Free-standing InSb nanoflags for quantum device applications

InSb offers a narrow band gap, a high carrier mobility, and a small effective mass, and thus has recently attracted tremendous attention for the implementation of topological superconducting states. Here, we show optimized growth of free-standing 2D InSb nanoflags (NFs) via Au-assisted chemical beam epitaxy (CBE). An electron mobility of 29,500 cm^2/Vs and a mean free path of 500 nm at 4.2 K are measured on Hall-bar devices. InSb NF-based Josephson junctions show gate-tunable proximity-induced supercurrent, with phase-coherent transport and high transparency of the interfaces. Our study places InSb NFs in the spotlight as a versatile and convenient 2D platform for advanced quantum technologies.

High-quality heteroepitaxial two-dimensional (2D) InSb layers are difficult to realize because of the large lattice mismatch with other widespread semiconductor substrates. A way around this problem is to grow freestanding 2D InSb nanostructures on nanowire (NW) stems, thanks to the capability of NWs to relax elastic strain along the sidewalls when lattice-mismatched systems are integrated. Nevertheless, controlling the aspect ratio of freestanding InSb nanostructures is challenging, due to the low vapor pressure of Sb and the surfactant effect. We first investigated the morphology evolution of freestanding InSb nanostructures like NWs (1D), NFs (2D), and nanocubes (NC) (3D) on InAs NW stems by means of Au-assisted CBE as a function of the growth conditions (Fig. 1) [1]. In particular, we found that 2D InSb NFs are single crystalline, defect-free with zinc blende structure, and provide a high degree of freedom in device fabrication. Next, by employing more robust and tapered InP NW stems and precisely orienting the substrate with the aid of reflection high-energy electron diffraction patterns, we could maximize length and width, and minimize the thickness of these NFs (Fig. 2a) [2]. The optimized InSb NFs have been used to fabricate Hall-bar devices, from which we measured electron mobility of 29,500 cm^2/Vs (Fig. 2b) and a mean free path of 500 nm at 4.2 K, which is the highest value reported for free-standing 2D InSb NFs in literature. We also successfully fabricated InSb NF-based Josephson junction devices with Ti/Nb contacts that show gate-tunable proximity-induced supercurrent up to 50 nA at 250 mK (Fig. 2c) and a sizable excess current. The devices show clear signatures of subharmonic gap structures, indicating phase-coherent transport in the junction and a high transparency of the interfaces [3]. We envision the use of 2D InSb NFs for fabrication of advanced quantum devices.

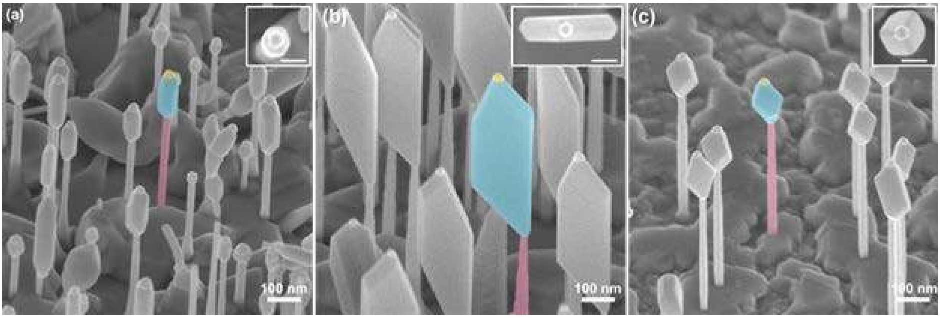

Fig. 1
InAs-InSb hetero-nanostructures with different morphology. 45°-tilted and top view (inset) SEM images of (a) 1D InSb NWs, (b) 2D NFs, and (c) 3D NCs grown on InAs NW stems. All scale bars are 100 nm. The false color is used to highlight the InAs stems (pink) and InSb nanostructures (blue).

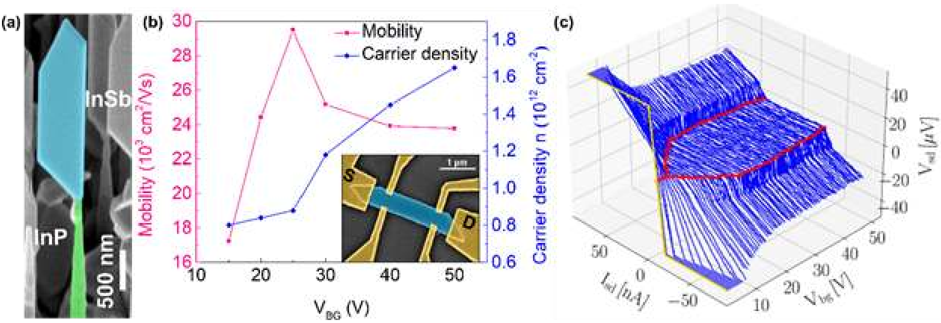

Fig. 2
(a) 45°-tilted SEM image of freestanding InSb NFs on InP NW stems. The false colour is used to highlight the InP stem (green) and InSb NF (blue). (b) Hall mobility and carrier density obtained from Hall measurements. Inset shows the SEM image of an InSb NF Hall-bar device. (c) Voltage drop V_{sd} across an InSb-based Josephson junction versus current bias I_{sd} and back gate voltage V_{bg}. The red line indicates the critical current.

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