ELLIPSOMETRIC STUDIES OF NANOMETRIC CdS AND CdTe FILMS

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The thickness of the layers CdS and CdTe grown on the Si, Ge, GaAs was determined from the analysis of the polarization ellipse of the reflected light from the surfaces of structures thin layers – substrate. The thermal treatment of the samples CdS-CdTe in the presence of $CdCl_2$ leads to the increasing of the crystalline phase from layers.

Introduction

The modern semiconductor technologies need the samples and multilayer structures with the well determined physical parameters composed by layers of nanometrical thicknesses. The ellipsometry is one of the nondestructive methods used in practice, which the theory of Drude reflection is based on. The performed calculations in many experimental papers [1, 2] demonstrate the possibilities of correct application of Drude equations up to the thicknesses of layers of 50?100 A order, but in some cases up to 5?10 A [3].

The passage of reflected light rays is represented schematically from the surface of the thin layer – substrate structure in fig.1. As the refraction index of the semiconductor materials and dielectric ones is a complex value, the linear polarized light ray obtains elliptical polarization at reflection. The presence of one thin layer of semiconductor or dielectric one on the reflecting surface forms a supplementary phase difference between reflected rays from the external surface and reflected ray from the substrate surface. The state of elliptical polarization is determined univocally with two parameters ψ and Δ [4] which is determined by relations:

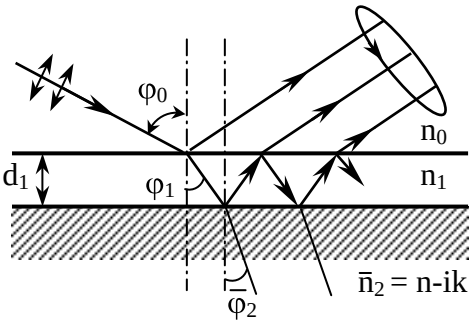


Fig.1.

$$tg\psi = \left(\frac{R_p}{R_s}\right)^{1/2} \tag{1}$$

$$\Delta = \delta_p - \delta_s \tag{2}$$

where R_p and R_s are the reflection energetic coefficients, but δ_p and δ_s are the phases of the components *p* and *s* of the reflected light from the sample.

The next relation [5] is available in the spectral range of transparence of the thin layer among the Fresnel coefficients of reflection from the surface of structure r_{1p}, r_{1s} and r_{2p}, r_{2s}, the parameters of polarization ellipse Δ and ψ and the thickness *d* of the layer from the surface:

$$tg\psi \cdot e^{i\Delta} = \frac{r_{1p} + r_{2p}e^{2i\delta}}{1 + r_{1p}r_{2p}e^{-2i\delta}} \cdot \frac{1 + r_{1s}r_{2s}e^{-2i\delta}}{r_{1s} + r_{2s}e^{2i\delta}} \tag{3}$$

The value δ presented with grades is equal to:

$$\delta = \frac{360d}{\lambda}\left(n_1^2 - \sin^2\varphi\right)^{1/2}, \tag{4}$$

where φ is the incident angle of the light ray to the surface of the sample.

The experimental technique and method of researching

The ellipsometrical parameters Δ and ψ were measured by an ellipsometer which optical scheme does not differ principally from the classical model [6] and is represented in fig.2. The wavelengths were selected from the field of transmission of film layer by monochromator MDR-2 from the light beam generated by the Xe lamp (1000 Wt), the thickness and optical constants of which are determined. The monochromatic light beam is polarized by Rochon prism so that the polarization plane of the light makes 45^o with respect to the incident plane on the sample. The polarization degree of the reflected light from the surface is analyzed by Glan-Thomson prism and is registered by a selectively amplified photomultiplifier complex FME-51 and adjusted at the modulation frequency of the light beam equal to 325 Hz. Optical scheme is adjusted by He-Ne laser radiation (λ=632 nm).

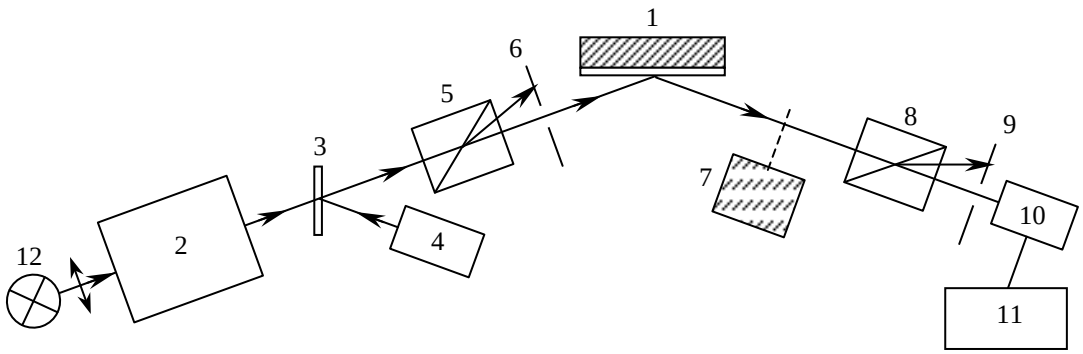


Fig.2. The block-scheme of the ellipsometer. 1 – the sample; 2 – the monochromator MDR-2; 3 – glass plate; 4 – He-Ne laser (LG-52); 5, 8 – Rochon prism; 6, 9 – circular diaphragms; 7 – modulator; 10 – photomultiplifier FME-51; 11 – selective amplifier V6-4.

The samples that are thin layers of CdS deposited on the CdTe substrate were obtained by deposition in the closed volume. The monocrystals of CdS and CdTe grown from the pure spectral components Cd, S and Te were used as the source of vaporization.

The experimental determinations of the refractive index and the thickness of CdS layers that are the components of the CdS-CdTe samples were performed at two wavelengths from the field of optical transparence of the CdS layer. In order to establish the influence of homogeneity of the layer structure of CdS on the optical characteristics, the samples of CdS-CdTe were treated thermally in the presence of $CdCl_2$ during 20 – 30 seconds at the temperature of ≈ 700 K.

Experimental results

As the Fresnel coefficients of reflection and $e^{2i\delta}$ are the complex values then after the selection of real part of equation (3), the theoretical dependences of the ellipse parameters of polarization Δ and ψ on the thickness and the refractive index of the thin layer deposited on the substrate surface of dielectric or semiconductor were calculated. Such calculations were

performed for thin layers of CdS and CdTe grown on the substrate of Si, Ge, GaAs, GaSe and CdTe or CdS respectively.

The diagrams Δ – ψ for thin layers of CdS and CdTe grown on the substrate of GaAs (a) and Ge (b) are presented in fig.3 and 4. The numerical indications from the graphic show the phase variation obtained as a result of light passage through thin layer with thickness *d*.

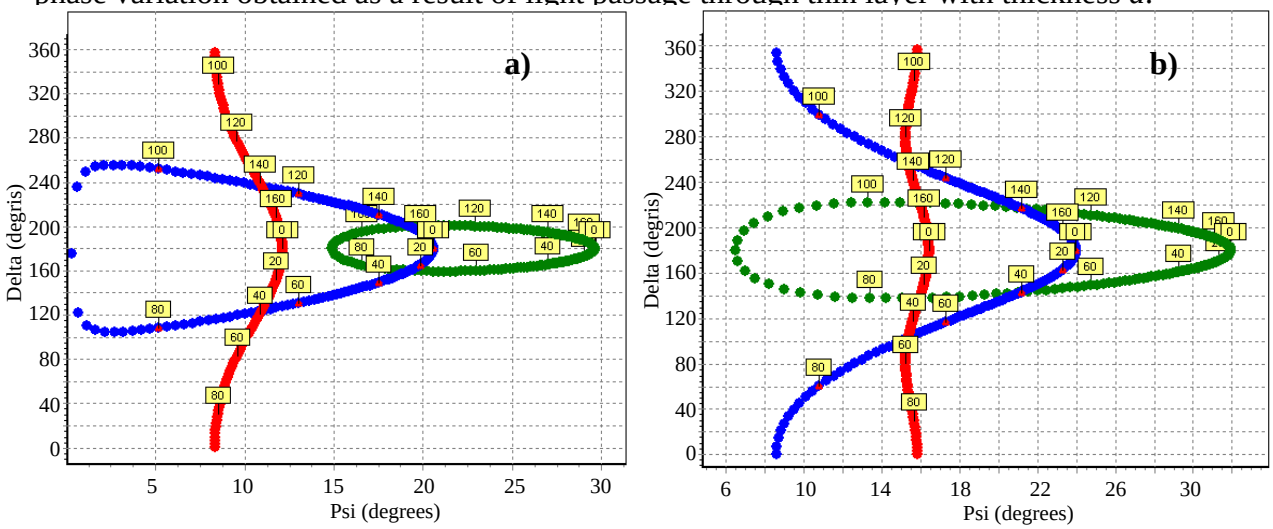


Fig.3. The dependence of the ellipsometric parameters (Δ-Ψ) of the phase difference (δ) for submicronic CdS thin films deposited on: a – GaAs; b – Ge.

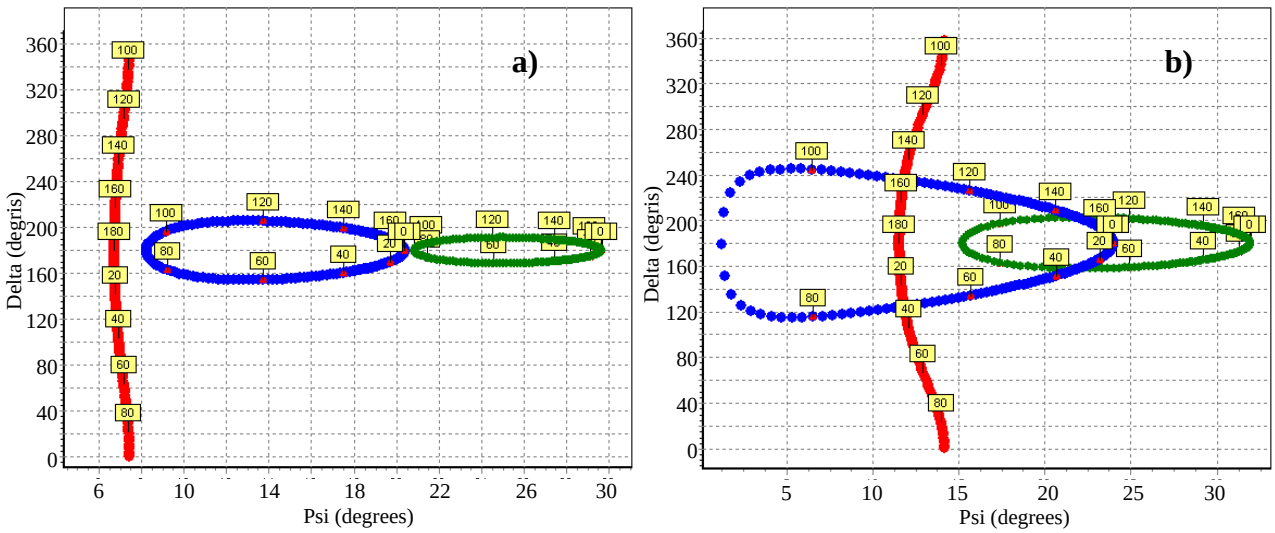


Fig.4. The dependence of the ellipsometric parameters (Δ-Ψ) of the phase difference (δ) for submicronic CdTe thin films deposited on: a – GaAs; b – Ge.

We can easily see from these dependences that with the increasing of the incident angle from 45° till 70° the resolution in the determination of the parameter δ and the thickness is increased.

The diagrams Δ – ψ for the layers of CdS grown on CdTe and CdTe grown on CdS respectively are presented in fig.5 and 6.

We can see from the analyses of dependences presented in fig.3, 4 and 5, 6 that the variation interval of the parameters Δ and ψ of the polarization ellipse is increased with the

increasing of the refractive index of the substrate for the incident angles smaller than total refraction angle. The diagrams $\Delta - \psi$ are periodical functions of the thickness and are repeated approximately after 2000?2500 A.

If the incident angle is polarized linearly with the angle 45^o with respect to the incident plane then selecting the real part and complex from (3) we obtain the commode relations for the determination of the refractive index *n* and for the wavelengths of the optical transparent range of the layer with the condition k=0.

$$n = \left[0.5 + \frac{\cos^2 2\psi - \sin^2 2\psi \cdot \sin^2 \Delta}{2(1 - \sin 2\psi \cdot \cos \Delta)^2} \right]^{1/2}. \qquad (5)$$

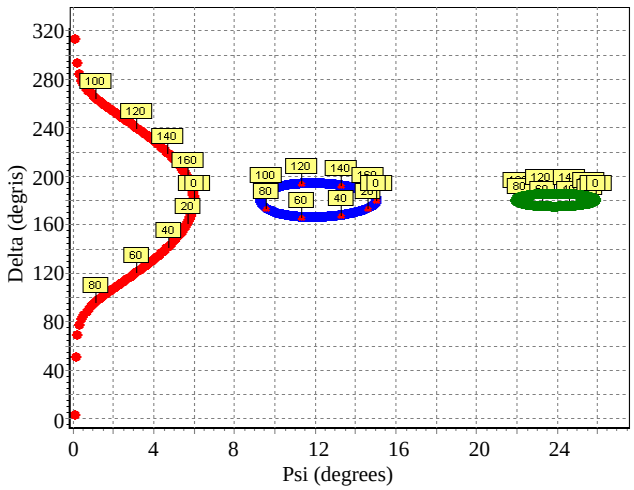


Fig.5. The dependence of the ellipsometric parameters (Δ-Ψ) of the phase difference (δ) for submicronic CdS thin films deposited on CdTe.

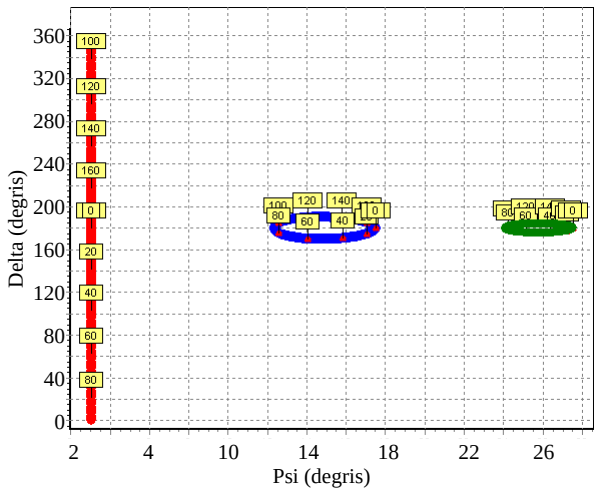


Fig.6. The dependence of the ellipsometric parameters (Δ-Ψ) of the phase difference (δ) for submicronic CdTe thin films deposited on CdS.

The results of experimental determinations of the thickness and refractive index of the samples CdS-CdTe are shown in the table at the wavelengths 0.8 μm and 0.95 μm with the theoretical diagrams $\Delta - \psi = f(\delta)$. The thicknesses of determined layers from interferential structure of the reflected spectra indicated from the respective surface of the samples CdS-CdTe in the range of 500?2500 are also shown in the table. We can also see a good correlation in the determination of the thicknesses of CdS and CdTe layers by ellipsometric method and from the interferential structure of reflection spectra.

Table

λ, nm	CdS on CdTe				CdTe on CdS			
	n	*n**	*d*, μm	*d**, μm	*n*	*n**	*d*, μm	*d**, μm
800	2.383	-	0.053	-	2.721	2.748	0.06	-
	2.385	2.391	0.150	0.17±0.03	2.720	2.750	0.18	0.16±0.04
	2.386	2.390	0.800	0.82±0.01	2.726	2.749	0.78	0.75±0.02
950	2.379	2.380	0.054	-	2.720	2.743	0.06	-
	2.379	2.384	0.150	-	2.720	2.745	0.20	-
	2.380	2.383	0.800	-	2.723	2.745	0.79	-

n^* is the refractive index of layers CdS and CdTe thermally treated in the presence of $CdCl_2$;

d^* is the thickness of layer determined from interferential structure of reflective spectra in the range 0.5?2.5 μm.

Conclusions

The dependences of the ellipsometrical parameters Δ and ψ of the phase variation were calculated using the basic equation of ellipsometry as a result of light passage through thin layers of CdS and CdTe by which the refractive index and the thickness of respective layers were determined.

The thermal treatment of the samples CdS-CdTe in the presence of solution $CdCl_2$ leads to the increasing of refractive index both of the layer CdS grown on the substrate of CdTe and thin layer of CdTe grown on CdS. The increasing of refractive index indicates the increasing of the homogeneity degree and crystallization of thin layers of CdS and CdTe.

A good correlation between interferential and ellipsometrical methods of determination of the thickness of thin layers of CdS and CdTe grown on the sublayer of semiconductor was established.

References

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