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PHOTOREFLECTANCE OF GaAs DOPING SUPERLATTICES

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Photoreflectance of GaAs doping superlattices has been measured at 300K. The spectra exhibits features corresponding to spatially direct transitions due to quantized electron or hole states. We demonstrate the utility of the photoreflectance technique for studying quantum size effects in doping superlattices.

Electromodulation is an extremely valuable method for investigating the semiconductors and their interfaces.[1] Recently several researches of electroreflectance[2,3] (ER) and photoreflectance (PR)[4,5] on semiconductor compositional superlattices and quantum well structures (mainly in GaAs-$Ga_{1-x}Al_xAs$ system) have been reported. The PR is a contactless form of electromodulation spectroscopy, in which the optical constants are modulated by the photo-injection of electron-hole pairs by a secondary (pump) light source. As in ER, such a modulation produces "third derivativelike" features of the optical dielectric function in the vicinity of critical points. Consequently, even at room temperature very sharp differential reflectance lines can be observed.

In this letter we report photoreflectance of GaAs doping superlattices at 300K. We demonstrate the utility of the PR technique for studying quantum size effects in doping superlattices. A fit of the spectra to the Aspnes third-derivative functional form (TDFF) lineshape expression[1] is performed. This enables us to accurately determinate the energies of the electromodulation features from the microstructural geometries. The doping superlattice samples used in our experiment were grown by MBE with a home-made MBE equipment at the Institute of Semiconductors, Academia Sinica. These doping superlattices, which consist of very thin alternate layers of n-and p-doped GaAs, has a tunable optical band-gap and extremely long minority carrier lifetime due to the spatial separation between electrons and holes in the n and p layers. In addition

to these unique features, the doping superlattices also exhibit quantum size effects similar to those observed in quantum wells. The experimental arrangement for PR has been described in ref.6. The measurements were carried out at 300K using the 6328Å line of a He-Ne laser as the pump beam with a power density of about 10mW/cm². The pump beam was chopped at 270Hz. The measurement conditions were such that the lineshapes were independent of the intensity of the pumping beam.

Figure 1 shows the PR spectra (solid lines) from sample 107# and 105# at 300K, respectively. The origin of the peaks are indicated by arrows in the figure. The feature labelled E_0 corresponds to the direct band gap of GaAs. This feature appears to originate from the GaAs substrate. The structures in the energy range 1.430-1.520eV are identified to correspond to spatially direct transitions due to quantized electron or hole states rather than Franz-Keldysh oscillations. The dotted lines in fig.1 are a fit of the experimental data to the Aspnes TDFF expression. The energies for the various quantum transitions are listed in table 1.

Table 1.

	1HH-CB(eV)		VB-1e(ev)		1LH-CB(eV)		VB-2e(eV)	
sample	exp.	theory*	exp.	theory	exp.	theory	exp.	theory
107#			1.447	1.450	1.465	1.470	1.495	1.500
105#	1.436	1.448	1.455	1.454	1.478	1.476	1.503	1.511

* $m_c^* = 0.0665\ m_0$ (ref.3).

We have performed theoretical calculations for the energies of these levels using known expressions for the electrons[7]:

$$E_{cn} = h(4\ e^2 N_D / K_0 m_c^*)^{\frac{1}{2}}(n+\tfrac{1}{2}) \quad ,$$

and corresponding expressions for the light and heavy holes. The experimental results are in good agreement with that of the theory shown in table 1.

Figure 2 shows the PR spectra of the sample 107# from the E_1 energy region. The topmost trace shown in fig.2 is a PR spectrum of bulk GaAs. It can be observed from fig.2 that the PR features of doping superlattices shift to higher energies. This also show the quantum size effects in doping superlattices.

In conclusion, PR of GaAs-doping superlattices has been measured at 300K. We have observed a number of PR features corresponding to spatially direct transitions due to quantized electron or hole states, and demonstrated the great potential of the PR technique for studying quantum size effects in doping superlattices.

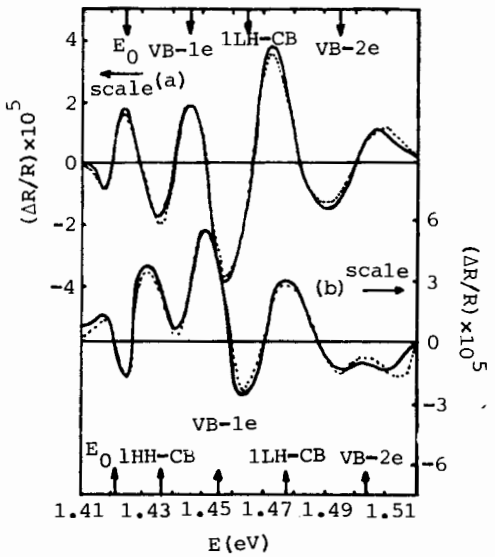

Fig.1 Room-temperature PR spectra for (a) sample 107# ($N_A=N_D=1.5\times10^{18}cm^{-3}$; $d_n=d_p=150\mathring{A}$) and (b) sample 105# ($N_A=N_D=2\times10^{18}cm^{-3}$; $d_n=d_p=400\mathring{A}$). The energies of the various features are indicated by arrows.

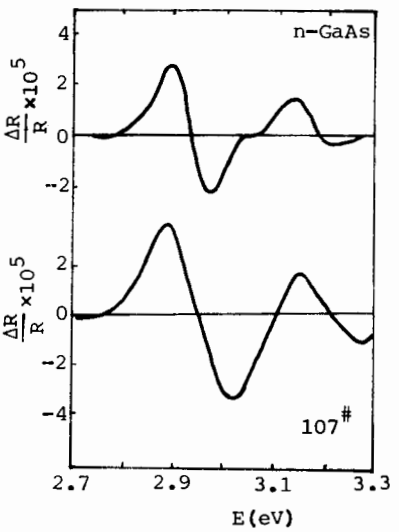

Fig.2 PR spectra in the E_1 energy region.

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