THE TECHNIQUE OF MEASUREMENT OF MODULATED OPTICAL SPECTRA

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Abstract: In the lust two decades the researchers pay attention to the optical properties of semiconductor layers which are used in different electronic devices. The special role of these investigations has the study of electronic states in the semiconductor materials using optical measurements. The important data obtained when some gropes of researchers [1,2] start to investigate the optical spectra modulated by parameters such as: the wavelength, temperature, electrical field… Some particularities of optical spectra, which not founded in the absorption and reflection spectra, it was identified using the modulated spectroscopy.

Keywords: optical spectra, modulated spectra, thin layers

1. INTRODUCTION

The variation of the transmission *t* function of wavelength λ can be distinguished near the critical points called Van-Hove points. In the semiconductor materials with direct optical transition the transmission grow from zero to the maximum value when the wavelength changes with ~ 100 Å for $\hbar\omega \approx E_g$, at the same time the absorption coefficient change the value by four orders. The reflection coefficient (~ 10 ÷ 20 %) reacts slower when the wavelength is changed. There is the connection between the optical transmission, reflection coefficient $\left(\Delta R \sim \left(10^{-4} \div 10^{-5}\right) R\right)$ and the absorption coefficient α. When one of these parameters varies, the last two change the value too.

The absorption coefficient α of light in the samples in which the interferential phenomena can be neglect (the thickness of sample $d \gg \lambda$) can be calculated from the transmission *t* and reflection *R* spectra using the formula:

$$\alpha = \frac{1}{d} \ln \frac{(1-R)^2}{t} \tag{1}$$

From (1) results that for the studied sample the variation of absorption coefficient depends on ΔR and Δt. We can omit the ΔR in calculus of absorption coefficient Δα in the domain of direct optical transition between the bands ($\Delta t \gg \Delta R$).

The relation between the transmission variation *dt* and the variation of absorption coefficient *dα* can be established if the relation (1) is differentiated:

$$d\alpha = \frac{1}{d(1-R)^2} \cdot \frac{dt}{t} \tag{2}$$

If the relation (2) is differentiated by wavelength $d\lambda$ we will obtain:

$$\frac{d\alpha}{d\lambda} = \frac{1}{d(1-R)^2} \cdot \frac{1}{t} \cdot \frac{dt}{d\lambda} \tag{3}$$

The equation (3) show the absorption coefficient modulated by wavelength and it is equivalent to the modulated optical transmission. If the reflection coefficient modulated by wavelength $dR/d\lambda$, then the shape of optical spectra will be persuade by the variation of dielectric permittivity $d\varepsilon_1$ and $d\varepsilon_2$.

The relative permittivity ε, near the critical three-dimensional point M_0, for the direct optical transitions [3], is:

$$\varepsilon - 1 \sim \left(\omega + i\eta\right)^{-2} \left[2\omega_g^{\frac{1}{2}} + \left(\omega_g - \omega - i\eta\right)^{\frac{1}{2}} - \left(\omega_g + \omega + i\eta\right)^{\frac{1}{2}} \right] \tag{4}$$

where ω_g is the resonance frequency at the band-band transitions and η is the parameter of spectral line enlargement.

2. EXPERIMENTAL

There is a lot of experimental methods of modulated optical parameters such as ΔR and Δt – as well as $\Delta\varepsilon_1$, $\Delta\varepsilon_2$, Δn and Δk which is amplified function of the goal. First, if the electrical resistance of sample is big, the electrical field applied directly using the electrodes (the capacitor model). The experiments made with electrical field orientated parallel and perpendicular to the propagation direction of light [4]. The modulated electrical field in the photoconductor materials is generated by light beam with wavelength from the photo sensibility domain [5].

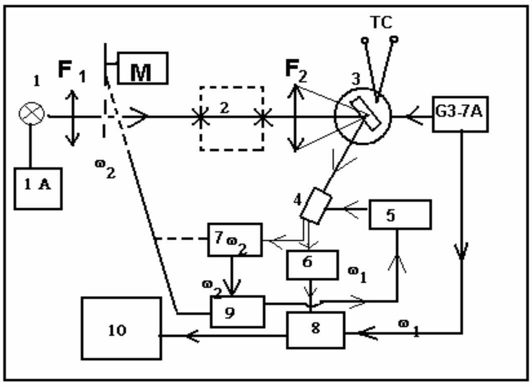

Fig. 1: The experimental block diagram for the reflection spectra modulated in electric field:
1 and 1A – tube DKSS-1000 with supply block 30 V – 60 A; 2 – monochromator MDR – 2; 3 – the sample in the crucible; 4 – the electric photo multiplier FME – 79; 5 – power supply 700 ÷ 2500 V; 6 and 7 – amplifier Y2 – 8; 8 and 9 – phase detector K3 -2; 10 – writer KSP -4; F_1 and F_2 – lens with focal distance 94 ÷ 110 mm; M –

the light beam modulator with frequency ~ 33 Hz; G3 – 7A – sinusoidal voltage generator $\omega_1 \approx 1000 Hz$; TC – thermocouple Cu –Constantan.

The block diagram of spectrometric installation is in the figure 1. The reflection coefficient modulated in alternating electric field with the frequency ~ 1 kHz. It is used the lamp DKSS – 1000 with arc discharge in Xe atmosphere. This lamp generates the continuous spectra in the spectral domain 250 ÷ 820 nm (figure 2). The figure 2 present also the emission spectra of lamp with wolfram filament [6]. The xenon lamp is used in such experiments because these light sources change the intensity of light beam by 1,2 times in the wavelength domain from 350 nm to 800 nm whereas the etalon wolfram lamp changes the same parameter by 2 order (~ 100 times).

The spectral distribution of emission at the temperature ~ 300 K of etalon lamp SI - 8 with wolfram plate (curve 1) and the DKSS – 1000 lamp with arc discharge in Xe atmosphere (curve 2) are shown in figure 2. The emission spectra of both sources, measured with Vth-1 thermometer with SiO_2 window are standardized to 1.

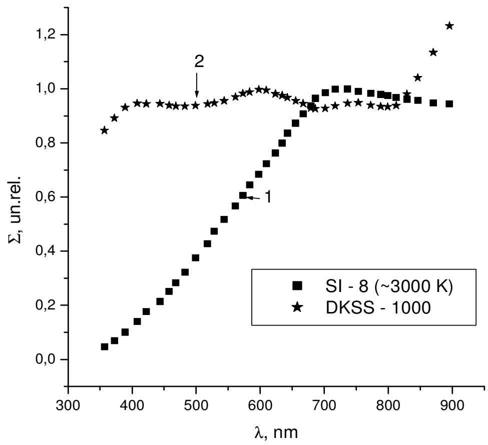

Fig.2 : The spectral distribution of etalon lamp SI – 8 type and DKSS – 1000 lamp.

The light beam focused on entrance slot plane of monocromator MDR – 2 is transformed in symmetric light - dark impulses with the frequency $\omega_1 \approx 29 Hz$ using the modulator M. The beam with the known wavelength go out from the monocromator and it focalize on sample surface (the CdS-CdTe heterojunction) through CdS layer. The sinusoidal voltage (~ 3 V) with the frequency ~ 1030 Hz, from the G3 – 7A generator, applied to the Ni and SnO_2 electrodes. The ~ 1,5 V voltage from the same source serve to compare the signal from the phase detector (8) which has the own sinusoidal voltage with the frequency ω_1, generated by photo multiplier.

The frequencies ω_1 and ω_2 are chosen in the way that they never coincide with the voltage harmonics of power supply (50 Hz) as well as they have to be different from the maximum of entrance signal because they can influence reciprocal the amplification channels. The ω_1 frequency has to be small because the capacity resistance of sample does not shunt the selective amplifier. This could be verified if the electric field is applied at the contact interface of junction CdS-CdTe.

3. RESULTS AND DISCUSSION

The reflected light from the sample consists of two harmonics. One with the frequency ω_2 that encode the information about the reflection coefficient $R = \frac{I_1}{I_0}$, where I_0 is the intensity of incident beam. The second harmonic I_1 is the intensity modulated by frequency of electrical field applied to the sample, which contain the information about the variation of reflection coefficient ΔR as the result of the action of electrical field with the frequency ω_1. The connection of electronic elements (7) – (9) and (5) of block diagram keep constant the signal I_1 in the spectral sensibility domain of work unit. The signal obtained in this way from the phase detector (8) after rectification is recorded on tape (10) and represent the relationship $\frac{\Delta R}{R}$.

It was done the test experiments in which the electrical field was photo generated by laser beam He-Ne ($\lambda = 0,6328\mu$) through the CdS layer of heterojunction. The light with this wavelength generate the electron – gap pair at the interface layer of heterojunction (the depth of penetration of light in CdTe layer is ~ 10 ÷ 20 nm). These electric carriers create the electrical alternating field that is applied just to the interface layer of heterojunction.

4. CONCLUSIONS

The important role in the study of semiconductor materials has the optical measurements that are very simple to execute and the original analyzed sample are not destroy. The experimental unit for modulated methods was made by our team. Using this diagram bloc the variation of absorption coefficient spectra from wavelength ($\Delta\alpha/\alpha\Delta\lambda$) and from electrical field ($\Delta\alpha/\alpha$) was studied.

The reflection coefficient ($\Delta R/R$) modulated by wavelength and electrical field was studied. The spectral domain for experiments were 3,5 ÷ 15 eV and the temperature domain was from 78 K to room temperature.

The relationship between the basic optical parameters of semiconductor materials $\Delta\varepsilon_1$, $\Delta\varepsilon_2$, Δn and Δk was analyzed. In addition, the characteristics of electromagnetic radiation obtained using different modulated methods, such as wavelength (λ - modulated), was studied.

The physical parameters of semiconductor crystals can be examined using the block diagram presented in the paper.

5. AKNOWLEGMENTS

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