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DETERMINATION OF THE THICKNESS OF THIN METAL FILMS BY THE INTERFERENCE EFFECT ON SELENIUM FILMS

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Abstract

Current trends in the development of thin-film technologies and the semiconductor industry lead to a decrease in the characteristic dimensions of the structures being created, which places increased demands on the control of their geometric characteristics - layer thicknesses. Methods for determining the thickness of thin metal films are considered. Thin films of amorphous selenium, silver and silver layers on a selenium film are synthesized. Optical transmission spectra are recorded using a UV-vis spectrophotometer. A new method for determining the thickness of thin metal films by the interference effect on certain thicknesses of selenium films is proposed. The corresponding calculations are carried out.

Keywords: thin-film systems, selenium films, thin metal films, silver, interference maxima, spectrophotometry, film electrodes for capacitors, measurement of metal film thicknesses

1. INTRODUCTION

Thin films are thin layers of material with thicknesses ranging from fractions of a nanometer (polyatomic layer) to several microns. Light interference is the redistribution of light intensity as a result of superposition of several coherent light waves. Modern trends in the development of thin-film technologies and the semiconductor industry inevitably lead to a decrease in the characteristic dimensions of the structures being created. This places increased demands on analytical means for monitoring the parameters of layered structures during their production: the composition of the layers, the crystalline perfection of the materials, and, first of all, their geometric characteristics - the thickness of the layers. This paper considers the issue of using the interference effect in assessing the thickness of film structures. The purpose of this study is to develop a technique for determining the thickness of thin metal films by the interference effect on selenium films.

2. RESEARCH METHODS

Film thickness measurement during vacuum deposition is controlled using a quartz resonator. Film thickness measurement in microelectronics after the deposition stage is measured by the following methods [1-8]:

- Ellipsometric method;
- Measuring the "step" (the boundary between the deposition and the substrate) on an atomic force microscope;
- X-ray photoelectron spectroscopy and reflectometry;
- Interference methods
- Various spectrophotometric methods, etc.

The analytical equipment developed on their basis allows measuring film thickness from units (and even less) of nanometers to hundreds of nanometers (and more). The disadvantage of these methods is their high cost and relative technological complexity.

The ellipsometric method of research is as follows: a plane-polarized wave falls on the sample under study, which, after reflection, generally becomes elliptically polarized. The parameters of the polarization ellipse, i.e. the orientation of its axes and eccentricity are determined by the optical properties of the reflecting structure and the angle of incidence of light. In the experiment, the ratio of complex reflection coefficients is measured for two types of light wave polarization: in the plane of incidence (p) and perpendicular to it (s).

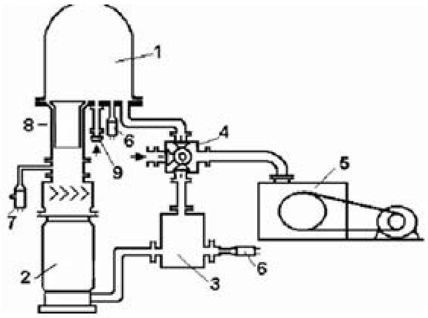
Under certain conditions, the reflection of light from the structure is accompanied by an interference effect, which can be used to measure the thickness of the layers. For interference to occur, it is necessary that the incident radiation be reflected not only from the surface layer, but also from its boundary with the substrate. This means that the layer must be transparent in the wavelength range used, and the optical constants of the layer in this spectral range must differ from the optical constants of the substrate.

3. RESULTS AND DISCUSSION

Selenium is a grey, brittle non-metal with a metallic luster (Fig. 1). At atmospheric pressure, there are several dozen modifications of selenium. The most stable is grey selenium, γ-Se, with a hexagonal lattice (a = 0.436388 nm, c = 0.495935 nm). Melting point is 221°C, boiling point is 685°C, density is 4.807 kg/dm3. The density of liquid selenium at 221°C is 4.06 kg/dm3. Grey selenium is obtained from other forms by prolonged heating and slow cooling of the melt or selenium vapor. Its structure consists of parallel spiral chains [9].

Figure 1. Amorphous selenium granules

The experimental samples were films of amorphous selenium, films of selenium and films with silver deposition (Fig. 3). Sputtering was carried out on glass substrates of the brand on a vacuum installation UVR-3M at a pressure of 10-2-10-3 Pa. The substrates were preliminarily subjected to ion cleaning in a glow discharge (with argon ions). The working scheme of the installation is shown in Fig. 2.



1- working volume; 2- diffusion pump
3 – fore vacuum cylinder; 4 – valve box
5 – fore vacuum pump; 6 – low vacuum sensor
7 – high vacuum sensor; 8 – shut-off valve
9 – air inlet valve into the working volume

Figure 2. Schematic diagram of UVR-3M vacuum unit

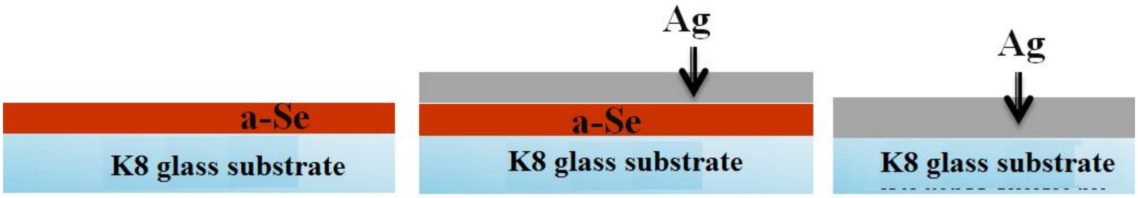
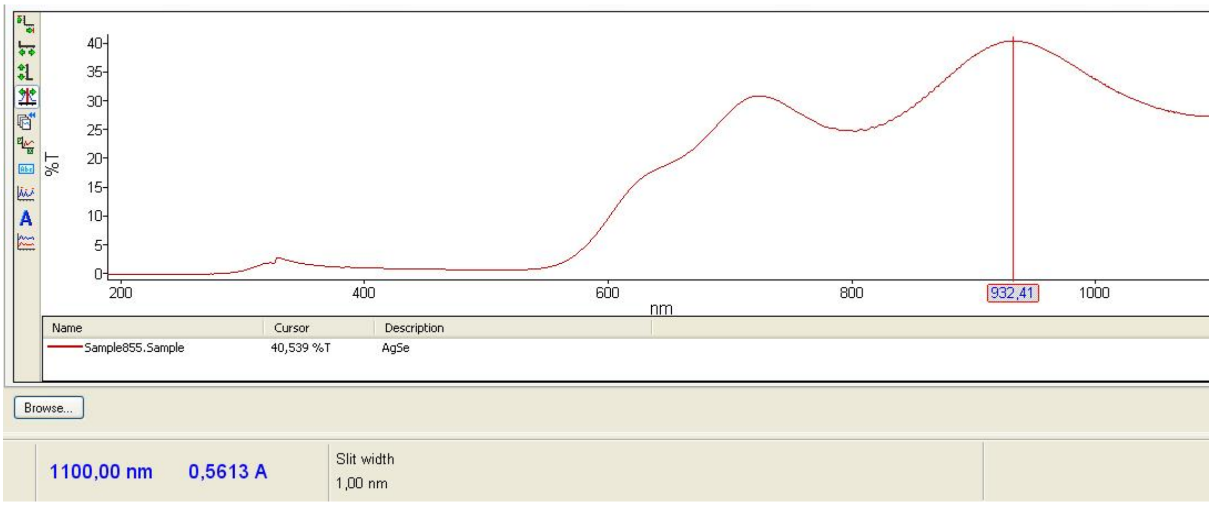


Figure 3. Scheme of deposition of Se, Ag, Ag+Se film samples

During the experiment, a spectrophotometer "Lambda 25 UV/Vis" was used. The spectrophotometer was controlled and data were obtained using a personal computer equipped with UV WinLab software. In this device, a deuterium lamp and a halogen tungsten lamp are used as radiation sources, which made it possible to study samples in the wavelength range from 190 to 1100 nm [10]. Below in Figures 4-7, the transmission spectra of amorphous Se films, Ag films and Ag+Se films are presented.

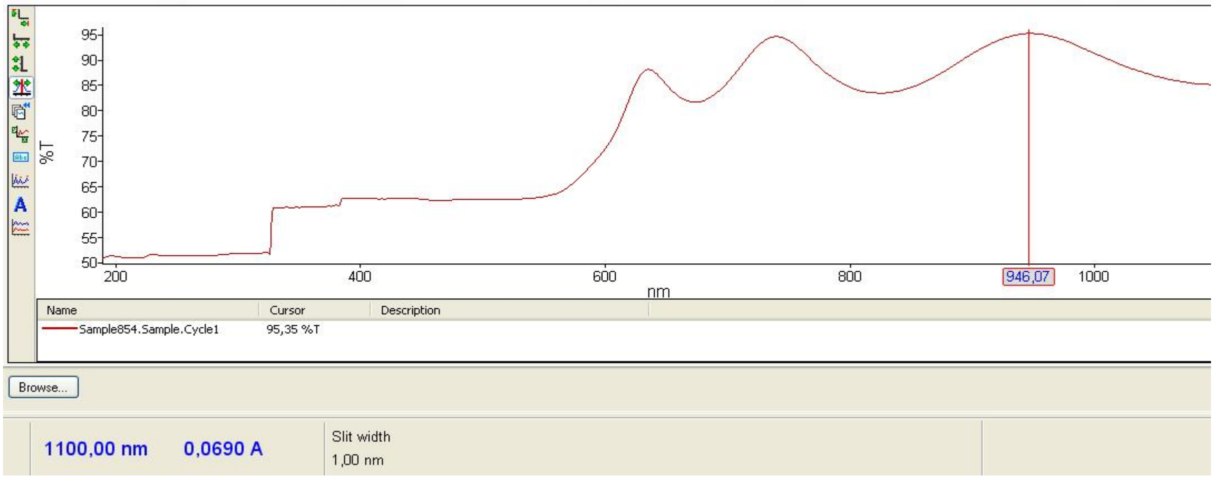


Name	Cursor	Description
Sample855.Sample	40,539 %T	AgSe

1100,00 nm 0,5613 A

Slit width 1,00 nm

Figure 4. Transmission spectrum of Ag+Se films



Name	Cursor	Description
Sample854.Sample.Cycle1	95,35 %T	

1100,00 nm 0,0690 A

Slit width
1,00 nm

Figure 5. Transmission spectrum of Se films

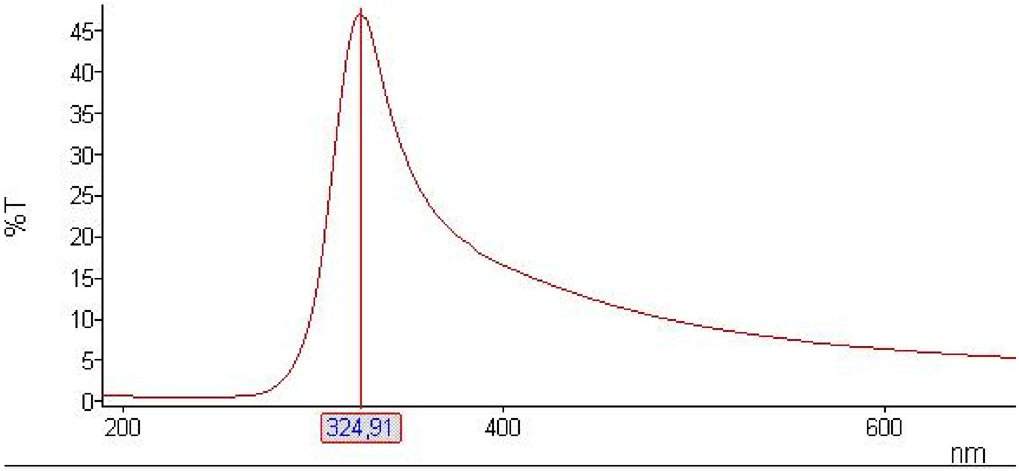


Figure 6. Transmission spectrum of Ag film

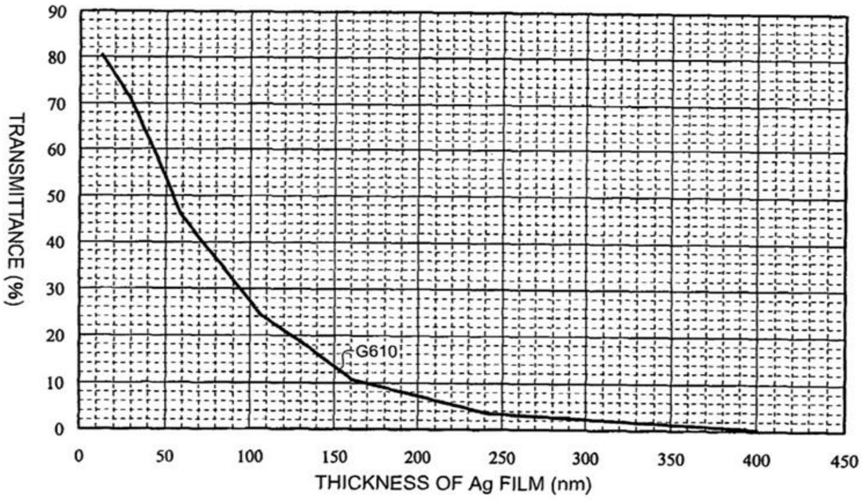


Figure 7. Transmittance coefficient of silver film at maximum transmittance [2] from film thickness

Note that an interference effect with corresponding interference maxima is observed on selenium films. Due to the dependence of the refractive index on the wavelength, a shift in the interference maxima in the spectra of Ag+Se films occurs compared to pure Se films.

Determining the order of maximum:

$\lambda_2 m=2dn(\lambda_2)$ $\qquad$ $(\lambda_1 m(m+1))/n(\lambda_1) = \lambda_2 m/n(\lambda_2)$

$\lambda_1 m(m+1)=2dn(\lambda_1)$ $\qquad$ $m= \lambda_1/(n(\lambda_1)/ /(n(\lambda_1)/(n(\lambda_2))*\lambda_2-1$

Determination of Se film thickness:

$\lambda_2=739{,}51$ nm

$\lambda_3=946{,}07$ nm

$n(\lambda_2)=2{,}385+168385/\lambda^2_2=2{,}385+168385/546875{,}04=2{,}693$

$n(\lambda_3)=2{,}385+168385/\lambda^2_3=2{,}385+168385/895048{,}45=2{,}573$

$m= \lambda_2/(n(\lambda_2)/(n(\lambda_3)*/(\lambda_3-\lambda_2)=739{,}51/216{,}2=3{,}42$

$d=m\lambda_2/2n(\lambda_2)=3{,}42*739{,}51/2*2{,}693=468{,}4$ nm

Determination of Ag+Se film thickness:

$\lambda_2=725{,}66$ nm

$\lambda_3=932{,}41$ nm

$d=m\lambda_2/2n(\lambda_2)=4*725/2*2{,}8=517{,}9$ nm

Calculation of the Ag film thickness by the subtraction method: d(Ag)=d(AgSe)-d(Se); d(Ag)≈50 nm – calculated; d(Ag)≈54 nm – obtained from the calibration graph.

4. CONCLUSIONS

Se, Ag+Se, Ag (as a standard) films were synthesized by thermoresistive deposition in vacuum. Transmission spectra were obtained. The thicknesses of Se, Ag+Se films were calculated from interference maxima. The thickness of the Ag film was determined by subtracting the film thicknesses. The proposed technique can be used as a new indirect method for determining the thicknesses of thin films of various metals and is a relatively simple and inexpensive technique. It is applicable in various technological processes in the field of micro- and nano-electronics. Control of the thickness of conductive electrodes can play an important role in their application in the developed variable capacities for tire pressure sensors.

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