Electronic Supplementary Information:

Carbon-doping of InSb nanowires for high-performance p-channel field-effect-transistors

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Figure S1. Schematic illustration of the NW growth setup (both with and without the in-situ carbon doping).



Figure S2. (a) SEM image and (b) EDS spectrum (collected from the corresponding SEM observation) of intrinsically undoped n-InSb NWs; (c) SEM image of a back-gated n-InSb NWFET with Ni metal contacts and (d) transfer characteristics of the representative NWFET, demonstrating the intrinsically n-type electrical conduction.



Figure S3. SEM image of the carbon-doped InSb NWs grown with the use of 0.2 nm thick (nominal thickness) Au catalyst film with the optimized growth conditions.

As shown in the SEM image, it clearly demonstrates that the NWs are grown with significant surface coating which can be attributed to the Gibbs-Thomson effect that Sb supersaturation in the catalyst is reduced due to the high Sb vapor pressure in small diameter catalysts (*ACS Nano*, 2013, **7**, 3668). This way, higher precursor partial pressures are needed for the nanowire nucleation and easily yield the uncontrolled overgrowth/surface coating (*Nanotechnology*, 2013, **24**, 202001). Although thinner InSb nanowires ~10 nm in diameter have been previously reported (*Materials Chemistry and Physics*, 2010, **121**, 397), the growth mechanism involved is believed to be entirely different from this current work.



Figure S4. Epitaxial growth of p-type InSb NWs from $AuIn_2$ catalyst alloy. (a) In(111) sublattice in InSb(111) plane, (b) In(111) sublattice in $AuIn_2(111)$ plane, (c) In(110) sublattice in $AuIn_2(110)$ plane, and (d) In(100) sublattice in $AuIn_2(100)$ plane. Since the lattice mismatch between InSb(111) and $AuIn_2(111)$ is the smallest among all orientations, InSb(111) NWs are thermodynamically preferable to grow epitaxially from the $AuIn_2(111)$ orientated catalyst alloys.



Figure S5. Schematic illustration of the growth mechanism of Au-catalyzed p-InSb NWs in our studies. (a) Formation of Au nanoparticles from the 2.5 nm thick Au catalyst film after annealing; (b) $AuIn_2$ alloy seeds are formed by the diffusion of In atoms into the Au catalyst particles; (c) InSb NWs are grown by supplying Sb constituents and carbon dopants to the interface between the NW tip and body and then reacting with In from supersaturation in the catalytic tips; (d) Continuous axial growth of the InSb NWs.



Figure S6. High-resolution XRD spectra of InSb (111) peaks.

When measured at the scan resolution of 0.001° , the undoped and carbon-doped InSb (111) peaks are determined at 23.896° and 23.898°, respectively, with the Gaussian peak fit as well as after the correction with Si (004) substrate peak. In this case, based on the Bragg's Law, the carbon doped NW has a smaller lattice (0.001 Å) than the undoped ones. This way, the corresponding carbon concentration can be estimated by the Vegard's Law (*Applied Physics Letters*, 1990, **56**, 1040):

 $\Delta a = (4/3^{1/2}) \times (\Delta r_{In}C_{In} + \Delta r_{Sb}C_{Sb}) / (InSb_{atomic density}/2)$

where Δa is the change of lattice parameter, $\Delta r_{In} = 0.69$ Å, is the difference between the C and In covalent radii, $\Delta r_{Sb} = 0.61$ Å, is the difference between the C and Sb covalent radii, C_{In} is the concentration of C on In sites, C_{Sb} is the concentration of C on Sb sites and atomic density of InSb is 2.94 x 10^{22} cm⁻³. Since the electrical measurement provides a clear indication of the p-type doping, the substitutional C_{Sb} concentration must be higher compared with the substitutional C_{In} concentration, dominating the lattice mismatch (*Journal of Physics D: Applied Physics*, 2008, **41**, 025304). In this regard, for the Δa of 1×10^{-3} Å, the C_{Sb} concentration can be estimated as ~ 1×10^{19} cm⁻³, which is larger than the active carbon concentration of ~ 8×10^{17} cm⁻³, showing about 8% of the doping efficiency.