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Characterization of Reflective Coating Material to Enhance the Photon Propulsion in Solar Sail

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Abstract: In this work, aluminium (Al) thin film was prepared on mylar by wet chemical technique. Scanning electron microscope was used to characterize the surface morphology of the aluminium coated mylar film. The reflectivity of aluminium coated mylar film was calculated using UV-VIS-NIR double beam spectrophotometer. Evidently, the reflectance of aluminium coated mylar film increases comparative to pristine mylar film. This study is the first know characterization for aluminium coated mylar film to achieve the rate of acceleration using theoretical calculation.
Keywords: Solar sail; reflectance; mylar film; aluminium; SEM

I. INTRODUCTION

In current scenario carrying larger amount of fuel for space missions drastically impact on the cost spend and limitation of exploration[1,2]. However, researchers are recently working in various source of renewable energy and technology that can use it. One of the promising source is quantum packets of energy from sun creating radiation pressure on hitting against reflective material[1,3–8]. Photon propulsion is achieved through sail of the spacecraft, which is a metallic reflective coated polymer[1,3–8].

Aluminized Mylar had been in use since COSMOS 1[1]. Selection of mylar for real-time application due to their excellent reflective property accompanied by chemical stability and high tensile strength[1,4]. Photon propulsion can also be achieved through materials such as Kapton that can service at 700°F and above, CP-1 100 times thinner sheet and temperature resistance, Paralene that can work at low temperature, B-100 can result at high temperatures and PEN (Poly Ethylene Naphthalate) as metallic materials[1,3,4,9]. Graphene, Chromium and Aluminium hybrid as Non-metallic materials due to their property of lightweight, atomic layer thickness and exceptional strength[1].

Mylar film are also used for the application of retardation plate in display[10], Electron –Beam Mylar for charge distribution[11], Mylar films for high field conduction[12], Rectenna fore plane produced with thin Mylar film[13], Mylar for the use of microwave application and also serviced as electrical and thermal insulator[14]. Through coating Mylar film, the optical properties result with effective change accompanied with increase in aging of material[1]. Using reflective coating such as Aluminium, Silver and Chromium the reflectivity of sail is said to be increased along positive thermal withstand ability[1,3,4].

In recent years Aluminium is applied as high electrical conductors[15] and Alloy material component such as for aircraft and spacecraft's[16], prevailing by its high strength to weight ratio, corrosion resistance and excellent optical properties[17]. Significance of aluminium as coating is their response to full solar spectrum of solar radiation and acceptable to atmospheric effects while coating[3], which results in increased reflectivity, corrosion resistance and lightweight[17].

Although previous results of aluminized Mylar prevail the coating technique selected for fabrication is from the available methods such as electrospraying[18], electrospinning, chemical vapour deposition[19], material reinforcement[20] and plasma spraying[21]. Here structure of Mylar does not accept coatings due to their lack of adsorbing and low interlocking surface morphology and expose as a glossy surface. In order to prevail over this weakness etching followed by drop casting and drying was processed to achieve a thin layer of aluminium coating over Mylar film.

II. EXPERIMENTAL SECTION

The Mylar film (Ganapathi industries, Bangalore, India) was mechanically polished using 2000 grit silicon carbide resin emery paper in all directions and then ultrasonically washed with acetone (Merck, India) for 15 min to remove the contaminated particles on the surfaces. A cleaned Mylar film of 5 cm × 5 cm size was dried at room temperature for few hours. The coatings were prepared as follows: 1g of aluminium Nanopowder (Sigma-Aldrich, India) was added into the 100ml of DI water and stirred at room temperature for 30 min. Later, the prepared solution was dropped-casting on to the Mylar film using 2ml filler. The obtained coated Mylar film were kept at room temperature for 24 hours.

The surface morphology was observed using scanning electron microscope (SEM; Tescan Vega 3). The reflectance of the coating film was studied using UV-VIS-NIR double beam spectrophotometer (VARIAN, Cary 5000 scan).

III. RESULTS AND DISCUSSION

A. Surface morphology studies

SEM images of raw aluminium Nanopowder, pristine mylar film and aluminium coated mylar film are showed in Figure 1. (Figure 1a) clearly shows the aluminium nanostructure grains with an average size of 10μm under low magnification. The surface of the mylar film remarkably smooth over relatively large areas and shows small bumps[22] (Figure 1b). SEM surface morphology of the aluminium coated PET surface has evidenced smooth surface and the nanostructure grains with an average size of 1000 to 2000nm are shown in Figure 1c. Even at high magnification the coating clearly displays the uniform spreading of nanostructure grains over the mylar film[23]. As a result, the even deposition of aluminium nanostructure grains significantly increases the strength and reflective properties of the film.

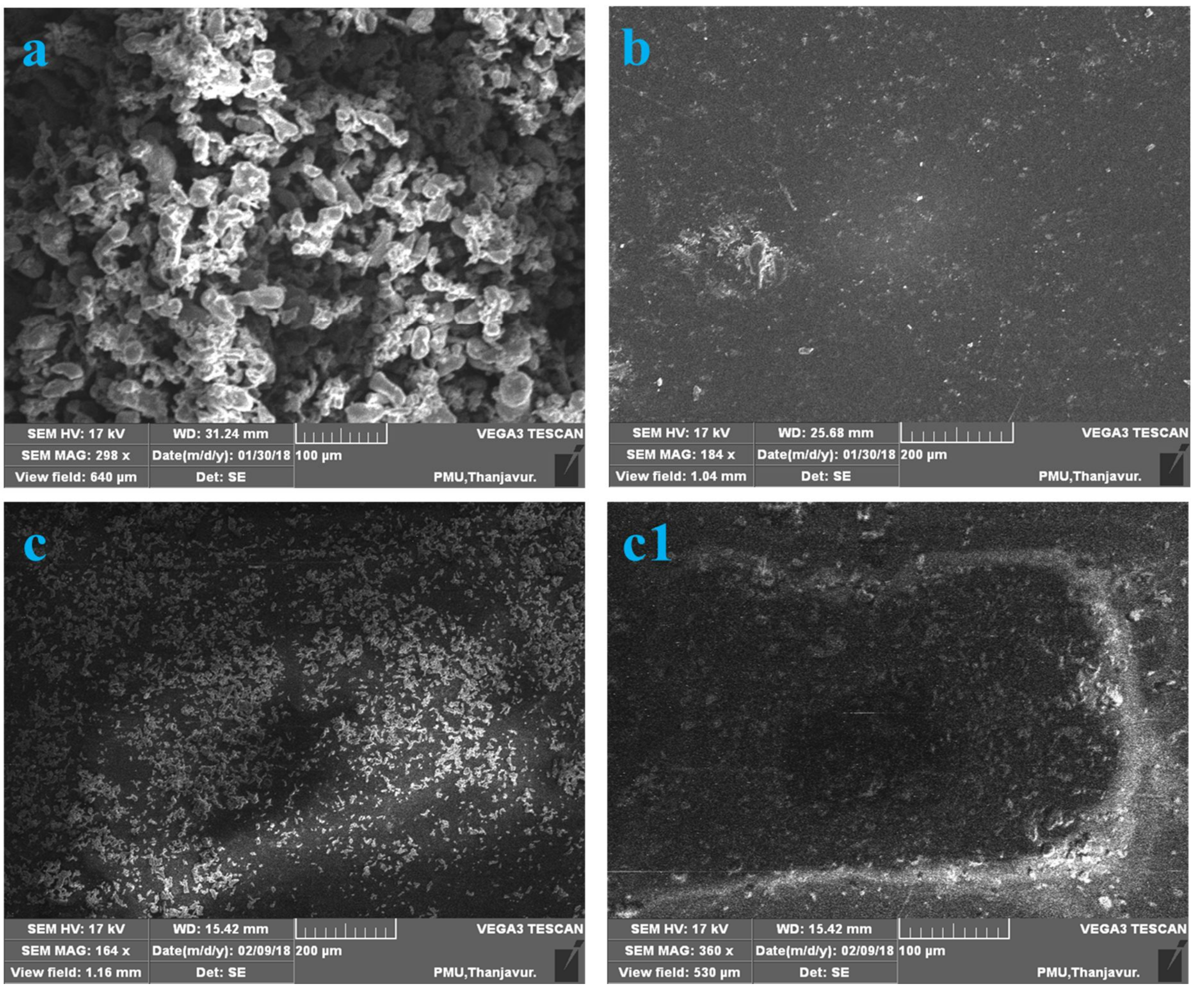

Figure 1. SEM images of (a) raw aluminium Nanopowder, (b) pristine mylar film, and (c) aluminium coated mylar film.

B. UV- Spectrum analysis

The UV-visible reflectance spectrum of pristine mylar film and aluminium coated mylar film are shown in Figure 2. The Mylar film shows reflectance of about 60% in the wavelength range of 310nm. It is clear from the figure that the reflectance at wavelengths above about 400 nm decreases, but that below about 400 nm increases[24]. On the other hand, although reflectance of 60% to 20% is shown in the wavelength region of 400 to 310 nm, and above 310 nm, it drops to 20% to 9%. The reflectance peak drops at 352nm in aluminium coated mylar film. From this result, the reflectance of coated thin film increases rapidly below about 300nm. In other words, as the reflectance of the aluminium coated mylar surface is increased, the pristine mylar film is decreased. It is also conceivable that the variation of surface reflectance is due to an aluminium thin film being formed on the mylar film.

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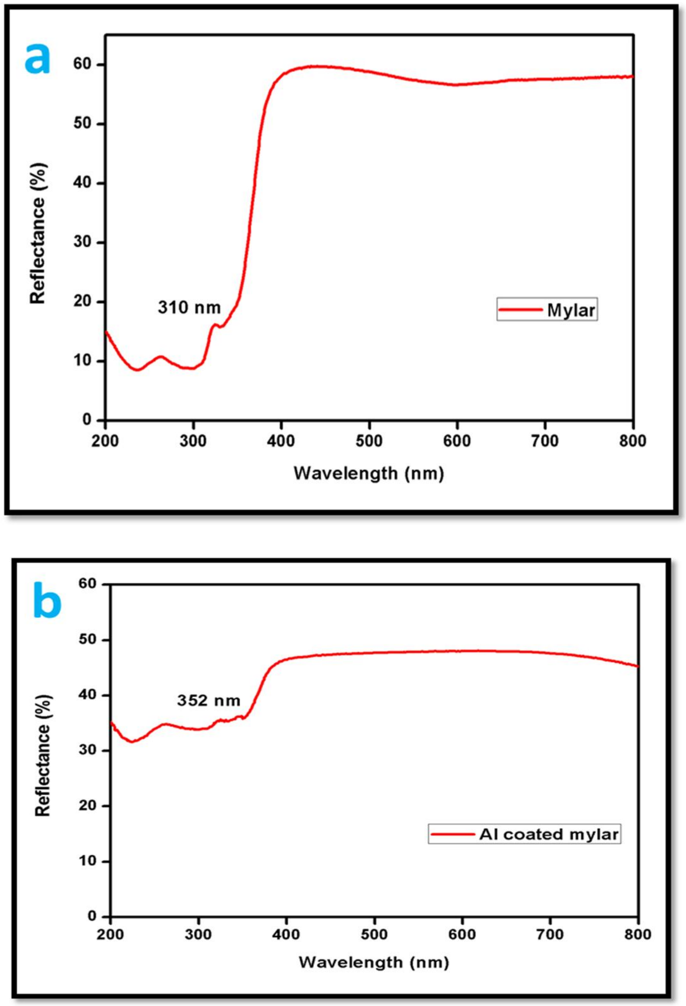

Figure 2. UV images of (a) pristine mylar film, and (b) aluminium coated mylar film.

C. Theoretical Calculations

In order to calculate the acceleration for sail of the space craft's reflectance was characterized using UV spectrum and the following equations can be used.

Pristine mylar film

$$F = \frac{hc}{\lambda} \qquad (1)$$

Where F is the force or momentum transfer to the sail, h is the Planck's constant, c is the speed of light in vacuum, and λ is the wavelength of light.

$$F = \frac{6.626\, x\, 10^{-34}\, x\, 3\, x\, 10^{8}}{310\, x\, 10^{-9}}$$

$$F = 6.412\, x\, 10^{-19}\, m^2\, kg/s$$

$$F = 6.288\, x\, 10^{-12}\, \mu N/m2$$

$$a_c = F\, x\, {}^{£}/_{\sigma} \quad mm/s^2 \qquad (2)$$

Where a_c is the acceleration of the solar sail, £ is the efficiency, and σ is the total mass divided by the sail area.

$$a_c = 6.412\, x\, 10^{-12}\, x\, 0.20/5.27$$

$$a_c = 2.433\, x\, 10^{-13}\, mm/s^2$$

Aluminium coated mylar film

Equation (1) and (2) can be used

$$F = \frac{6.626 \, x \, 10^{-34} \, x \, 3 \, x \, 10^{8}}{352 \, x \, 10^{-9}}$$

$$F = 5.647 \, x \, 10^{-19} \, m^2 \, kg/s$$

$$F = 5.5378 \, x \, 10^{-12} \, \mu N/m2$$

$$a_c = 5.5378 \, x \, 10^{-12} \, x \, 0.36/5.27$$

$$a_c = 3.782 \, x \, 10^{-13} \, mm/s^2$$

IV. CONCLUSION

In this study, Preparation of Al thin films on mylar by wet chemical technique at room temperature had been demonstrated. The surface morphology and structural properties of Al films on mylar substrates were investigated using SEM. The results showed that the structure of Al-coated mylar film has high reflectance when compare with pristine mylar. Finally, Uv-Vis reflectance spectrum results reveal the Al-coated mylar film has high reflective properties.

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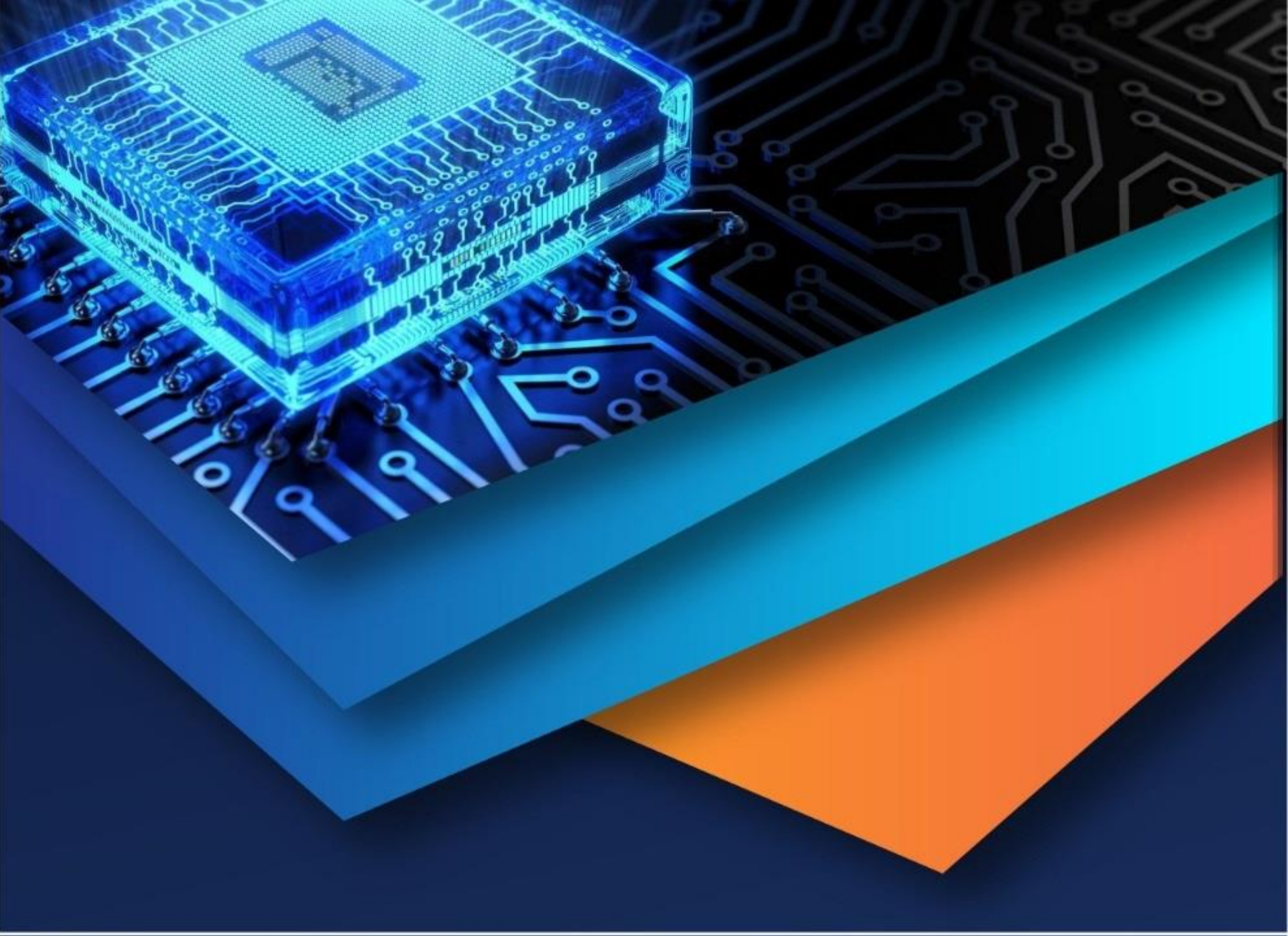

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