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GaSb-AlSb QUANTUM WELLS. ELABORATION AND OPTICAL PROPERTIES

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RESUME

Nous présentons les résultats de caractérisation des surfaces au cours de la préparation et les propriétés optiques d'un puits quantique.

ABSTRACT

We present the results of surface characterization with respect to the preparation process and some optical properties relevant to the quantum well structure.

INTRODUCTION The mismatch between GaSb and AlSb is small ($\frac{\Delta a}{a} = 7.10^{-3}$). The interface is strained, but this strain is not too high and therefore the interface quality is good enough to permit interesting studies of the effects induced by the strain. This paper is devoted to a strained GaSb-AlSb single quantum well structure obtained by the confinement of a GaSb layer between two AlSb spacer layer (1). We describe the main features of the elaboration processes and present a study of the low temperature electroluminescence, reflectance and photoluminescence of a single GaSb-AlSb quantum well.

ELABORATION. GaSb-AlSb QW obtained by confinement of GaSb between two spacer layer of AlSb are type I hetero-interfaces system (2). It is necessary to be able to fabricate reproducible high quality interfaces. We have used the Molecular Beam Epitaxy (MBE) growth process and a characterization technique capable of giving details about the quality of an interface. The home-made apparatus used consists of three chambers : a loading chamber, an analysis chamber and a deposition chamber (3). Transportation between chambers is carried out by a magnetically coupled transfer rod. The growth chamber is equipped with a RHEED system and a quadripolar mass-spectrometer. The analysis chamber allows AES and surface potential measurements 0 by the Kelvin probe (4).

The GaSb (100) substrates were indium-soldered on to the sample holder and chemically polished in a Brome-Methanol solution. Then, they were heated at 580°C under Sb₂ plus Sb₄ flux, under these conditions the oxide film was removed, the surface was clean and presented good RHEED pattern.

The sample studied consisted of a substrate with a 1 μm GaSb buffer layer, and a quantum well grown with the following sequence : a 1 000 $\text{\AA}$ thick AlSb barrier, a 90 ± 5 $\text{\AA}$ GaSb well, 200 $\text{\AA}$ AlSb barrier and finally a 90 $\text{\AA}$ of GaSb passivation layer to prevent oxidation of AlSb. AlSb and GaSb were grown at 560°C with flux ratios V/III ≈ 3 ; the growth rates maintained at ≈ 1 $\text{\AA}/\text{s}$. Under these conditions we observed the same surface reconstruction (1×3) during the growth of GaSb and AlSb layers. (see the fig. 3 insert).

SURFACES AND INTERFACES CHARACTERIZATIONS RESULTS. The growth was initiated onto oxide free smooth GaSb substrate surface Sb depleted (0.3 atomic-monolayer) and with residual carbon contamination less than $5 \cdot 10^{-2}$ monolayer (fig. 1b). The work function (WF) increases because of superficial oxide layer desorption (fig. 2).

The growth layer was monitored in situ using RHEED which provided information on both the film smoothness and the surface reconstructions. Spotty bulk-like patterns when the thickness of the layer is in the 20-70 $\text{\AA}$ range illustrate the rough growth due to substrate surface roughness (3). No further changes were observed in this pattern, which is characteristic of Ga(Al) stabilized (1×3) and Sb stabilized (2×3) or c (2×6) surface reconstructions. The work function topographies (T.W.F) are nearly flat (fig. 2), $\Delta\phi$ inhomogeneities are smaller than 100 meV on GaSb and AlSb layers. Our TWF measurements indicate that WF (AlSb)-WF (GaSb) ≈ 200 meV.

FIGURE 1 : AES SPECTRA

- a/ Chemically polished GaSb substrate.
- b/ Clean GaSb substrate
- c/ GaSb epilayer

FIG. 2 : WORK FUNCTION TOPOGRAPHIES
CHEMICALLY POLISHED (a), CLEAN SUB-
STRATE (b), GaSb (c) AND AlSb (d) epi-
layers.

The GaSb-AlSb interface is studied during the formation by RHEED. The continuity of the diffraction streaks throughout the entire growth of the quantum well structure indicates the smoothness and abruptness of the hetero-interfaces despite the significant lattice mismatch. The study of physico-chemical and electrical characteristics of GaSb-AlSb interfaces are reported in this conference (5).

OPTICAL PROPERTIES. The 30 K electroreflectance (ER) spectrum shown in fig. [3] exhibits several structures. The first one near 831 meV comes from the contribution of the exciton A_0-X in GaSb quantum well. Assuming 5×10^{-3} for the ϵ_1 GaSb strain, 40 meV for the heavy hole valence band offset E_{HH} and standard values for the AlSb and GaSb band parameters [6], one obtains using the multi-band envelope function formalism [7] the energies of the main structures of the ER spectrum ($LH_1 \rightarrow E_1 = 845$ - meV, $HH_1 \rightarrow E_1 = 872$ meV, $HH_2 \rightarrow E_2 = 1076$ meV, $LH_2 \rightarrow E_2 = 1092$ meV and $LH_1 \rightarrow E_3 = 1.26$ eV [8]). Between 0.92 eV and 1 eV a three fold structure appears. In view of its anomalous electric-field dependence and the absence of expected QW transition in this energy range, this structure seems to be due to the surface quantum well formed by the 90 Å GaSb cap-layer. The three lines of the 2 K photoluminescence spectra shown in fig (3) are easily identified : at 779 meV the electron-acceptor $e-A_0$ and at 796 meV the A_0-X bound exciton recombination in the bulk-like GaSb buffer layer. At 831 meV the high intensity line corresponds certainly to a recombination process within the GaSb QW. From comparison with the electroreflectance data it is clear that the QW luminescence arises from the recombination of exciton bound to shallow defects. The corresponding Stokes shift is 14 meV. The linewidth of ≈ 20 meV results from the broadening and the spreading of the defect binding energies.

FIGURE 3 : ER SPECTRUM (—) AND PHOTOLUMINESCENCE (....), FROM STRUCTURE SCHEMATIZED IN THE INSERT.

Reflectance spectra has been performed in the 2-5 eV range for various temperatures. Fig. 4 shows the 4 K reflectance spectra. The reflectance structures correspond to transitions between higher band extrema of the GaSb (bulk, QW and cap-layer) or fundamental and higher extrema of AlSb (1000 Å and 200 Å spacers). Energy transitions are obtained using second derivative technique on the reflectance spectra. In the low energy range as in bulk-GaSb the E_1 transition occurs at 2.18 eV [9]. The 2.16 eV structure corresponds to the E_1 transition of the QW or the GaSb cap-layer. For the E_1 gap quantum effects are smaller than near the E_1 gap due to lower energy barriers and higher effective masses [10]. So the observed 20 meV red shift arises primarily from the strain which lowers the E_1 gap of the QW or GaSb cap-layer. The reflectance spectra also shows the $E_1 + A_1$ gap of GaSb at 2.6 eV, the E_1 (2.94 eV), $E_1 + A_1$ (3.35 eV) gap of AlSb. The structure near 4.4 eV corresponds to the E_2 edge of GaSb and AlSb. All these energies transitions are in agreement with bulk-values [9,11,12,13].

FIGURE 4 : REFLECTANCE FROM GaSb-AlSb QW STRUCTURE.

CONCLUSION. A high quality GaSb-AlSb QW structure has been grown. The quality and properties of surfaces and interfaces has been characterized with respect to the elaboration process. These structures present nice electroreflectance, reflectance and photoluminescence properties, the analysis of which can be correlated to confinement energy effect and to the plastic relaxation of AlSb spacer and strained GaSb layer, consistent with mean features of the structure.

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