

## Real space imaging of electronic states in inverted InAs/GaSb quantum well systems

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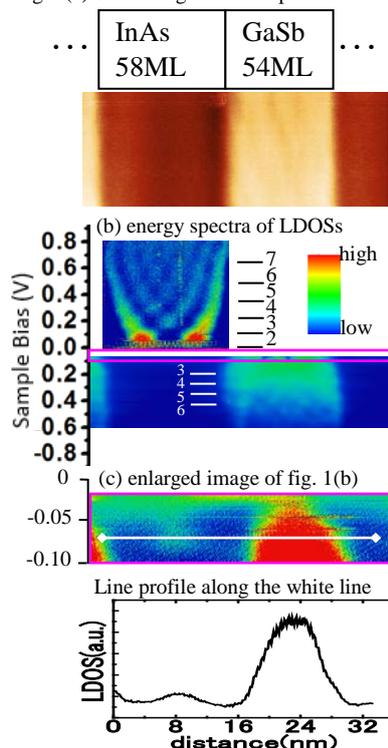
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Since InAs/GaSb heterojunctions have type-II band lineup, their quantum well systems(QWs), in which the lowest electron subband designed to be lower than the highest hole subband, can be 2D-topological insulators(TIs) with 1D-edge states. Although the properties of the edge states in the QWs have been investigated by transport measurements[1] so far, the real space imaging of the edge states is still missing. Several studies about the real space imaging of topological 1D-edge states by STM/STS(scanning tunneling microscopy/spectroscopy) technique have been already reported on the surface of Bi-bilayer[2] and graphene-bilayer[3] systems. Although the electronic subbands in InAs/GaSb QWs having normal electronic structures had been investigated by STS technique[4], the electronic states in inverted InAs/GaSb QWs have not been well investigated yet.

Multiple InAs/GaSb SLs having different layer thicknesses, were grown on a n-type InAs(001) substrate by molecular beam epitaxy. The sample was cleaved in UHV and was observed at a low temperature of around 4.5 or 78K using a STM system with a W-tip in UHV( $< 2 \times 10^{-10}$ Torr).

Figure 1(a) shows a STM image on the cleaved (110) surface of a InAs(58ML)/GaSb(54ML) QW. Fig. 1(b) shows the energy profile of local density of states(LDOSs) obtained by a  $dI/dV$  measurement. The numbers shown in the figure are the subband indices estimated from the anti-node number of each standing wave. The arrangement of electron and hole subbands suggests that band inversion is achieved in the present QWs, namely the lowest electron-subband is located lower energy than the highest hole-subband. Furthermore, the wave functions of this energy region have its probability density both in InAs and GaSb layers as shown in fig. (c), which is the enlarged LDOS profiles at the energy gap region. This suggests that the LDOS consists of both the edge states and inverted subbands.

Fig. 1(a) STM image on the superlattice



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