Molecular beam epitaxy growth of near surface InAs two-dimensional electron gas for topological quantum computation

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Hybrid superconductor-semiconductor heterostructures subjected to an in-plane magnetic field have experimentally demonstrated their potential to host non-abelian Majorana Zero Modes (MZMs) in both bottom-up nanowires [1] and recently with two-dimensional electron gas (2DEG) [2], the latter allowing scalable top-down fabrication of more and more complex devices. Specifically, MZMs have been observed with InAs 2DEG grown on InP (100) substrates. However, the large lattice mismatch (3.3%) between these two materials result in threading dislocations and surface roughness that play a prominent role in electronic transport by introducing disorder.

To address this issue, we consider the molecular beam epitaxy (MBE) growth of InAs 2DEG on quasi-lattice matched GaSb (100) substrates (lattice mismatch of -0.6%). As GaSb is not perfectly insulating, the growth of a high bandgap and lattice matched buffer of AlGaSbAs is utilized and allows an isolation between device mesas of the order of the GΩ, as required for density of state measurements in the tunneling regime. The As/Sb incorporation ratio and thus the lattice matching of this quaternary compound are mostly tuned by the substrate temperature. By growing 20 nm deep InAs quantum well on top of 800 nm-thick AlGaSbAs buffer, 2DEG with carrier mobility larger than $2x10^6$ cm²/Vs for a density of about $6x10^{11}$ cm^{-2} is achieved (see Fig. 1).

The MBE growth development of these heterostructures will be reported relying on structural and electrical characterizations. Moreover, we will present our efforts to transform these semiconductor structures into a topological quantum computing platform. This will include optimization of the heterostructure design through the implementation of an in-situ back gate.

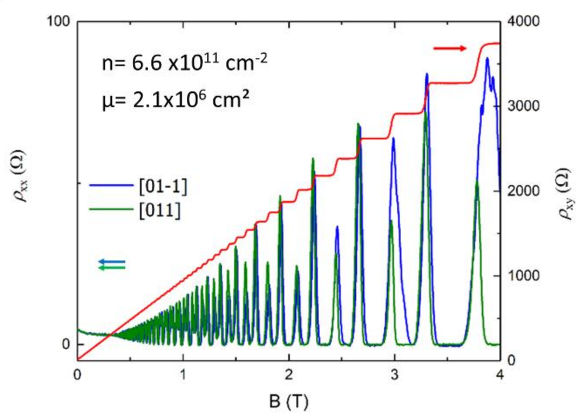

Figure 1- 20 nm deep InAs 2DEG electronic transport measured at 300mK

[1] V. Mourik *et al*., Science, 336, 1003-1007, (2012)
[2] F. Nichele *et al*., Physical Review Letters, 119 (13), 136803, (2017)

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Structural characterizations

High resolution X-ray diffraction analysis has been performed, using a X'pert PANalytical laboratory diffractometer to estimate the strain profile of the InAs/GaSb structure (see Fig. 2(a)) with reciprocal space mapping in the (224) asymmetric reflection. The vertical alignment of the diffraction peaks of Fig. 2(b) with GaSb peak indicates the matching of the in-plane lattice parameters of the full structure and the absence of relaxation. The overlap between the GaSb and AlGaSbAs peaks characterizes the good lattice matching of this buffer. Fig. 2(c) displays a scanning transmission electron micrograph highlighting the crystalline quality of the AlGaSbAs buffer.

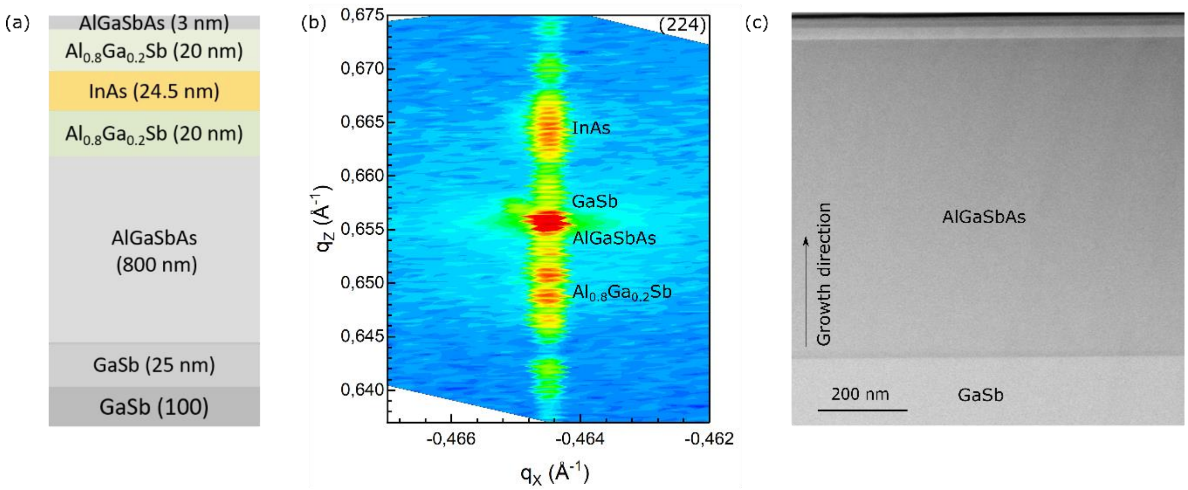

Figure 2: (a) Layer stack of a typical structure of InAs/GaSb. (b) X-ray diffraction reciprocal space mapping in the (224) asymmetric reflection. (c) Scanning transmission electron micrograph in high angle annular dark field mode.