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Original research article

Experimental analysis for electromagnetic scattering characteristics of aluminum-doped zinc oxide (AZO) coated glass

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ABSTRACT

Aluminum-doped zinc oxide (AZO) coated glasses with different sheet resistances were made by unbalanced magnetron sputtering technology. Radar cross section (RCS) of the glasses and the reference metal plate were measured in microwave anechoic chamber in horizontal–horizontal (HH) and vertical–vertical (VV) polarization and 10 GHz and 15 GHz incident wave. The relative reflectivity was proposed to analyze electromagnetic scattering of AZO coated glass. Based on RCS test results, the relationship of relative reflectivity, sheet resistance and optical transmittance was studied. It is shown that proper choice of sheet resistance of AZO coated glass can satisfy both optical admittance and relative reflectivity performance. The optical admittance can be greater than 77% while relative reflectivity is greater than 30%.

1. Introduction

The shape stealth is an important method to improve aircraft stealth performance. Conventional aircraft cockpit is strong cavity scattering source. One of the effective ways to reduce backscattering of cavity is to change the cavity scattering into surface scattering. This can alternate scattering direction and weaken electromagnetic waves by coating canopy with transparent conductive (TC) film and cockpit shape design in practice. There some method to study the electromagnetic scattering the cavity scattering, such as physical optics (PO) and shooting and bouncing ray (SBR) [1,2]. The comparison of electromagnetic scattering for cockpit without and with TC film is shown in Fig. 1.

Fig. 1a shows the case that canopy was coated without TC film. The relative strong cavity scattering which returns to radar in same way would be formed after the electromagnetic waves propagates to the cockpit, which can result in high scattering. However, for canopy with TC film in Fig. 1b, the scattering direction of electromagnetic wave can be changed by the canopy's shape, thereby weaken the electromagnetic energy scattered to radar. Therefore, the canopy with TC film can effectively shield the cockpit and change the incident direction of electromagnetic waves, which benefits the implementation of shape stealth and greatly reduce cavity scattering.

The TC film for the cockpit may contain one or more layers of metal film and transparent conductive oxide (TCO) such as such as indium tin oxides (ITO) and aluminum-doped zinc oxide (AZO) [3]. Compared with metal film, TCO has a good optical transmittance [4,5]. The conductive mechanism of TCO can be holes or free electrons, which categorize TCO into P-type and

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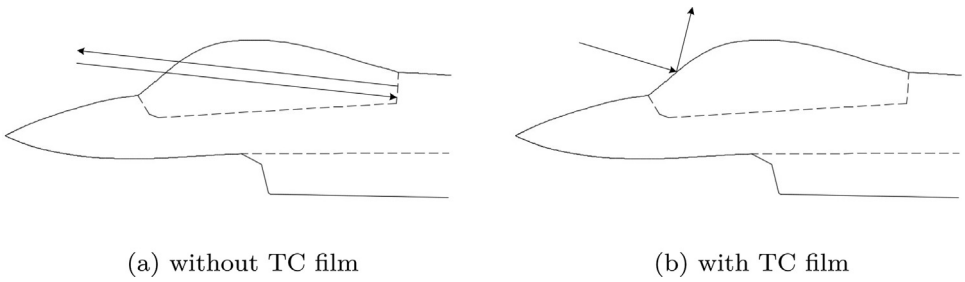

Fig. 1. Comparison sketches of electromagnetic scattering for canopy without and with TC film.

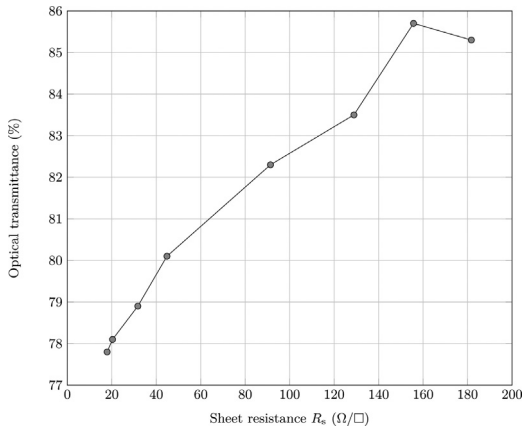

Fig. 2. Optical transmittance as function of sheet resistance.

N-type doping, respectively. ITO and AZO are both N-type doping, which electrons make the material conductive. This paper studies electromagnetic scattering characteristics of AZO films and its dependence with sheet resistance. The normalized radar cross section (RCS) was proposed to assess the scattering characteristics of AZO films.

There are some accuracy numerical algorithm to calculate the scattering of the target, such as method of moments (MoM) [6]. However, these method have limited ability to calculate the scattering of thin film like AZO films. Thus, experiment method was used to obtain the scattering of AZO films. The RCSs of coated glasses of different sheet resistances were measured in horizontal–horizontal (HH) and vertical–vertical (VV) polarizations at frequencies of 10 GHz and 15 GHz. For HH polarization, the incident wave is horizontal polarized and receiving antenna collect the horizontal component of backscattering wave. While for VV polarization, the incident wave is vertical polarized and receiving antenna collect the vertical component of backscattering wave. The RCS plots and the influence of sheet resistance on the electromagnetic scattering were analyzed. The research shows that as sheet resistance increases, normalized RCS decreases. For a compromise in engineering application, with a proper choice of sheet resistance of 31.7 Ω/□, both relative reflectivity and optical transmittance can get satisfying performance. At this sheet resistance choice, relative reflectivity is greater than 30% and optical transmittance is greater than 77%.

2. Experimental

2.1. AZO coated glass

The AZO film was deposited on non-tin surface of float glass with thickness of 4 mm by room temperature coating technique with unbalanced magnetron sputtering equipment [7,8]. It was then deposited through a series of process such as pure water cleaning, plasma cleaning, room temperature coating.

A metal plate and eight AZO coated glasses of 10 cm × 10 cm were utilized for experiments. The values of sheet resistance R_S and optical transmittance T of AZO coated glasses are shown in Fig. 2, which shows that the optical transmittance increases as sheet resistance increases. The SEM micrograph of AZO film with R_S = 31.7 Ω/□ is shown in Fig. 3, which illustrates the deposited film is amorphous at room temperature.