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DETERMINATION OF THE ROUGHNESS LEVELLING DEPTH FOR METALLIC SURFACES BY OPTICAL MEASUREMENTS BASED ON THE LIGHT REFLEXION

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Abstract:
The used optical method is based on the roughness metallic surface model, which supposed one superficial inhomogeneous film. This is considered a mixture of the basic metal and the air.
For this film, the thickness, the amount of the metal per unit area of the surface and the weight fraction of the metal in the film are determined by the ellipsometric method. These values for Cu, Ni and steel allow the determination of the roughness leveling depth.

Key words:
ellipsometry, roughness, superficial film

1. INTRODUCTION

As a result of mechanical processing of metallic surface arise rupture of the crystal lattice and the formation of a transitional layer composed of amorphous crystalline areas of metal and impurities from the processing method [1,3].

Impurities existing on the rough surface can be removed by washing the area with various solvents, and transition layer will have properties intermediate two adjacent medium.

As well it should polish, metal surface has a roughness that can be characterized by mean deviation of the roughness to the median line:

$$R_a = \frac{1}{\ell}\int_0^{\ell} |y - m| \cdot dx \tag{1}$$

Median line taken as a reference is characterized by roughness leveling depth R_p taken to the outside line of profile or to the inside line of it:

$$R_p = \frac{1}{\ell}\int_0^{\ell} y \cdot dx \tag{2}$$

y is coordinate of a point of the profile diagram to the inside line, $m=R_p$ coordinate of the average line to the inside line and ℓ is the measured length [4].

In the case of the minute surface, use of mechanical feeler is limited by the size of pick-up.

Ellipsometric method, based on variation of the polarization of light when reflected on the surface between two media, can be used to characterize roughness of metal surfaces [2]. By this method can determine the thickness and optical properties of superficial films on metal surfaces with an accuracy of the order hundredth of nanometer.

The method used is based on a model of the rough metallic surface as in Figure 1. Rough surface may be resembled with a superficial film made from a mixture of metal (with the index of refraction $\tilde{n}$ and density ρ) and the immersion medium (with the index of refraction n_0 and density ρ_0), as in Figure 1. Refraction index n_f and thickness d_f of the film can be determined by ellipsometric readings based on the optical model of the superficial intermediate film, shown in Figure 1,

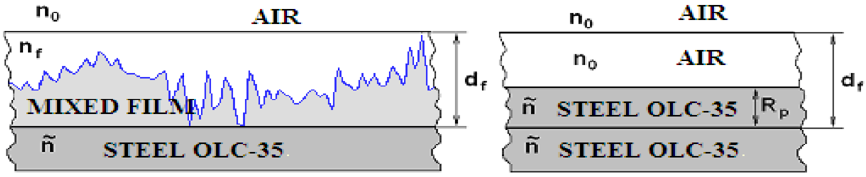

Figure 1. Model of rough surface resembled with a transition layer

The weight fraction of the metal in the film:

$$f = \frac{r_f - r_0}{\tilde{r} - r_0} \tag{3}$$

and the amount of the metal per unit area of the surface:

$$m_f = \rho_f \cdot d_f \cdot f \tag{4}$$

on determine from these optical values.

In this relationship ρ_f represents film density calculated with the phrase:

$$\rho_f = \frac{1}{\dfrac{f}{\rho} + \dfrac{1-f}{\rho_0}} \tag{5}$$

r_0, $\tilde{r}$ and r_f are the specific refractions of immersion environment (air), metal, and the superficial film:

$$r_0 = \frac{n_0^2 - 1}{n_0^2 + 2} \cdot \frac{1}{\rho_0} \quad ; \quad \tilde{r} = \frac{\tilde{n}^2 - 1}{\tilde{n}^2 + 2} \cdot \frac{1}{\rho} \quad ; \quad r_f = \frac{n_f^2 - 1}{n_f^2 + 2} \cdot \frac{1}{\rho_f} \tag{6}$$

Model shown in Figure 1 shows that the product between density of metal ρ and roughness leveling depth R_p is equal to the amount of metal per unit area of the film:

$$m_f = \rho \cdot R_p \tag{7}$$

2. EXPERIMENTAL PART

Measurements of the roughness of metal surfaces of copper, nickel and steel OLC-35 were carried out.

Samples of metallic copper, nickel and steel OLC-35 were cut to size 45x22x5 (mm), then were polished with glass paper grain size 12. Samples were burnish extra-bright before measurements with abrasive metallographic paper to grain M14, then with the burnishing powder of aluminum oxide "Presi 2" Italy. The samples were washed with absolute ethanol.

Metallic surface roughness was measured with a profilograph "Profilograf-201". For accounting of roughness we used the M system, which uses the median line of profile for the baseline [6]. Calculated physical and statistical parameters for the effective profiles were: the roughness leveling depth R_p and average deviation of roughness R_a reported to the median line.

Ellipsometric measurements were made with a photoelectric ellipsometer IFTAR (PCSA assembly) using monochromatic light with wavelength λ = 546.1 nm, at the angle of incidence φ_0= 70°.

3. RESULTS AND DISCUSSION

In Figure 2 shows, for example, profile diagram recorded for the surface of a sample of nickel.

Table 1 are given values of R_p and R_a for metal surfaces studied, calculated from profile diagram recorded. The calculations were made using a computer one's own program in Matlab language.

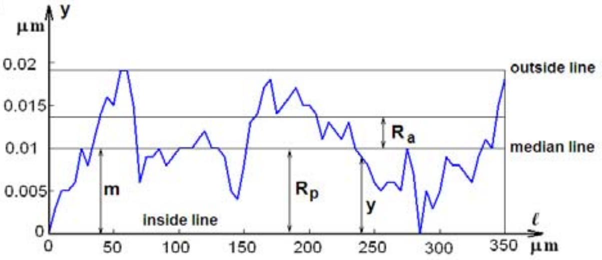

Figure 2. Profile diagram for nickel

Table 1

Metal	ℓ	R$_p$	R$_a$
-	µm	µm	µm
Copper	60	0.026	0.022
Nickel	350	0.010	0.004
Steel OLC-35	60	0.010	0.004

Ellipsometric measurements and optical values calculated for rough superficial film, based on optical model shown in Figure 1, are presented in Table 2. To calculate optical values for superficial film were used optical constants of metal, and ellipsometric quantities measured at incidence angle φ_0= 70° and wavelength λ = 546.1 nm.

All calculations were performed using a software own, based on the McCrackin program for processing ellipsometric measurements [5].

Table 2

Metal	optical constants of metal		ρ	Δ	Ψ	d_f	n_f
	n	k					
	-	-	g/cm³	grd.	grd.	nm	-
Copper	0.82	2.21	8.93	74.47	35.51	345,6	0.98
Nickel	1.79	3.30	8.90	97.56	35.37	23.4	1.25
Steel OLC-35	2.54	3.42	7.86	98.44	32.03	11.5	2.12

Were calculated the weight fraction of the metal in the film f and the amount of the metal per unit area of the surface m_f , according to the relations (3) and (4), using the optical values n_f and d_f calculated for rough superficial film. Levelling depth of roughness R_p , shown in Table 3, was calculated according to the relationship (7).

Table 3

Metal	d_f	f	m_f	ρ	R_p^{optic}	$R_p^{mechanic}$
	nm	-	mg/cm²	g/cm³	μm	μm
Copper	34,6	0.50	0.0031	8.93	0.035	0.026
Nickel	23.4	0.84	0.0077	8.90	0.009	0.010
Steel OLC-35	11.5	0.97	0.0076	7.86	0.010	0.010

It notes that in general there is a pretty good correlation between the leveling depths of roughness, optically determined (by ellipsometric measuring) R_p^{optic} and the same, mechanically determined (with profilograph) $R_p^{mechanic}$. Differences that may arise due to the fact that the base length of profil graph is of the order tenth of a millimeter while the optical surface of the metallic sample examined has an area with radius of about 2mm. Differences may occur because of errors due to limitations imposed by the size of profilograph pick-up.

4. CONCLUSIONS

For characterization of micro-roughness of metal surfaces ellipsometric method, based on modifying of the polarization of light reflected from the solid surfaces, is used. This method has an accuracy of the order tenth of a nanometer can provide information about the structures of various films on solid or liquid surfaces. The method does not require direct contact with the measured area and requires approximately 20 minutes measuring time.

Although a simple ellipsometric measurement not allow determination of roughness (expressed by the mean deviation of the roughness R_a to the median line taken as reference), it provides very valuable information about areas in terms of roughness. Levelling depth of roughness R_p determined by the optical measurement can be used later as middle reference line for calculating the roughness.

Ellipsometric measurements at several angles of incidence, or to different states of polarization of radiation, may provide additional information that can be used to characterize the roughness of surfaces.

Ellipsometric method can be used only for highly polished solid surfaces, reflecting specular light.

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