Thin Solid Films xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Thin Solid Films

journal homepage: www.elsevier.com/locate/tsf

Development and degradation behavior of protective multilayer coatings for aluminum reflectors for solar thermal applications

S.K. Mishra [a,*], Vikash Kumar [a,1], S.K. Tiwari [a], T. Mishra [a], Gopal Angula [b], Saikat Adhikari [b]

[a] CSIR-National Metallurgical Laboratory, Jamshedpur 831007, India
[b] Aditya Birla Science and Technology Company Pvt. Ltd., Mumbai, India

ARTICLE INFO

Article history:
Received 20 June 2016
Received in revised form 25 October 2016
Accepted 31 October 2016
Available online xxxx

Keywords:
Solar thermal applications
Aluminum reflectors
Multilayer coating

ABSTRACT

The fabrication of multilayers Al-SiO_2, Al-SiO_2-TiO_2, Al-Ni-Ag-SiO_2, Al-Ni-Ag-SiO_2-TiO_2 on anodized aluminum sheet by the combination of physical vapor deposition sputtering and sol-gel coating process has been done. The multilayers of very high reflectivity (95% or more) could be developed on Al. The Al mirror reflectivity has been enhanced to 95% by a thin coating of Ag on aluminum in between the substrate and transparent and protective layers of SiO_2 and SiO_2-TiO_2 The degradation behavior of these multilayers in accelerated weathering condition and under salt spray with different hours of exposure vis a vis reflectance is investigated. These coatings showed higher reflectance and sustenance in accelerated weathering and salt spray environment making it potential multilayered coating for solar thermal applications.

1. Introduction

Solar concentration utilizes devices that range from simple designs, such as flat solar collectors surrounded by mirrors, to solar concentrators that employ a parabolic trough, a parabolic dish or a central tower surrounded by heliostats to achieve temperatures of a few hundred to several thousand degrees Celsius. All of these design use flat or curved mirrors and several decades' worth of development have resulted in improved specular reflectance, life, and cost. First generation surface mirror used reflective material deposited on a glass and plastic substrate and coated with a protective, transparent film to eliminate abrasion and corrosion [1–2]. In second-generation surface mirror, silver or aluminum was deposited on the back of the transparent glass substrate [3–8]. The glass substrates normally incur more losses due to difficulties of handling large being heavy glass reflectors and their formability in different shapes. On the other hand, polymers have much lesser life due to temperature and weathering effects [9,10]. Hence, currently the efforts at large levels are to use aluminum sheets as base substrate, which makes handling and formation much easier and its life is more compared to glass and polymer substrates. However, the aluminum surface degrades rapidly due to weathering causing substantial decrease in the reflectance, thus, making it unsuitable for solar thermal applications [11,12]. Hence, efforts have been globally made to use suitable thin adherent reflective coatings to enhance its specular reflectance in combination with a transparent protective coating, which can resist its degradation without sacrificing the specular reflectance [13–17]. Some studies have shown very potential coating substrate combinations for solar thermal reflector for power generation and other related industries [18,19]. Aluminum reflectors generally provide an initial reflection (of solar radiation) of 85–91%, exhibit good mechanical properties and are easy to recycle. However, exposure to atmosphere causes serious degradation of the optical properties. Nonetheless, high purity aluminum must be used in order for the mirror to produce good reflectance, which makes the process costly. Few reports have been reported on SiO_2 sol-gel thin film coatings, where dip coatings have been applied to protect front surface of silver and aluminum mirrors. [20,21,22]. It is reported that adherence of silver on aluminum is not good and hence require bond interface layer. Silica-titania based sol-gel antireflective coating is well studied on glass surface [22–23]. However, coating on aluminum mirror surface is limited.

The present study demonstrates the processing of multilayers synthesis on anodized aluminum sheet to achieve higher reflectance and sustenance in accelerated weathering and salt spray environment. The Al mirror reflectivity has been enhanced to 95% by a thin coating of Ag on aluminum in between the substrate and transparent and protective

* Corresponding author.
E-mail addresses: skm_smp@yahoo.co.in, suman.nml@gmail.com (S.K. Mishra).
[1] Currently at: Central University Jharkahand, Ranchi, India.

http://dx.doi.org/10.1016/j.tsf.2016.10.067

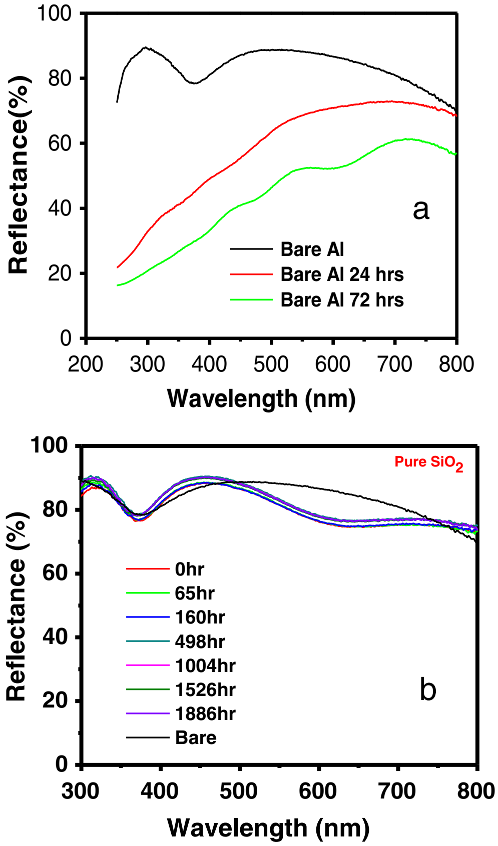

Fig. 1. Reflectance after different exposure times in weathering chamber a) uncoated Al sheets; b) Al-SiO_2.

layers of SiO_2 and SiO_2-TiO_2. Such coatings will be very useful for different solar thermal applications.

2. Experimental

2.1. Ni and Ag deposition by magnetron sputtering

Multilayer of Ni/Ag was deposited onto a clean anodized aluminum substrate of dimension 5 cm × 3 cm × 0.025 mm sheet using DC Magnetron Sputtering. Ni (99.9% pure) and Ag (99.9% pure) targets of thickness 50 mm diameter and 3 mm thickness were used. The deposition chamber was evacuated to the base pressure of 1×10^{-5} mbar prior to deposition. The depositions were carried out at 1×10^{-2}–2×10^{-2} mbar pressure at room temperature in argon plasma. The rate of deposition was controlled by varying the current and time of deposition. Different thicknesses of Ni and Ag in the multilayer in the range 15–500 nm were deposited for optimization.

2.2. SiO_2 and SiO_2-TiO_2 layer deposition

Sol gel coating of Silica and silica- titania was coated on anodised aluminum sheets and silver coated aluminum sheets. Silica sol was prepared from tetraethyl orthosilicate (TEOS) hydrolyzed in ethanol water mixture. After coating, the plates were heated at 150 °C for 30 min. For silica-titania coating, required amount of titanium isobutoxide was mixed with TEOS and hydrolyzed in ethanol water mixture. Nitric acid is used to catalyze the hydrolysis. The coating was performed by dip coating technique. Titania amount was varied from 1 to 10 wt%. The coating thicknesses were between 180 and 200 nm in all the case for both SiO_2 and SiO_2- (0–10 wt% TiO_2) coating.

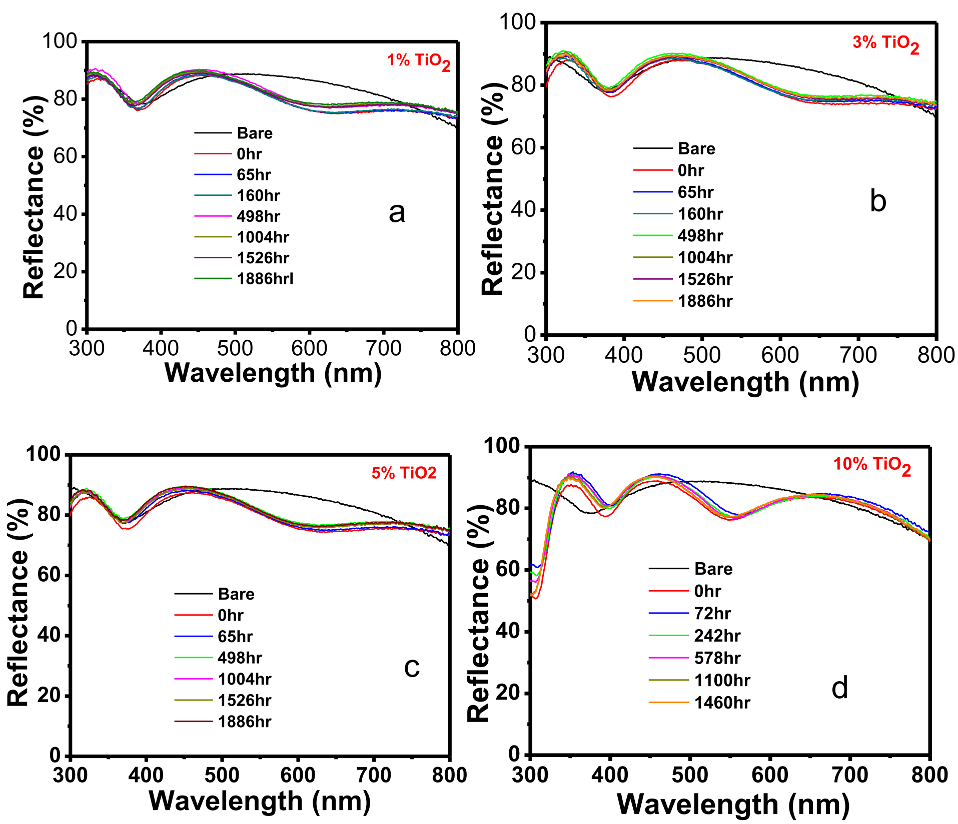

Fig. 2. Reflectance of SiO_2–TiO_2 coated Al sheet for different exposure durations in weathering chamber for different wt% percentages of TiO_2 a) 1 wt%, b) 3 wt%, c) 5 wt%, d) 10 wt%.

Please cite this article as: S.K. Mishra, et al., Development and degradation behavior of protective multilayer coatings for aluminum reflectors for solar thermal applications, Thin Solid Films (2016), http://dx.doi.org/10.1016/j.tsf.2016.10.067