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CHARACTERIZATION OF THE BAND BENDING IN ZnSe–GaAs HETEROJUNCTIONS BY RAMAN SCATTERING*

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The band bending effect at the ZnSe–GaAs interface was studied by means of Raman scattering induced by electric-field related to longitudinal-optical (LO) phonons. It has been shown that the variation of the band bending in GaAs can be modified by changes in the electron concentration of ZnSe epilayer and the variation of the sample temperature.

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In recent years Raman scattering in semiconductors has been used as a useful tool to study the electrooptical properties of interfaces in heterostructures [1–3]. This kind of studies has been mainly concentrated on III–V heterostructures. Much less attention was given to the effects induced by a II–VI epilayer when grown on III–V semiconductor substrate (e.g. barrier height, Fermi level pinning, and recombination velocity [4]).

In this paper we present Raman scattering spectra for ZnSe epilayers grown by molecular beam epitaxy on GaAs substrate [5]. The ZnSe epilayers were deposited at 555 K on the (001) surface of GaAs substrates with bulk carrier concentration of 2×10^{18} electrons/cm^3 from elemental sources of ZnSe. The growth rates were in the range of 0.4–0.8 μm/h. The Se/Zn beam pressure ratio of about 2 was employed.

The Raman polarized spectra were measured at room temperature and 600 K using back-scattering geometry. An argon ion laser operating at 458 nm with the output power 140 mW as a source of light was used. The more details of the measurement were described elsewhere [6].

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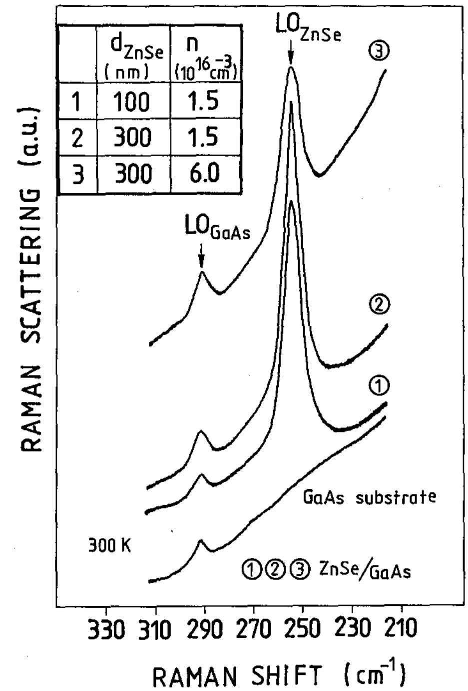

Fig. 1. Raman spectra of the ZnSe–GaAs heterojunctions with different thicknesses and different free carrier concentrations of the ZnSe epilayer obtained at RT. For comparison the Raman spectrum of the air-exposed GaAs surface is also included.

The properties of the ZnSe epilayers with both different thicknesses and different free carrier concentrations were studied with electric-field induced Raman scattering by LO-phonons. In Fig. 1 the typical polarized Raman spectra for selected values of free carrier concentration and different thicknesses of ZnSe epilayers are presented. The peak frequencies at room temperature are 292 cm^{-1} and 250 cm^{-1} for LO_{GaAs} and LO_{ZnSe}, respectively. As seen from the Fig. 1, the LO_{GaAs} intensities are stronger for the ZnSe-GaAs heterojunctions than for the GaAs substrate. When compared LO_{GaAs} mode in ZnSe–GaAs heterostructures with the air-exposed surfaces of the GaAs substrate as a reference, the LO_{GaAs} intensities increased when the free carrier concentration in ZnSe epilayer increased (Fig. 1, curve 1 and 3). Similar behaviour was observed when the thicknesses of the ZnSe epilayers increased (Fig. 1, curve 1 and 2). As one can also see from Fig. 1 (curve 2 and 3) the LO_{ZnSe} mode broadens and its intensity decreases as the free carrier concentration increases. These results suggest that the plasmon in n-ZnSe epilayers has large damping rates and the LO_{ZnSe} phonon in thicker (and with higher free carrier concentration) epilayers is coupled with the plasmon. The line shape analysis of the coupled LO_{ZnSe} mode has shown that the dominant

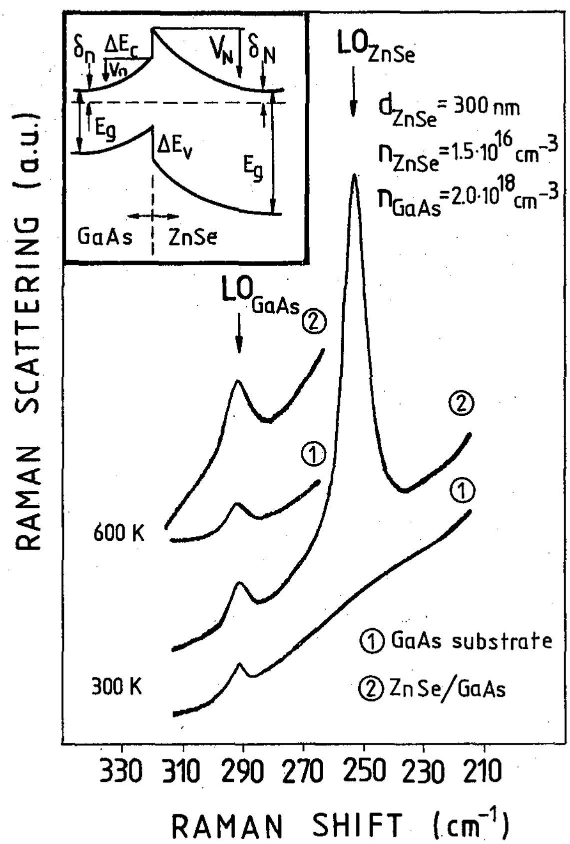

Fig. 2. Raman spectra of the ZnSe–GaAs heterojunction and the air-exposed GaAs surface obtained at different temperatures. In inset – the band structure of the n-ZnSe/n-GaAs heterojunction, where: ΔE_c, ΔE_v – the offsets in the conduction and valence band. δ_n, δ_N – the Fermi level position measured from the bottom conduction band in n-type GaAs and ZnSe, respectively. V_n, V_N – the band bending of the conduction band of the GaAs and ZnSe, respectively.

phonon scattering in n-type ZnSe epilayers is caused by the deformation potential, electro-optical and charge density fluctuation mechanisms [7, 8]. The electric-field induced scattering mechanism is the main scattering process for the LO_{GaAs} mode. Moreover, the variations of the LO_{GaAs} intensities with the thickness of ZnSe epilayer at the ZnSe-GaAs interface indicate that the electric field has changed here as compared with the situation at the air-exposed surface of the GaAs substrate [1, 9]. The electric-field-induced contribution to the LO intensities is in the first order linearly proportional to the magnitude of the band bendings (V_n – for GaAs and V_N – for ZnSe) [1, 9]. The ratio α of the intensities between the LO_{GaAs} peaks of the ZnSe–GaAs heterojunctions and the air-exposed surface of GaAs at RT are 2.17 and 1.86 for $d = 100$ nm and $d = 300$ nm thick ZnSe epilayer, respectively. We have assumed that for the air-exposed GaAs surface the Fermi level is pinned at around midgap and the band bending of GaAs, $V_n = 0.8$ eV [10]. For this value the band bending at ZnSe–GaAs interface $V_n \times \alpha$ are equal 1.60 eV ($d = 300$ nm) and 1.86 eV ($d = 100$ nm). These values are in good agreement with the values estimated by photo-luminescence measurement [2]. Figure 2 shows the first order Raman spectra measured at RT and 600 K for the typical ZnSe–GaAs heterostructures and for an air-exposed, uncoated surface of the GaAs substrate. The changes in the intensity of the LO_{GaAs} mode with temperature displayed in Fig. 2 indicate that the ZnSe epilayers are modifying the band bending at the interface [1]. The higher LO_{GaAs} intensities correspond to the increased strengths of the electric field and higher surface potentials (V_n) [9].

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