A-P6 AAPPS-DPP2020

4th Asia-Pacific Conference on Plasma Physics, 26-31Oct, 2020, Remote e-conference

Low energy plasma based ion beams for tuning optical properties of metallic thin film mirrors

Krishn Pal Singh and Sudeep Bhattacharjee

Department of physics, Indian Institute of Technology Kanpur, Kanpur-208016 (India)

Email (speaker): krishnp@iitk.ac.in

The study of the optical properties of materials has been an interesting area of scientific research because of their vast application in our daily life. Metallic thin films (MTFs) have been widely used in various applications such as optical and biosensors, photonic devices, plasmonics, photodetectors, enhanced transmission in holey metals, and metallic mirrors in spacecraft or satellites [1]. Hence the investigation of optical properties of MTFs become important because of their wide range of applications. A relatively new area of research has been opened for the scientific community to investigate the optical behavior of MTFs under the implantation of ion beams. Ion beams are becoming a useful tool to tailor the properties of MTFs such as electrical, optical and surface [2]. The impact of high energy (~ 30-160 keV) particles like protons, alpha particles and argon ions on various type of MTFs have been reported [3]. However, the effect of low energy ion implantation has not been looked at thoroughly. Hence, exploring the effect of low energy ion implantation will provide new insights into physics in plasmonics as well as space-related investigations and other areas.

To investigate the effect of low energy (~ 0.5 keV) inert gaseous Ar ion beam implantation on optical properties (reflectivity, transmissivity, and absorptivity) of various types of MTFs such as aluminum (Al), copper (Cu), silver (Ag), and gold (Au), a recent experimental study has been carried out in our laboratory [4]. The mentioned optical properties are investigated by varying the fluence of incident low energy argon ion beams in the wavelength range of 250 nm to 1200 nm, and the possibility of tuning the optical properties of MTFs with argon ion fluence has been investigated. It is found that the reflectivity of all the MTFs decreases with an increase in argon fluence. While the transmissivity of MTFs is observed to increase with fluence. The observed peaks in the transmission curve of MTFs can give rise to the potential application of MTFs in the fabrication of narrow band width filters. The observed peaks in transmissivity and dips in reflectivity represent the corresponding interband transitions.

Low energy ions are embedded up to a few nanometers inside the lattice of host metal and make the medium heterogeneous. Hence the optical constants (real and imaginary parts of the refractive index) and thereafter the optical properties of pristine MTFs are expected to be modified upon irradiation of low energy argon ion beams. The optical constants of pristine and irradiated MTFs are measured by employing the pseudo-Brewster angle technique using He-Ne laser (632.8 nm), as shown in Fig. 1(a) [5]. The measured optical constants are found in accordance with the theoretically obtained results using Maxwell-Garnett and Bruggeman approximations [6]. The pseudo-Brewster angle technique is used for a single wavelength i.e., 632.8 nm and the corresponding reflectivity of p-polarized (R_P) light with various incidence angles is shown in Fig. 1(b). Optical constants of MTFs can be calculated using R_P and Brewster angle (θ_B). Kramers-Kroning (KK) analysis is being used to obtain the optical constants in the full range of investigating wavelengths (250-1200 nm) [7]. KK analysis is used to calculate the phase angle between electric fields of incident and reflected beam using the experimentally measured reflectivity of all the MTFs as an input parameter and thereafter the Fresnel equations of two media system for optical constants are used to calculate the real and imaginary parts of the refractive index. The optical constants provide information about the optical nature of the material. The dielectric function, skin depth, and optical conductivity can be calculated using optical constants. The dielectric function tells about the electronic structure of the material, while the skin depth provides the penetration depth of electromagnetic radiation inside the matter.

In the conference I will present the effect of low energy ion implantation on optical constants, skin depth, optical conductivity, and optical properties of MTFs. The effect of implantation will be discussed by varying the low energy argon ion fluence.

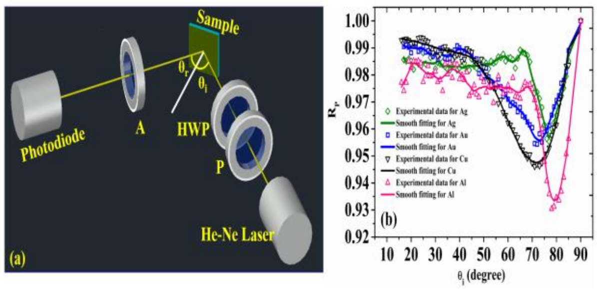

Fig.1 (a) Pseudo-Brewster angle technique, and (b) reflectivity of p-polarized light with incidence angles.

References

[1] I. D. Sarcina et al., Applied opt. **53**,314-320 (2014).
[2] S. Chatterjee et al, EPL **118**, 68006 (2017).
[3] Q. Wei et al., Thin solid films. **519**, 5046-5049 (2011).
[4] K. P. Singh et al., Applied opt. **59**, 4507-4516 (2020).
[5] R. Sengupta et al., IEEE Trans. Instrum. Meas. **68,** 1814-1820 (2018).
[6] A. I. Barreda et al., J. Quant. Spectrosc. Radiat. Transfer. **162**, 190-196 (2015).
[7] O. Bazkir et al., Opt. and Lasers in Eng. **45**, 245-248 (2007)