Magnetron sputtering in rigid optical solar reflectors production

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Abstract. Magnetron sputtering was applied to meet the growing need for glass optical solar reflectors. This plasma method provided more uniform deposition of the silver based coating on glass substrates resulted in decrease of defective reflectors fraction down to 5 %. For instance, such parameter of resistive evaporation was of 30 %. Silver film adhesion to glass substrate was enhanced with indium tin oxide sublayer. Sunlight absorption coefficient of these rigid reflectors was 0.081–0.083.

Optical solar reflector (OSR) is an important part of thermal control system of satellites. This element consists at least of thin glass substrate which back side is covered with silver based multilayer coating [1]. Glass substrate has low coefficient of sunlight absorption (A_s) and so it does not heat under influence of solar radiation. The substrate thickness is usually of 0.1 mm. It is enough for protection of reflective coating and provision of lightweight of the substrate.

Reflective coating includes a few layers: silver film with thickness of 110–130 nm, protective layer (20–30 nm) and adhesive layer (10–20 nm). The first one usually is deposited directly on the substrate. Protective Ni80Cr20 layer prevents damages of reflective film during storage of the element or it mounting on a satellite. Adhesive silicon oxide layer is used when the reflector is fixed on spacecraft surface by means of conductive silicate glue.

The growing need for glass OSRs demanded to raise productivity of reflective coating deposition process as well. Resistive evaporation in vacuum provides high reflection coefficient of silver layer. In terms of this method, productivity growth could be reached by mounting the greater number of evaporators in working chamber in order to process more quantity of glass substrates within the coating deposition cycle. But in this case the uniformity of deposited layers thickness goes down and it causes rising of defective reflectors fraction. The reduction of this negative effect by adjusting the working mode and relative position of evaporators, using special designed evaporators, etc., is still a quite difficult task.

There are many methods of thin film deposition and among them the magnetron sputtering provides efficient combination of deposition process productivity and coatings quality, especially when flat large substrates need to be covered with a thin film. Operating principle and design of magnetron sputtering system (MSS) enable to get thin layers with non-uniformity in thickness less than ±5 % along the length of this plasma source. In case of conductive targets the coating growth rate is a few tenths to several nm/s for oxides and about ten to a few dozen nm/s for metal films. The length of MSS can be relatively easy increased up to 2.5 m without loss of homogeneity in thickness of deposited coating and therefore large flat substrates are treated uniformly [2].

The laboratory plant was used to carry out magnetron sputtering deposition of reflective coating on glass substrates. The plant was equipped with mobile 500×500 mm^2 substrate holder which was able to move back-and-forth under fixed 700×100 mm^2 rectangular magnetron sputtering system. Distance between its target and holder surface was 100 mm. Power supply of magnetron sputtering system was provided by MF (130 kHz) DC unit.

There were some doubts about reflection coefficient of the silver layer formed by magnetron sputtering, but result of experiments showed $A_s = 0.08$ for the OSR with such layer. This value met to requirements and it was little bit more then in case of resistive evaporation ($A_s = 0.07$).

It was decided to apply the ion beam (3 kV, 0.05 A, Ar^+) for the surface treatment before silver layer deposition. This process took 0.5–1 h and it was enough to enable the layer passed the type test. The ion beam was generated by closed-drift ion source [3] which length was the same as that of the magnetron sputtering system.

Magnetron sputtering deposition of reflective layer on 100 glass plates (40×40 mm^2) placed on substrate holder showed that defective OSRs fraction decreased down to 5 %. For instance, such parameter of resistive evaporation was of 30 %. This fraction was estimated on the base of information about uniformity of A_s and coating thickness all over the surface of samples chosen from different positions on holder. The investigation of A_s was carried out by photometer FM-56. Thickness was measured by microscope-interferometer MII-4.

Results of the experimental work became one of the main reasons to design the vacuum plasma plant for rigid OSR making [4]. The plant was equipped with one ion source and four magnetron sputtering systems. Three of them were purposed to deposit reflective coating and one had indium(95 %)-tin(5 %) alloy target for obtaining indium tin oxide (ITO) layer on face side of the OSR. This transparent conductive oxide layer prevents OSR front surface charging [1].

During the technological testing of the plant there was an adhesion problem. After deposition it was found that the reflective coating held on substrate very good, but within a few days its adhesion became low and so the coating was not able to pass the type test. This difficulty most likely was caused by internal tension of silver layer. Some measures such as variations of working regime of the magnetron sputtering system with silver target, application of Ni80Cr20 film as an adhesive sublayer, etc., were taken but they were unsuccessful. In the latter case, A_s grew above upper limit of 0.086 as well, even when this film was deposited with minimal discharge power.

Under the circumstances only one solution of the problem was ITO adhesive sublayer (figure 1). Thickness of this film was chosen as thin as possible to provide lowest influence on A_s and required adhesion. In this way reflective coating adhesion was improved and stabilized while A_s of the OSRs was 0.081–0.083. The plant testing was successfully completed and it was accepted to produce rigid OSRs for satellites.

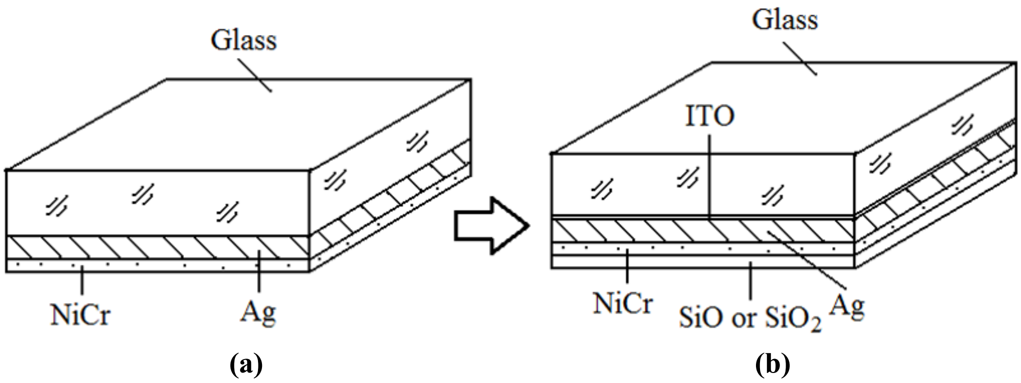

Figure 1. Evolution of the rigid OSR structure: (a) – basic composition; (b) – design with adhesive ITO sublayer and SiO or SiO_2 film.

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Thus, plasma magnetron sputtering enabled to get silver based reflective coating with good quality and uniformity of thickness on greater number of glass substrates. This resulted in significant decreasing of defective OSRs fraction and productivity of thin film deposition process growing. But technology on the base of the plasma method has to be developed taking into account its advantages and drawbacks, for instance internal tension of silver layers obtained by magnetron sputtering.

References

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