Free-standing InSb nanostructures: growth, morphology control and electrical characterization

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Abstract

Indium antimonide (InSb) has a narrow band gap, high carrier mobility, small effective mass, and it is a promising candidate for the implementation of topological superconducting states. Remarkably, the interest in this material has increased in recent years thanks to the possibility to overcome the limitation of its integration with lattice-mismatched substrates in nano-heterostructures. However, the realization of InSb nanostructures with a high crystal quality and a well-controlled morphology is still challenging. In this contribution, we show the growth of free-standing InSb nanostructures on InAs and InP nanowire stems by means of Au-assisted chemical beam epitaxy. We demonstrate that nanowires (1D), nanoflags (2D), and nanocubes (3D) can be obtained by tailoring growth parameters like growth temperature, precursor fluxes, sample rotation, and substrate orientation. Indeed, the InSb shape evolution is a result of the interplay between axial vapor-liquid-solid (VLS) growth, radial vapor-solid (VS) growth, and possibly directional-driven growth. Concerning the nanoflags, through morphological and crystallographic characterization we demonstrate that they are single-crystalline with a defect-free zinc blende structure and stoichiometric composition. The existence of two families of nanoflags, characterized by an aperture angle at the base of 145° and 160°, is observed and modelled [1]. Finally, we have further optimized the size of these free-standing 2D InSb nanoflags. In fact, by employing more robust and tapered NW stems and precisely orienting the substrate with the help of reflection high-energy electron diffraction (RHEED) patterns, we could maximize length and width, and minimize the thickness of the nanoflags [2]. This allowed us to fabricate Hall-bar devices with suitable length-to-width ratio enabling precise electrical characterization of single nanoflags. An electron mobility of ~29,500 cm2/Vs at 4.2 K was measured, which is the highest value reported for free-standing 2D InSb nanostructures in literature. We have also successfully fabricated ballistic Josephson junction devices with 10/150 nm Ti/Nb contacts that show gate-tunable proximity-induced supercurrent (∼ 50 nA at 250 mK) [3]. The devices also show clear signatures of subharmonic gap structures, indicating phase-coherent transport in the junction and a high transparency of the interfaces. Our study provides useful guidelines for the controlled growth of high-quality InSb nanostructures with different shapes and evince the use of 2D InSb nanoflags for fabrication of advanced quantum devices.

References

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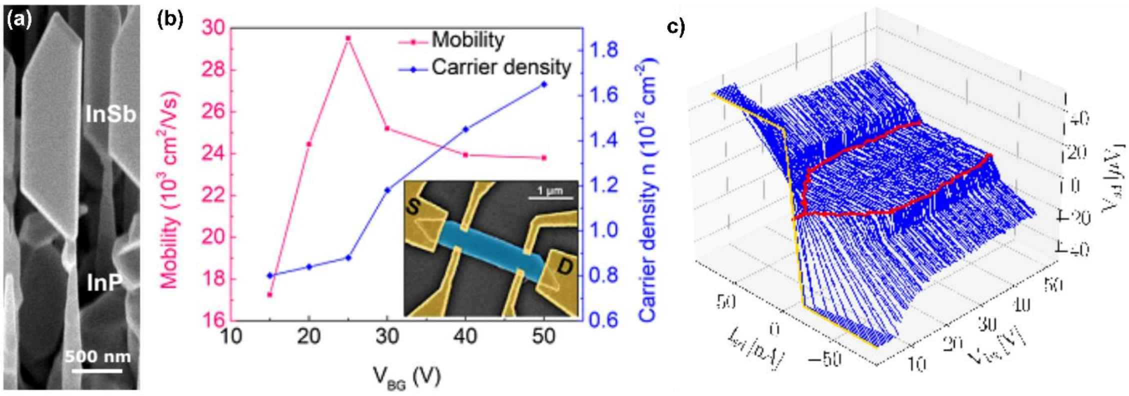

Fig. 1. (a) 2D free-standing InSb nanoflags grown on InP nanowire stems. (b) Mobility and charge carrier density obtained from Hall measurements. Inset shows the SEM image of an InSb nanoflag Hall-bar device. (c) Differential resistance dV/dI of an InSb-based Josephson junction versus current bias Ibias and back gate voltage V_{bg}. The red line indicates the critical current.