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Optical tuning of metallic thin films using microwave generated low energy plasma ion beams

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The various fascinating applications of metallic thin film (MTF) mirrors ranging from nanotechnology to space science have drawn a great deal of attention to the scientific community in recent years. Plasma-based ion beams both in the low and high-energy regime, have been widely used for creating atomically heterogeneous systems in metals, dielectric, and organic compounds, to realize their novel optical, electrical, and surface properties [1]. Metallic thin films have various applications in optical and biosensors, photonic devices, plasmonics, photodetectors, and especially metallic mirrors in spacecraft or satellites [2]. The space environment has long been a subject of interest because of its direct or indirect impact on our earth atmosphere or in missions related to earth exploration.

The spacecraft, satellites, and other space investigating tools such as solar orbiter have been deployed in space to gather information about solar activity or to study the solar environment. These tools encounter the solar wind particles (mainly high-energy protons and alpha particles) and cosmic rays (protons, electrons, and heavy ions). The performance of optical components used in space vehicles is therefore subjected to degradation in the harsh space environment. Hence, prior knowledge about the irradiation effect of helium and hydrogen ions on Al and Ag MTFs could be useful for their possibility of being used in the space environment and for making robust metallic film mirrors that can sustain the exposure. The alpha particles and protons from the solar wind and cosmic rays bombard the metallic thin films used in spacecraft and satellites and can hamper the proper functioning of various components connected to the MTFs. To study the impact of protons and alpha particles bombardment on various optical properties of MTFs, it is important to have a detailed knowledge of the energy range of protons and alpha particles with which they hit the target and their doses (total number of particles during the journey).

The velocity range of alpha particles and protons coming from the solar winds lies typically in the range of 300 km/s to faster than 750 km/s, with average speed of ~ 400 - 468 km/s, and their corresponding kinetic energy typically lies in the range of ~ (0.4 - 7.5) keV for protons and ~ (1.6 - 30) keV for alpha particles [3]. In addition to the above-mentioned energy range, there are solar wind particles, emitted from solar events such as Coronal Mass Ejection (CME) and solar flares, that have energies in the order of hundreds of keV or MeV.

To this regard, we have explored the irradiation effect of various ionic species (Ar, He, and H), obtained using microwave generated plasma in our laboratory, on optical properties of MTFs with varying fluence and energy and prominent results have been found which may help in the selection of best MTF before their launch for space mission.

The effect of low energy (~ 0.5 keV) inert gaseous Ar ion beam irradiation with varying fluence, on optical properties (reflectivity, transmissivity, and absorptivity) on MTFs such as aluminum (Al), copper (Cu), silver (Ag), and gold (Au), has been investigated. The wavelength range covers UV to NIR (250-1200 nm) regions [4]. The optical parameters have also been investigated using Kramers - Kronig technique and Maxwell - Garnett and Bruggeman approximation models, and the obtained results are further experimentally compared with pseudo- Brewster angle technique [5].

Additionally, the following study has also been carried out according to the European space agency program, which was planned to explore the solar system by sending a sun orbiting satellite i.e., solar orbiter (SOLO) to its closest distance (0.28 AU at perihelion) [3]. The metallic coating such as Al and Ag have been in use as heat reflectors to protect satellites and spacecraft from heat radiation from the sun as well as in the form of cosmic radiation. The reflectivity of Ag and Al MTFs upon irradiation of low-energy helium and hydrogen ion beams with varying energy (0.5, 1, 2, and 3 keV) and varying fluences ranging from $(1.1 - 1.56) \times 10^{16}$ cm^{-2} for helium and $(0.36 - 1.46) \times 10^{17}$ cm^{-2} has been measured [6]. The fluence of both He and H ions was chosen according to the four and six years journey of solar mission of a spacecraft in the solar orbit.

In this conference, I will discuss the stability of Al and Ag MTF mirrors under the bombardment of proton and alpha particles. The study of optical properties and optical parameters of MTFs under Ar ion implantation will also be presented.

References

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