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Interface states of AlSb/InAs heterointerface with AlAs-like interface

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1. Introduction

Heterostructures combining InAs with GaSb and/or AlSb exhibit a wide range of energy gaps and other properties due to there unique band configuration and their material properties. Thus the heterostructures have been applied not only to conventional devices such as field effect transistors and resonant tunneling diodes, but also to novel devices such as quantum cascade laser etc. In those heterostructures, their interface conditions become significant because anion and cation atoms completely changed at the interface in contrast to the common anion (Al,Ga)As heterostructure: e.g., for AlSb/InAs, both InSb-like and AlAs-like interface are possible due to the alignment of the anion and cation. In the case of AlSb/InAs, two-dimensional electron system, the InSb-like interface has exhibited an order of magnitude higher electron mobility than that with the AlAs-like interface and additional interface electron due to anticite As defects at interface [1], and optical properties, especially photoluminescence (PL) properties depends not only their interface but also buffers whose candidates are InAs, GaSb and AlSb [2]. For an example, multiple quantum wells (MQWs) with the AlAs-like interface grown on InAs buffer has exhibited better PL properties than that with the InSb-like interface [2]. Due to those results, their interface properties still have some questions. As a physical model of the interface states, Tamm states at the InSb-like interface has been proposed [3], however, there have been no report for the AlAs-like interface states except the anticite As defects that was confirmed by only additional carrier [1]. To clarify the interface states of AlSb/InAs heterostructure, we have experimentally studied those heterostructure with the AlAs-like interface.

2. Experimental procedure

To study the interface states by optical and electrical properties, MQWs were grown on semi-insulating (100)-GaAs substrates via AlSb buffer because the AlSb behaves better insulating property than that of InAs. Thus actual electrical properties of the MQWs can be observed. All structures were grown by molecular beam epitaxy. Figure 1 shows whole MQW structure with growth temperature. The MQW consisted of 50 periods of 14 mono layer (ML) AlSb for barrier and x ML InAs ($x = 4 - 7$) for well. Alternating shutter sequence (fig. 2) was used to make the AlAs-like interface and the As soaking time was changed to 1 to 20 sec due to non-unity sticking coefficient for the As. These MQWs were evaluated by PL measurement and Hall effect measurement.

3. Results and Discussions

Figure 3 shows As soaking time dependent PL spectra for the MQWs with 4 ML well thickness at 5 K. When the As soaking time increases, the PL disappears in the sample with 20 sec As soak. The origin of the phenomena would be originated from anticite As defects because an amount of the anticite defects did indeed increase with increasing the As soaking time [1]. Figure 4 shows room temperature (RT) PL results for the various well thickness samples with 1 sec As soak. The PL intensity were essentially same except for the sample with 6 ML well thickness and the PL intensity for the sample with 6 ML well thickness was over 2 times lower than those of other samples. To clarify the phenomenon, electrical property was evaluated by Hall effect measurement. Consistent results for carrier concentration and mobility couldn't observe in the Hall effect measurement, however, resistivity behavior seemed to be consistent within same samples. Over 100K (5M per well) $\Omega\mathrm{cm}^2$ resistivities were observed in all samples (fig. 5). This high resistivity, which is originated from quite low mobility in proportion to $1/thickness_{well}{}^{6}$ [4], might be responsible for the inconsistent Hall measurement. However resistivity decreased with increasing well thickness [4] except for the sample with 6 ML well thickness. Comparison between the PL and the resistivity results shows that the sample with 6 ML well thickness has inferior interface quality than those of other samples. Therefore a kind of defects which perturb optical and electrical properties, might be presence and the defects states might be located around 0.8 eV above valence band edge of AlSb because band configuration is type-II resulting QW of valence band located at the AlSb.

4. Conclution

We have studied optical and electrical properties of the InAs/AlSb MQWs with the AlAs-like interface. Distinguishable features were observed in the PL and the Hall effect measurement for the 6 ML well sample. Therefore, we might find out a kind of defect states which might be associated with the AlAs-like interface states.

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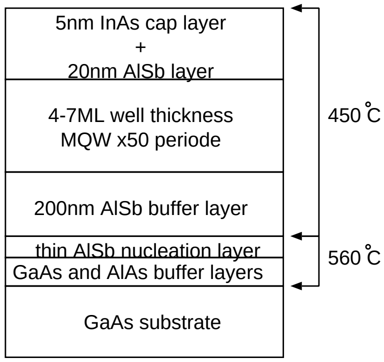

Figure 1: Whole MQW structure with growth temperature used in this study.

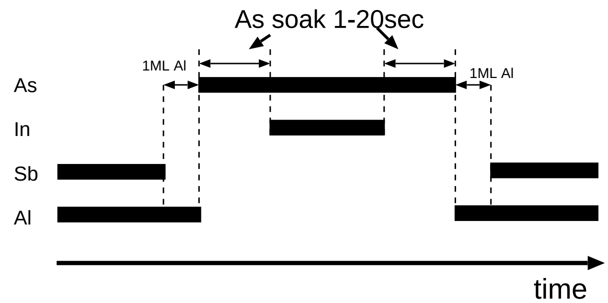

Figure 2: The shutter sequencing used to grow QW with the AlAs like interface.

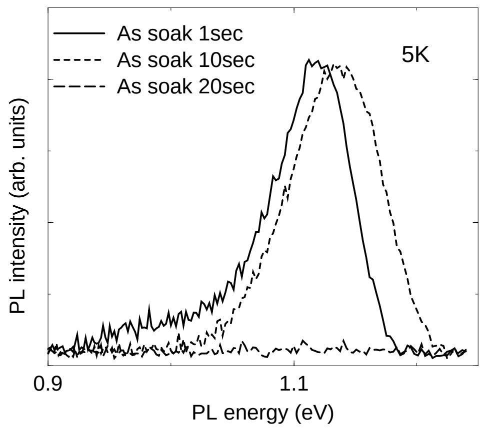

Figure 3: PL spectra of 4ML well thickness samples at laser intensity of 10 mW at 5 K.

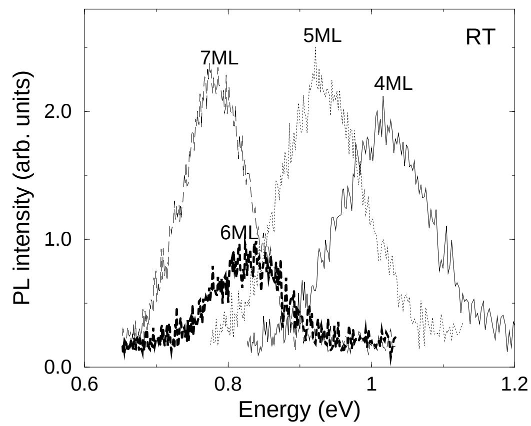

Figure 4: Room temperature PL results for the various well thickness samples with 1 sec As soak at laser intensity of 10 mW.

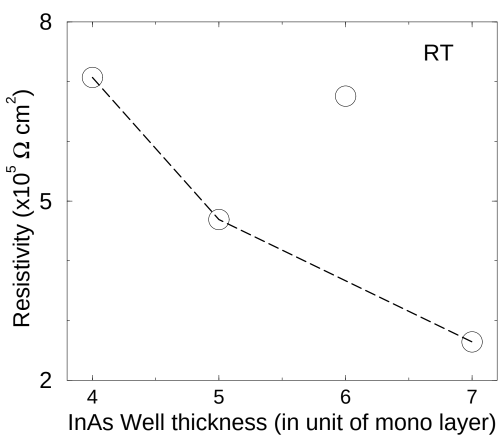

Figure 5: Room temperature resistivity for the various well thickness samples with 1 sec As soak.