

Dielectric functions of titanium in the regime of the limited light penetration

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Titanium films with a thickness in the range from about 10 nm to 2.1 μm were deposited using a gas impulse injection magnetron sputtering technique [1,2] on the Bk7 glass plates (1 mm thick).

To determine the complex dielectric function of Ti coatings, the three-phase (or four-phase - for the thinnest layers) optical model was used: ambient / rough layer / Ti layer / (Bk7 glass). To determine optical constants of the rough layer, the three component Effective Medium Approximation (EMA) model was used as a linear combination of optical properties of void, native titanium dioxide and titanium (the assumed volume fraction of each medium was 1/3). The optical response of titanium films was parameterized using the semi-classical Drude-Lorentz model of dielectric function.

The Drude parameters $\hbar\omega_p$ and $\hbar\Gamma$ are associated with the concentration and scattering frequency of free electrons, respectively. The obtained results show gradual decrease in the free-carrier damping from 2.4 eV ($d_{\text{Ti}}=12$ nm) to 0.98 eV ($d_{\text{Ti}}=2100$ nm). Based on the values of Drude parameters the mean relaxation time of conduction (τ) and the optical resistivity (ρ_{opt}) were calculated. The mean relaxation time increases with the increase of the titanium layer thickness (from 0.27 fs to 0.67 fs). However the plasma energy exhibits the other trend: increases from 6.48 eV ($d_{\text{Ti}}=12$ nm) to ~ 8 eV ($d_{\text{Ti}}=50$ nm) and then decreases to 5.4 eV ($d_{\text{Ti}}=2100$ nm). This behavior of Drude parameters directly affects the optical resistivity of titanium films. The lowest value of optical resistivity was observed for Ti films of thickness 50-100 nm (about 200 $\mu\Omega\text{cm}$). The dc- (ρ_{dc}) and optical resistivity take similar values for thinner Ti films, however for thicker coatings significant discrepancies can be observed.

The behavior of the plasma energy, optical resistivity and discrepancies between ρ_{opt} and ρ_{dc} values for thicker titanium coatings can be explained as an effect of limited light penetration.

Keywords: Magnetron Sputtering, Ti layers, Drude parameters, limited penetration of light

References

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