*Kazimierz Blankiewicz**

Piezoreflectance of Thin Cu Layers Obtained by Vacuum Evaporation within the Energy Range 1.9-2.7 eV

Piezoreflectance in thin Cu layers was measured within 1.9–2.7 eV energy range. The extreme observed in the piezoreflectance spectrum for the energy slightly exceeding 2 eV changed its position, depending upon the sample thickness. It has been also stated that the piezoreflectance effect is conditioned by the technology of the layer production. The obtained results suggest that piezoreflectance allow to study the changes in energy structure of thin layers.

1. Introduction

A number of papers published in 1965 [1–4] deal with a new field in spectroscopy, called modulation spectroscopy. The respective measurements methods have been presented in a monograph by M. CARDONA in [8]. Modulation spectroscopy turned out to find chief application in the investigations of band structure of solid bodies. This new discipline is based on changes in the reflectance spectrum occuring in samples whose physical parameters are perturbed by a modulating factor, e.g. by electric field, temperature, strength, etc. The modulation of these parameters causes a due modulation of the sample dielectric constant, which fully determines its optical properties. Since, however, the dielectric constant of the sample depends on its energy structure, the latter information may be obtained by means of optical measurements.

The modulation spectroscopy, characterized by a high sensitivity, is a method allowing to detect the changes in the energy structure undetectable by classical measuring methods. Since optical constants of thin films depend on the layer thickness [5], thus the changes in the energy structure of thin films should be related to this factor. In the present paper piezoreflectance (modulation by strength) has been applied to the examination of changes in energy structure of thin Cu films obtained by evaporation in vacuum.

* Institute of Physics, Technical University of Warsaw, Warsaw, Poland.

2. Measuring system

Thin Cu films were evaporated directly on a quartz transducer excited to resonant vibrations of frequency about 50 kHz (Fig. 1). The examinations performed with the help of an electron microscope have allowed to state the policrystalline type of the obtained layers (Fig. 2), the size of single crystallite ranging within 10^{-2} μm (Figs. 3 and 4). A relative change in the reflectance coefficient $\Delta R/R$ (by which piezoreflectance is measured) for photons of energy ranging within 1.9–2.7 eV has been determined by an immediate measurement. A scheme of measuring system is shown in Fig. 5.

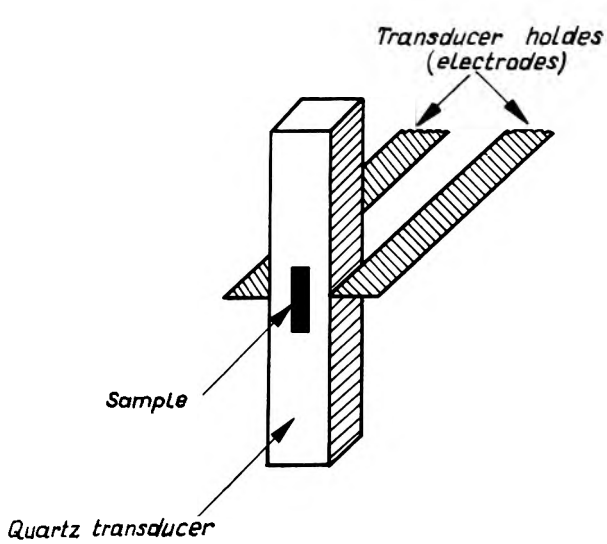

Fig. 1. A sample deposited on a quartz transducer

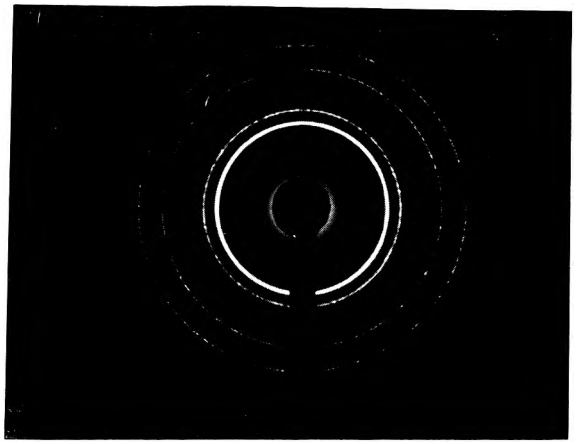

Fig. 2. Electronogram of the obtained Cu layers

The measuring light beam, having been let through the monochromator and reflected from the layer, reached a photomultiplier generating both d.c. output voltage, proportional to I_0R(I_0 the intensity of light incident on the sample), and a.c. voltage proportional to $I_0\Delta R$. If the d.c. voltage is kept unchanged within the whole measuring range (e.g. by changing the supply voltage of the photomultiplier), then the a.c. voltage signal will be proportional to $\Delta R/R$: because of its low value a phase-sensitive detection was necessary.

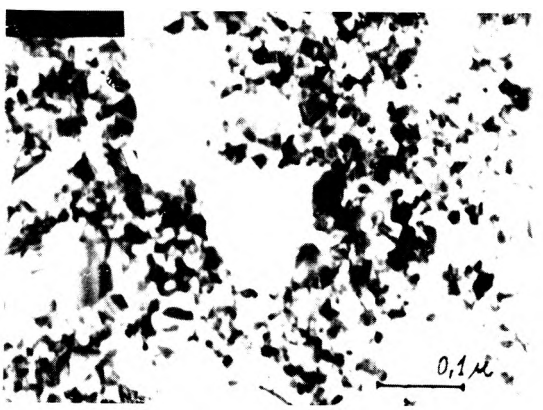

Fig. 3. The surface of a Cu layer obtained with a low evaporation rate ($\sim$ 10Å/s) in 10^{-4} Tr vacuum

2. Measurement Results

The results of measurements of piezoreflectance effect of thin Cu layers obtained under different conditions are shown in Fig. 5. The accuracy with which the $\Delta R/R$ may be measured, being related to the non-uniformity of sample surface, its value is constant and characteristic of the given sample. Hence, in Fig. 5, the extreme values $\Delta R/R$ have been normalized for all samples.

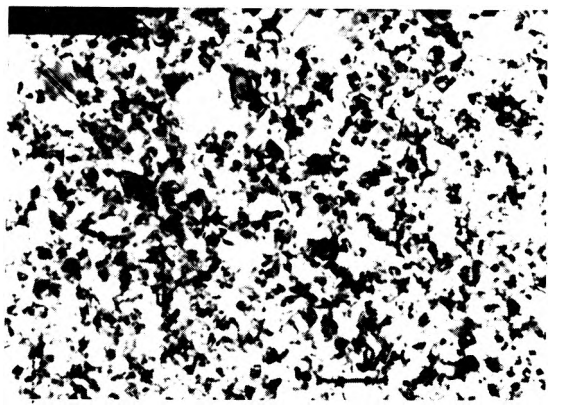

Fig. 4. The surface of a Cu layer obtained with a high evaporation rate ($\sim$ 50Å/s) in $5 \cdot 10^{-5}$Tr vacuum

Within the examined wavelength range the spectrum of piezoreflectance had a distinct energy structure, with the extreme exceeding slightly 2 eV. The level of the extreme energy proved to be dependent upon the film thickness. This relation, however, was true only for the film thickness not exceeding 300 Å.

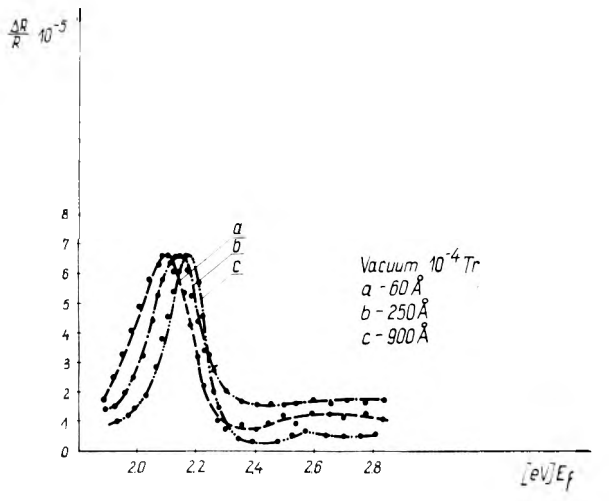

Fig. 5. Results of $\Delta R/R$ measurement obtained for various layers

3. Discussion of the Results

The piezoreflectance in thin Cu layers has been examined by some American scientists [4–6]. Experimental studies [4, 6] as well as theoretical calculations [7] have shown that for the energy slightly exceeding 2eV the extreme in piezoreflectance spectrum is related to the energy transitions from the Q_-, Q_- and Δ_5 points onto the Fermi level.

There is no reason to suppose that the extreme energy observed in the present work was of another origin. Its shifting toward higher values, occuring

with the increasing layer thickness, suggests that the Fermi level is shifting too. Final conclusions, however, cannot be formulated before the investigations are accomplished.

4. Final Remarks

From the so far performed measurements it follows, moreover, that the effect of piezoreflectance is conditioned by the technology of the layer, production, hence, it may be applied to determine the changes in energy structure occuring in thin layers due to the manner of their production.

Réflexion piézo-électrique dans les couches minces de Cu obtenues par vaporisation sous vide dans le domaine de 19 à 27 eV

On a mesuré la réflexion piézo-électrique dans kes couches minces du Cu dans le domaine de 17 à 27 eV. Pour l'énergie un peu supérieure à 2 eV, dans le spectre de la réflexion piézo-électrique apparaissait un extrémum dont la position dépendait ne l'épaisseur de l'échantillon. Dans la conlusion finale on a constaté que la réflexion piézo-électrique permet d'étudier les changements de la structure énergétique des couches minces.

Пьезоотражение в тонких пленках Cu получаемых вакуумным пропариванием в области 19-27 eV

Измеряли пьезоотражение в тонких пленках Cu в области 19–27 eV. Для энергии немногим выше 2 eV в спектре пьезоотражения выступал экстремум, точка которого зависела от толщины образца. В заключении выражено мнение, согласно которому пьезоотражение является методом, позволяющим исследовать изменения в энергетической структуре тонких пленок.

References

[1] Seraphin B. O. and Hess R. B., Phys. Rev. Lett. **14**, 138 (1965).

[2] Seraphin B. O. and Hess R. B. and Bottka N., J. Appl. Phys. **36** 2242 (1965).

[3] Gobeli G. W. and Kane E., Phys. Rev. Lett. **15**, 142 (1965).

[4] Engeler W. E., Fritzsche H., Garfinkiel M. and Tiemann J. J., Phys. Rev. Lett. **14**, 1069 (1965).

[5] Heavens O.S., *Optical Properties of Thin Solid Films*, Butter. Scien. Publ., London 1955.

[6] Garfinkiel M., Tiemann J. J., and Engeler W. E., Phys. Rev. **148**, 695 (1966).

[7] Segall B., Phys. Rev. **125**, 109 (1962).

[8] Cardona M., *Modulation Spectroscopy*, Academic Press, New York and London 1969.

Received, March 15, 1974.
In revised form June 16, 1974