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Optical properties and stability of metallic thin films under low energy plasma-based argon and helium ion beam irradiation

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Low energy plasma-based ion beams 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 (MTFs) have various applications in optical and biosensors, photonic devices, plasmonics, photodetectors, and especially metallic mirrors in spacecraft or satellites [2]. MTFs used as metallic mirrors in spacecraft or satellites are continuously exposed to low and high energy particles such as protons and alpha particles from solar wind along with electrons and heavy ions from cosmic radiation [3]. Hence, the degradation in their performance in space environment is a subject of concern and the detailed information about the implantation effect on MTFs is vital for making the space mission successful. Further, the investigation of the effect of low energy ion implantation on optical properties (reflectivity, absorptivity, and transmissivity) and optical parameters (refractive index, dielectric function, skin depth, and optical conductivity) of MTFs has been carried out to understand their optical behavior in plasmonics, space-environment etc.

In order to understand the low energy ion implantation effect on MTFs, we have investigated the effect of low energy (~ 0.5 keV) inert gaseous Ar ion beam irradiation on optical properties (reflectivity, transmissivity, and absorptivity) of various types of MTFs such as aluminum (Al), copper (Cu), silver (Ag), and gold (Au) [4]. The reflectivity and transmissivity of MTFs have been measured by varying the fluence $\{(1.6\text{-}8.3) \times 10^{15}$ $cm^{-2}\}$ of incident low energy argon ion beams in the wavelength range covering UV to NIR (250-1200 nm) region. It has been observed from the experimental results that both the reflectivity and transmissivity of all the MTFs can be tailored by varying the Ar ion fluence for e.g., reflectivity decreases with an increase in argon fluence. While the transmissivity of MTFs is observed to increase with fluence.

In extension of above-mentioned investigation, the following study has been executed 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) [5]. Hence, the effect of bombardment of helium ions on Ag and Al MTFs has been investigated by varying their energy and dose. The reflectivity of Ag and Al MTF upon irradiation of low energy helium ion beams with varying energy (0.5, 1, 2, and 3 keV) and varying fluences ranging from $(1.1\text{-}1.56) \times 10^{16}$ cm^{-2} has been measured. The fluence of helium ions was chosen according to the four (1.1×10^{16} cm^{-2}) and six (1.56×10^{16} cm^{-2}) years journey of solar mission of a spacecraft in the solar orbit [6]. Stability of aluminum (Al) and silver (Ag) metallic thin films (MTFs) has been looked in the laboratory to replicate the effect of alpha particle bombardment on spacecrafts and satellites in space environment. The metallic coating such as Al, Ag, and Au etc have been in use as the heat reflectors to protect the satellites and spacecrafts from heat radiation from the sun as well as in the form of cosmic radiation. Hence, the optical properties (reflectivity and absorptivity) of Al and Ag MTFs have been investigated using Lambda 950 UV-VIS-NIR spectrophotometer prior and post helium ion implantation. The electromagnetic response of these MTFs (Al and Ag) has been investigated in the wide range covering from ultraviolet to far infrared region (200-2500 nm) of electromagnetic spectrum. It has been observed that the reflectivity of both the MTFs does not show the significant impact of implantation in the whole range of investigation and opens the channel of utilization of these MTFs to provide more stable MTFs for the mission.

The implanted foreign ions (Ar and helium ions) get embedded into the host metallic medium and form a heterogeneous medium at atomic length scale. The refractive index and thereafter the optical properties of pristine MTFs are expected to be modified upon irradiation of low energy ion beams. The optical constants of pristine and irradiated MTFs are measured by employing the pseudo-Brewster angle technique using 405, 532, 632.8, and 670 nm lasers. The results are compared and found in accordance with the theoretically obtained results using Maxwell-Garnett and Bruggeman approximations [7] for irradiated samples. Kramers-Kronig (KK) analysis is being used to obtain the optical constants of pristine MTFs in the full range of investigating wavelengths (250-1200 nm).

In the conference, the effect of low energy Ar and helium ion irradiation on optical properties of MTFs, will be presented. The obtained optical constants, skin depth, and optical conductivity of MTFs will be presented after implanting low energy (~0.5 keV) Ar ions.

References

[1] S. Chatterjee et al, EPL **118**, 68006 (2017).
[2] R. Todrov et al., Thin Solid Films, **628**, 22-30 (2017)
[3] J. L. Barth et al., IEEE Trans. Nucl. Science, **50**, 466-482 (2003).
[4] K. P. Singh et al., Applied opt. **59**, 4507-4516 (2020).
[5] A. D. Rousseau et al., Proc. Of SPIE., **5900,** 590004 (2005).
[6] M. Nardello et al., Opt. Express, **21**, 28334-28343 (2013).
[7] A. Sihvola et al., Subsurf. Sens. Technol. Appl., **1**, 393-415 (2000)