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Magnetron discharge during Ti sputtering was examined by Langmuir probe. Electron densities and energies were determined at different Ar pressures, dc. powers and distances from magnetron target. Values in order of 10^{15}m^{-3} and 1eV were measured even at distances up to 15 cm.

1. Introduction

Magnetron sputtering systems are of growing importance for many practical applications of thin films. Therefore, great effort is devoted to the intensive research of basic mechanisms of both the sputtering and the film deposition, as well as, to the studying of correlations between the created film parameters and parameters of magnetron discharge, etc. This work presents some results of the probe measurements of the electron density and the average electron energy in the discharge of planar rectangular magnetron during the sputtering of Ti cathode $100 \times 300 \text{ mm}^2$.

2. Experimental arrangement

The magnetron (developed in Czech. Acad. Sci. /1/) was built into the bell jar of the commercial evaporation apparatus PP 601 pumped by the oil diffusion pump 500 l/s backed by the rotary pump $30 \text{ m}^3/\text{h}$ /2/. The magnetron was supplied by the dc. 1.5A/1.2kV source. The working gas was Ar (99.99%) at pressures p_{Ar} between 0.06 Pa and 0.3 Pa, corresponding to the stable discharge limit and the stable pumping limit, respectively. At constant magnetron current $I_d = 1.5 \text{ A}$ the voltage U_d varied with p_{Ar} . In the above mentioned p_{Ar} -interval, U_d had to be changed between 310 V and 270 V. The magnetic induction B at the magnetron target reaches the value $B_{\text{max}} = 5 \times 10^{-2} \text{ T}$ and decreases with increasing distance l from the target. The function $B(l)$ has an approximate form $B(10^{-4} \text{ T}) = 2.2 \times 10^5 (l/\text{mm} + 24)^{-1.88}$.

The simple cylindrical Langmuir probe (0.5 mm in dia., 8 mm long) was coaxially arranged in a grounded shielding. The probe was positioned in a central part of the target, just above the maximum erosion zone. The distance l of the probe from the target was varied between $l_{\text{min}} = 3\text{cm}$ and $l_{\text{max}} = 15\text{cm}$. Both, the probe and the shielding became covered by the Ti layer during measurements. However, the Ti deposition rate reaches at l_{min} maximum values $a_D \approx 25 \text{ nm/min}$, which represents only 1% increasing of the probe diameter after more than 200 min. The probe axis was approximate-

ly parallel with the magnetic field. As the magnetic induction at l_{\min} reaches only $B = 1.2 \times 10^{-2}$ T, the influence of magnetic field on the on the probe measurements could be neglected.

Both, the average electron energy and electron density were determined from the electron part of the probe current-voltage characteristics $I_p(U_p)$ using the dependence $\ln I_p$ vs. U_p . Examples of the measured probe characteristics are in Fig.1.

3. Results and conclusions

Dependences of both the electron density n_e and the average energy E_e on the distance l of the probe from the magnetron target are drawn in Fig.2 for different argon pressures. The constant

discharge current $I_d = 1.5$ A was maintained during measurements. Therefore, the changes in the pressure $p_{Ar} = 0.06 \div 0.3$ Pa correspond to the changes in U_d , so that the power $P_d = I_d \times U_d$ varies between 465 W and 405 W, i.e. within 13%. From Fig.2 it is seen, that :

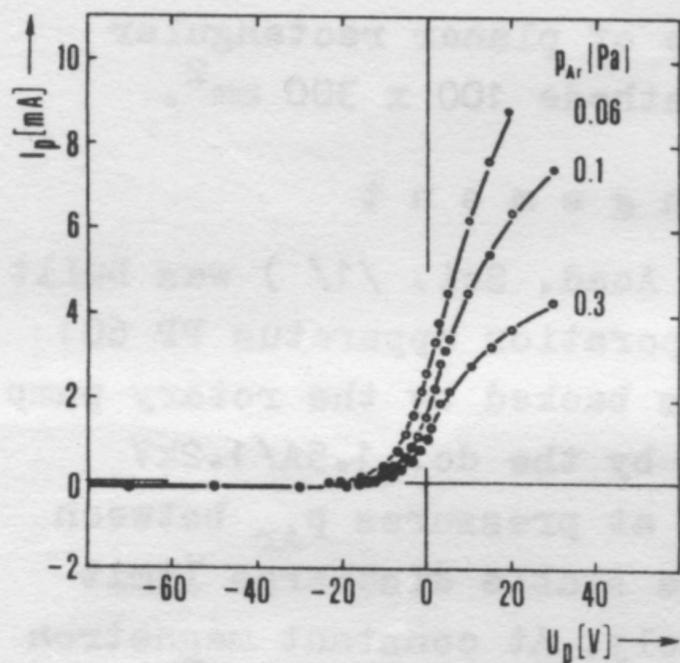


Fig.1 Typical probe characteristic measured at different argon pressures p_{Ar} (the probe-target distance $l=3$ cm).

A/ The electron density decreases with the increasing distance l approximately as $1/l$, at $p_{Ar} > 0.1$ Pa. At lower pressures the character of the decrease is different and the total change of n_e in the examined target - probe distance interval is smaller than that for $p_{Ar} > 0.1$ Pa. Measured electron densities are in order of $10^{14} \div 10^{15} \text{ m}^{-3}$, which corresponds to the plasma ionisation degree $n_e/N \approx 10^{-4} \div 10^{-5}$ (N - the density of neutrals).

B/ The electron energy E_e decreases with increasing l approximately as $1/l^2$. Even at distance $l = 15$ cm the average electron energy reaches $E_e \sim 1$ eV.

Dependences of n_e and E_e on the power P_d are in Fig.3 for two different distances l and at $p_{Ar} = 0.15$ Pa. It is seen that both, the electron density and energy increases linearly with P_d ,

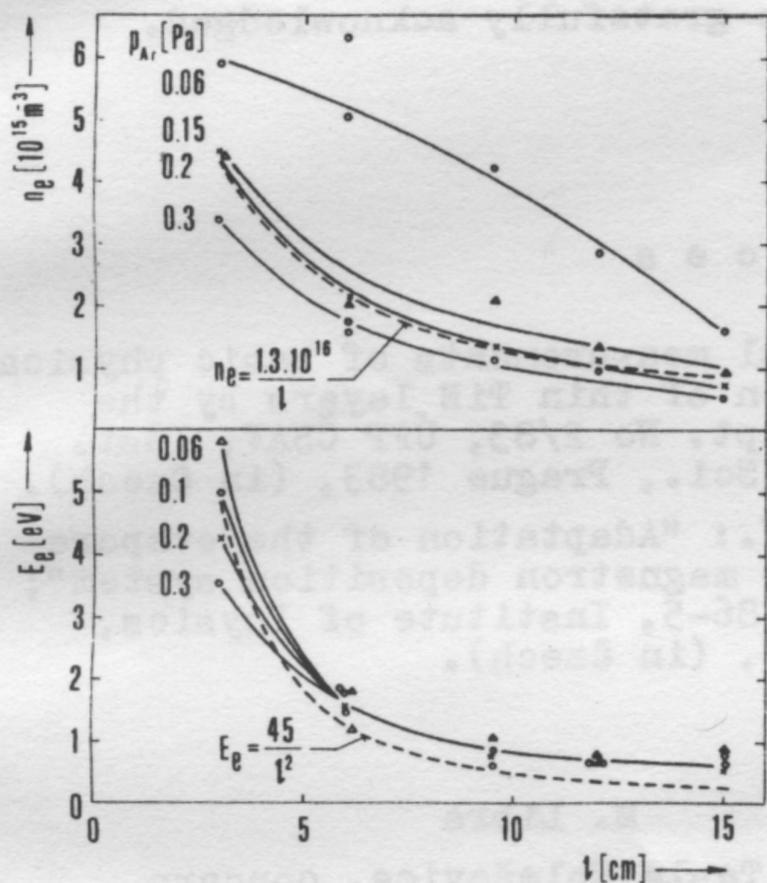


Fig.2 The dependence of the average electron energy and electron density on the probe - target distance at different argon pressures p_{Ar} . Magnetron current $I_d=1.5\text{A}$, voltage $U_d=310 \div 270 \text{ V}$.

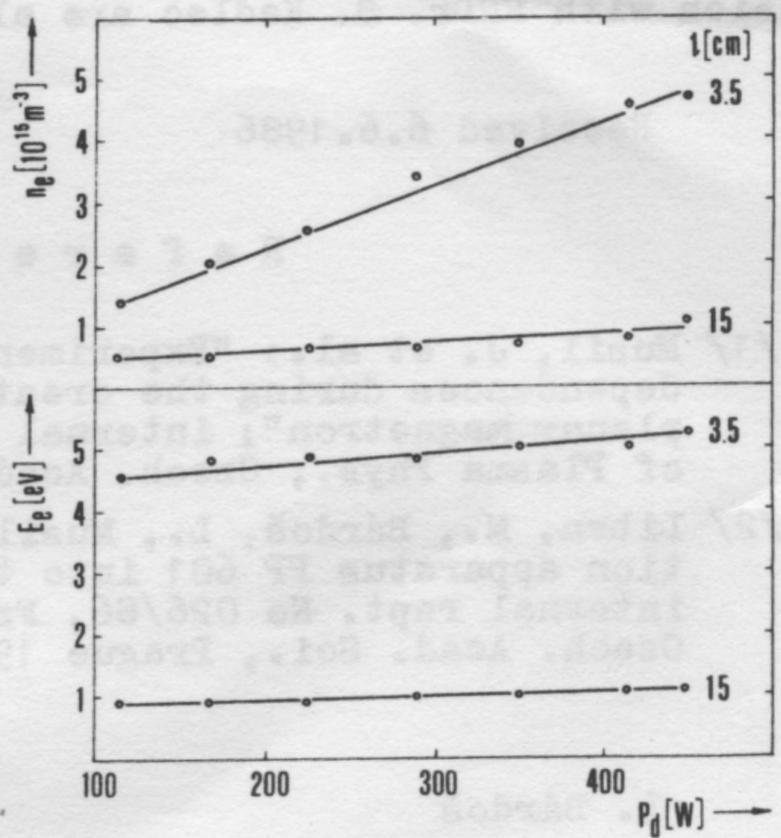


Fig.3 The average electron energy and electron density vs. dc. power P_d delivered into magnetron discharge for two probe-target distances l . Argon pressure $p_{Ar}=0.15\text{Pa}$.

however the density increasing is steeper. The electron density corresponds to the positive ions density and therefore the measured linear dependence $n_e(P_d)$ is in agreement with the usually measured linear dependence of the target sputtering rate on P_d , corresponding with the linear power dependence of the thin film growth rate.

Obtained results show, that relatively large density of charged particles can be present at large distances from the magnetron target (exceeding 5 cm), where the substrates to be deposited are usually located. Even at distances $l \approx 15\text{cm}$ the electron density can reach values in order of 10^{15} m^{-3} and average energy of electrons can be approximately 1eV. Therefore, the presence of charged particles could, particularly at pressures $p_{Ar} < 0.1 \text{ Pa}$, influence heterogeneous processes leading to creation of thin films during the magnetron sputtering.

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R e f e r e n c e s

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