OPTICAL-RESONANCE PROPERTIES OF NANOSCALE NICKEL FILMS

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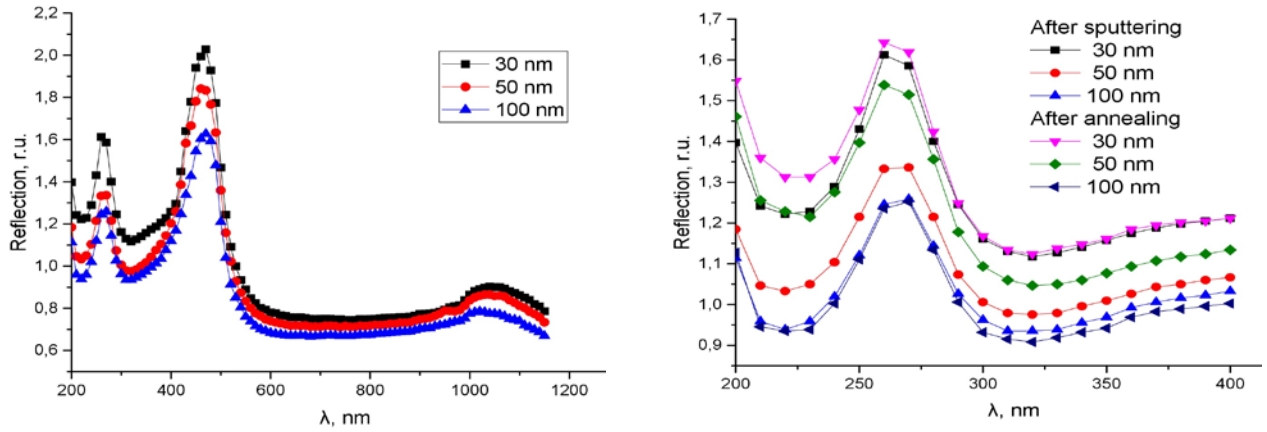
The paper presents researches results on the optical properties of Ni films produced by deposition of metal on quartz substrates from the vapor phase by electron beam method. It is found that obtained films have a cluster structure, which is caused by the cold surface of the quartz substrate.

Keywords: modulation polarimetry, plasmon resonance, nickel films.

The chemical element Ni attracts attention because it can be used as a synchrotron radiation microdetector [1]. The reason for this is the excitation of surface plasmons and interband transitions by low energy electron beam, which can be measured in the pure nickel metal surface [2]. However, on the Ni/Al_2O_3 system device, in which the sapphire is wafer for the metal film, there is a problem of composite materials science [3], due to the intermetallic formation of Ni-Al as an interface. Therefore, the nanosized Ni films on fused silica substrates are a more suitable structure for the emergence of surface plasmons and for the researching of their resonance properties.

The goal of this work is to research the optical properties of Ni films using the modulation polarimetry (MP) technique. The nickel films were produced by deposition of metal on quartz substrates from the vapor phase created by the electron beam in high vacuum. Fig. 1, *a* shows the experimentally obtained Fourier spectra of external reflection for nanoscale Ni films.



a) b)

Fig. 1. Reflection spectrum of 30, 50, and 100 nm thick Ni films on the quartz-glass wafer in the spectral range of 200—1150 nm (a) and in the UV range before and after annealing (b)

The obtained characteristics have features that indicate the resonant interaction of radiation with the substance of the films and are in good agreement with the data from other studies. For example, the extremum in the short-wavelength region is related to the spectral dependence of such nickel parameter as absorption coefficient that has resonance characteristics at the same frequencies [4]. However, the experimental result does not agree with the Bouguer-Lambert law. One of the reasons may be the structure imperfection

(cluster morphology) caused by the cold surface of the wafer. The confirmation of this assumption is shown in Fig. 1, *b*, where the Fourier external reflection spectra for Ni films in the UV range before and after annealing are shown. As can be seen from the figure, only for the 50 nm film there is a significant change in the characteristics, which can be explained by the transition of the film from solid to cluster structure. The spectrum extremum nature in the 1000—1200 nm wavelength range may be related to the interfacial properties of the film-glass interface.

The use of MP technique [5] in measuring of the dependences of the internal reflection coefficients in the Kretchman geometry [6] provides more information because the angular dependences contain information about the presence of surface plasmon resonance (SPR), while the spectral characteristics indicate the amplitude-phase resonance parameters. The measurement result at the angle of $\theta = 55°$ of the probe radiation is shown in Fig. 2, where it is seen that the parameter $\rho = R_s - R_p$ is the result of physical subtraction and it is deprived of the errors accompanying this operation in mathematical action. The experimental characteristics $\rho(h\nu)$ were found to have typical signs of the presence of SPR (extremum around 2.8 eV).

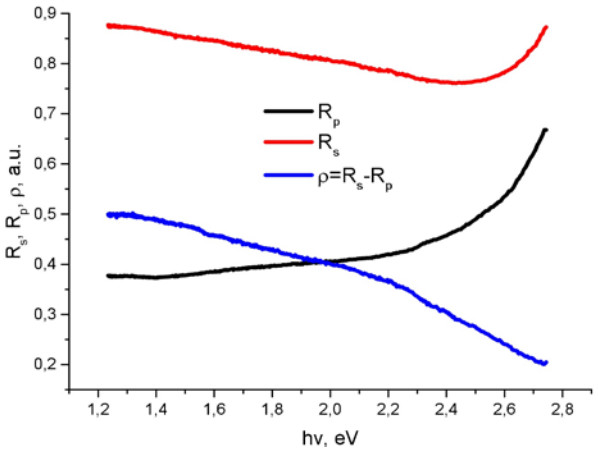


Fig. 2. Spectral dependencies of the internal reflection coefficients for polarized waves R_s, R_p, and ρ

Unlike continuous films, which are characterized by resonant interaction with *p*-polarized radiation, the samples under study showed an interaction primarily with s-polarized radiation. This fact confirms the previously made assumption about the cluster or rough structure of the obtained films since only in these cases the s-polarized wave will have the field component required for the SPR, oriented according to the phase synchronization condition along the normal to the metal surface.

REFERENCES

1. V. Pugatch, O. Kovalchuk et.al. Metal micro-detector TimePix imaging synchrotron radiation beams at the AERF Bio-Medical ID17 // Nuclear Instruments and methods in Physics Research.— 2012.— № 682.— P. 8.

2. Andrew P. Grosvenor, Mark C.Biesinger. New interpretations of XPS spectra of nickel metal and oxides. // Surface Science.— 2006.— Vol. 600, Iss. 9.— P. 1771.

3. Q. Zhong. Surface science studies on the Ni/Al_2O_3 interface. // J. Vac. Sci. Technol. A.— 1990.— Vol. 8, iss. 3. — P. 2107.

4. P. B. Johnson and R. W. Christy. Optical constants of transition metals: Ti, V, Cr, Mn, Fe, Co, Ni, and Pd. // Phys. Rev.— 1974.— B 9.— P. 5056.

5. Сердега Б.К. Модуляційна поляриметрія. Київ: Наукова думка. 2011. 260 с.

6. Kretschman E. Die bestimmung optischer konstanten von metallen durch anregung von oberflaschwingungen. // Z. Physik. — 1971. — V. 241. — P. 313.

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Оптико-резонансні властивості нанорозмірних плівок нікелю

Наведено результати досліджень оптичних властивостей плівок Ni, виготовлених методом осадження металу на кварцові підкладки із парової фази електронно-променевим методом. З'ясовано, що отримана плівка має кластерну структуру, яка зумовлена холодною поверхнею кварцової підкладки.

Ключові слова: модуляційна поляриметрія, плазмонний резонанс, нікелеві плівки.