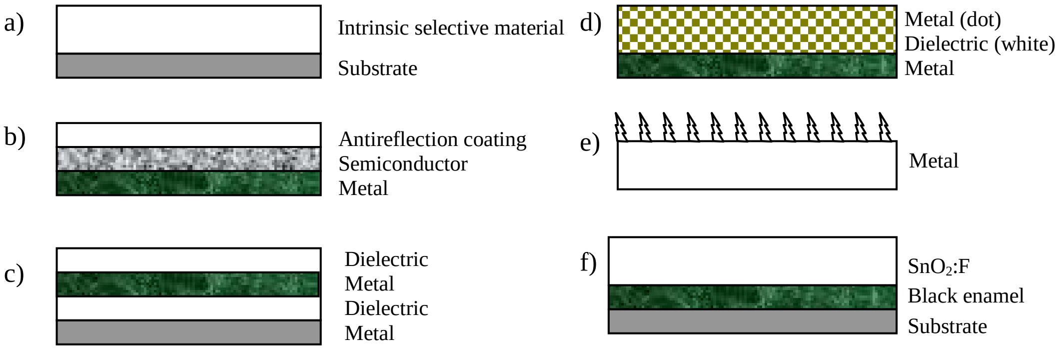

Figure 1 *- Schematic diagrams of the various types of selective coatings and surface treatments*

Today, commercial solar absorbers are made by electroplating, anodization, evaporation, sputtering and by applying solar selective paint coatings. From the many types of selective coatings developed the most widely used is the black chrome. Much of the progress during recent years has been based on the implementation of vacuum techniques for the production of fin type absorbers used in flat plate collectors which are suitable for low temperature applications. The chemical and electrochemical processes used for their commercialization were readily taken over from the metal finishing industry. The requirements of solar absorbers used in high temperature applications however, namely extremely low thermal emittance and high temperature stability, were difficult to fulfill with conventional wet processes. Therefore, large-scale sputter deposition was developed in the late 70's. The vacuum techniques are nowadays mature, characterized by low cost and have the advantage of being less environmentally polluting than the wet processes (Wackelgard, *et al.*, 2001).

Due to lack of suitable selective coatings parabolic trough collectors usually operate at temperatures of about 400°C. As part of a research project undertaken by the authors, advanced absorber coatings will be developed. These should ideally posses the required properties of high absorptance and low emittance at a temperature of about 500°C. Possible candidate materials to be used for this purpose are Diamond Like Carbon (DLC) materials, which are known for their good optical properties, characterized by strong absorption in the UVA-UVB spectral region (Kassavetis, *et al.*, 2007). An attractive feature of DLC, either in its hydrogenated or in the non-hydrogenated form [known as tetrahedral amorphous carbon (ta-C) with a high fraction of sp^3 hybrid bonding] is one that can tailor its optoelectronic properties by varying the sp^2/sp^3 fraction and the hydrogen content. Therefore, one can vary the optical gap of the material (Mathioudakis *et al.*, 2007) to tune it with the desired photon frequency for optimum absorption. DLC is also known for its high temperature stability (Kelires, 1992; 1994), which in combination with its good absorbing properties, makes it ideal for the proposed type of coating.

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