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Letter

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Crystal Structure and Transport in Merged InAs Nanowires MBE Grown on (001) InAs

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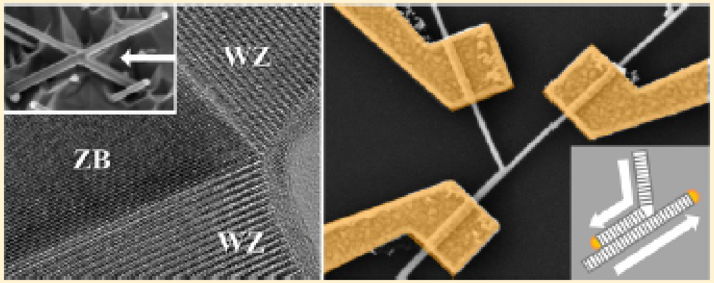
S *Supporting Information*



ABSTRACT: Molecular beam epitaxy growth of merging InAs nanowire intersections, that is, a first step toward the realization of a network of such nanowires, is reported. While InAs nanowires play already a leading role in the search for Majorana fermions, a network of these nanowires is expected to promote their exchange and allow for further development of this field. The structural properties of merged InAs nanowire intersections have been investigated using scanning and transmission electron microscope imaging. At the heart of the intersection, a sharp change of the crystal structure from wurtzite to perfect zinc blende is observed. The performed low-temperature conductance measurements demonstrate that the intersection does not impose an obstacle to current transport.

KEYWORDS: *InAs NWs, merging NW intersections, Y-shape, K-shape, wurtzite, zinc blende, Majorana fermions*

Tilted NW MBE with junctions

Gold-assisted VLS high purity MBE on 001 InAs substrate on Si wafer.
<1nm gold layer riped @ 550°C
InAs MBE @ 400°C with V/III ratio 100
Stacking fault-free (111)B wires.
Random, low yield InAs junctions.

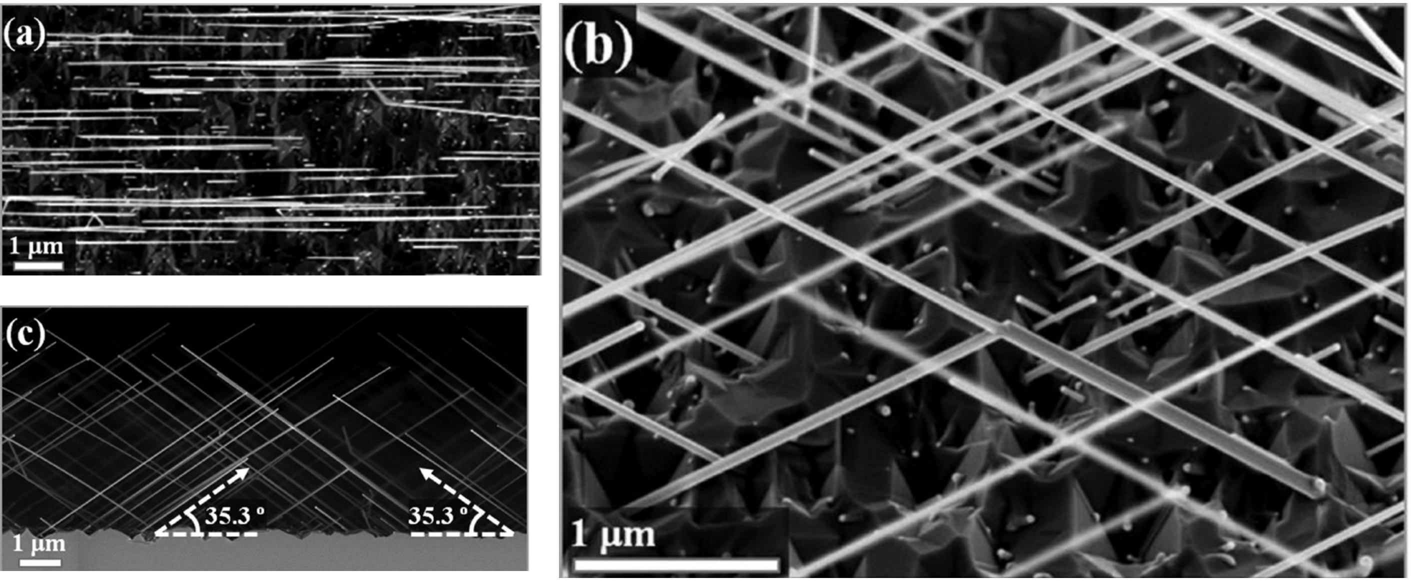


Figure 1. FE-SEM images of ⟨111⟩-oriented InAs NWs grown on (001) InAs substrate seen by (a) top-view; (b) bird's eye-view (45° tilted); and (c) side-view. (The sample edge is aligned along the (011) cleavage plane.)

Junction types

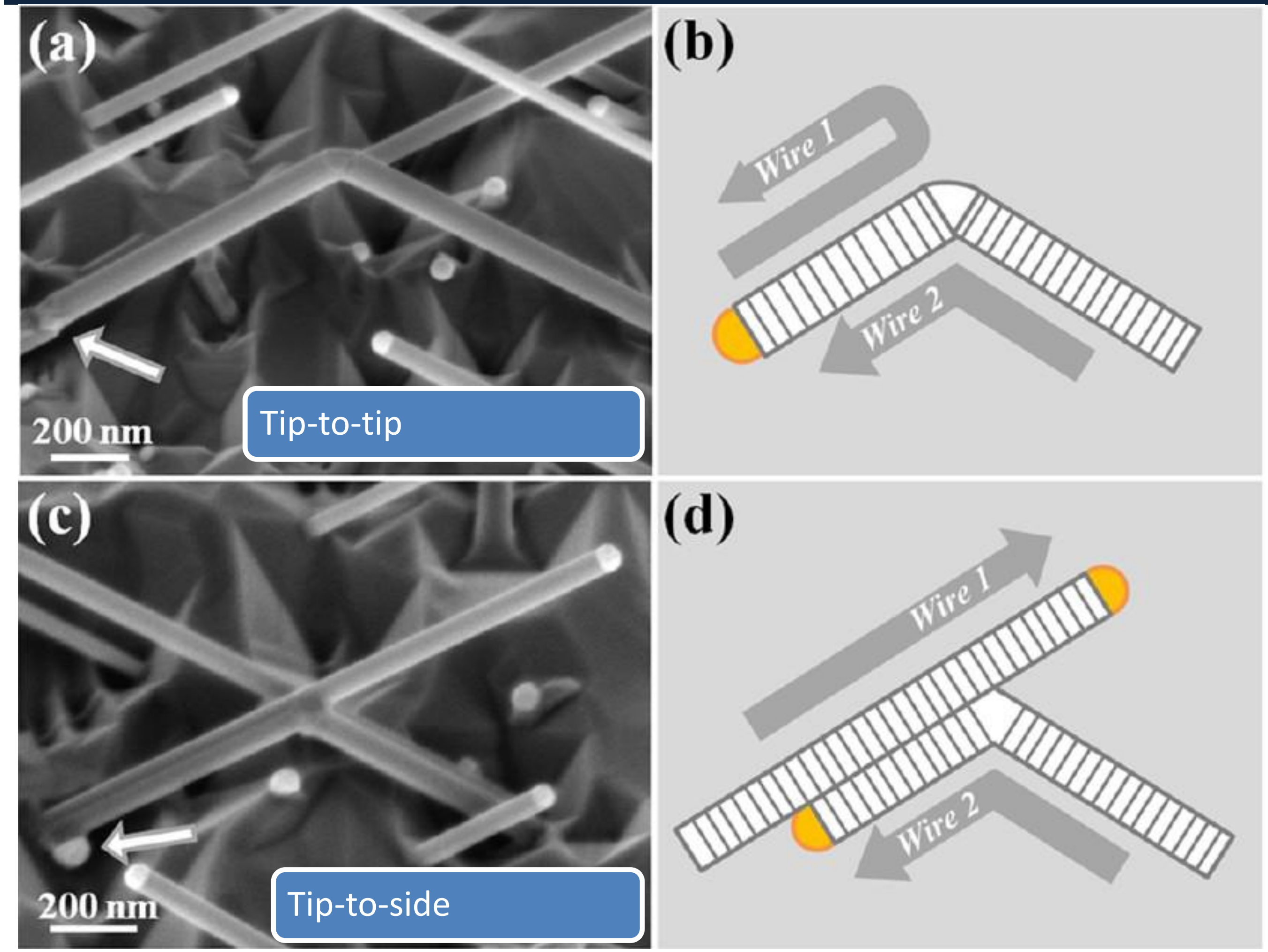
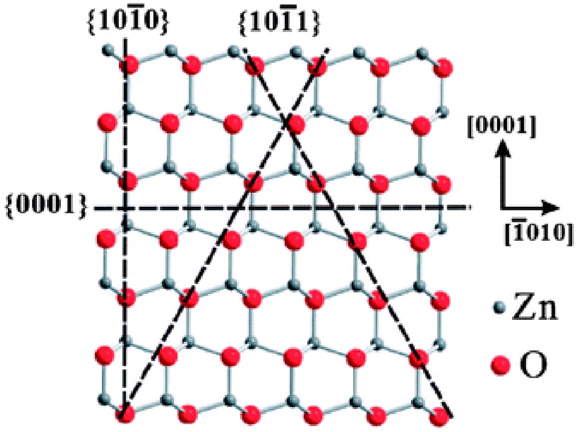


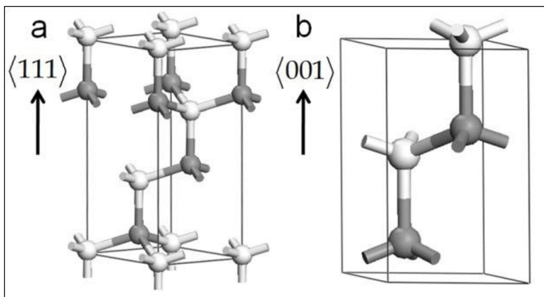
Figure 2. (a,b) and (c,d) are FE-SEM images and schematic illustrations of two InAs NWs merging *tip-to-tip* and *tip-to-side*, respectively. The arrows in panel (a) and (c) point at the position of the gold droplet after crawling down the left-hand NW.

Crystal polarity

Crystal polarity along the [0001] direction



http://www.rsc.org/ej/NR/2011/c0nr00560f/c0nr00560f-f21.gif



a) zincblence b) wurtzite structures
http://www.intechopen.com/source/html/17514/media/image7.jpeg

On a (001) surface the preferred growing directions are the four <111> directions:
[111] and [-1-11] with one polarity
[-111] and [1-11] with the inverse polarity

In a junction – due to the two polarity cases – the corresponding planes form 70.5° or 109.5° angle. (Long term spatial coherence is conserved.)

Tip-to-tip merging

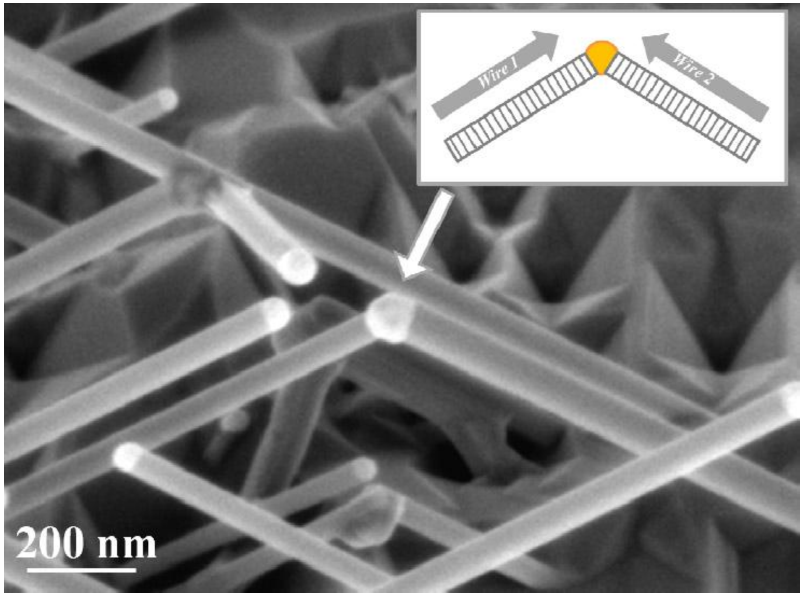


Figure S1 An FE-SEM image of two InAs nanowires merging tip- to -tip including a respective schematic illustration (in-set).

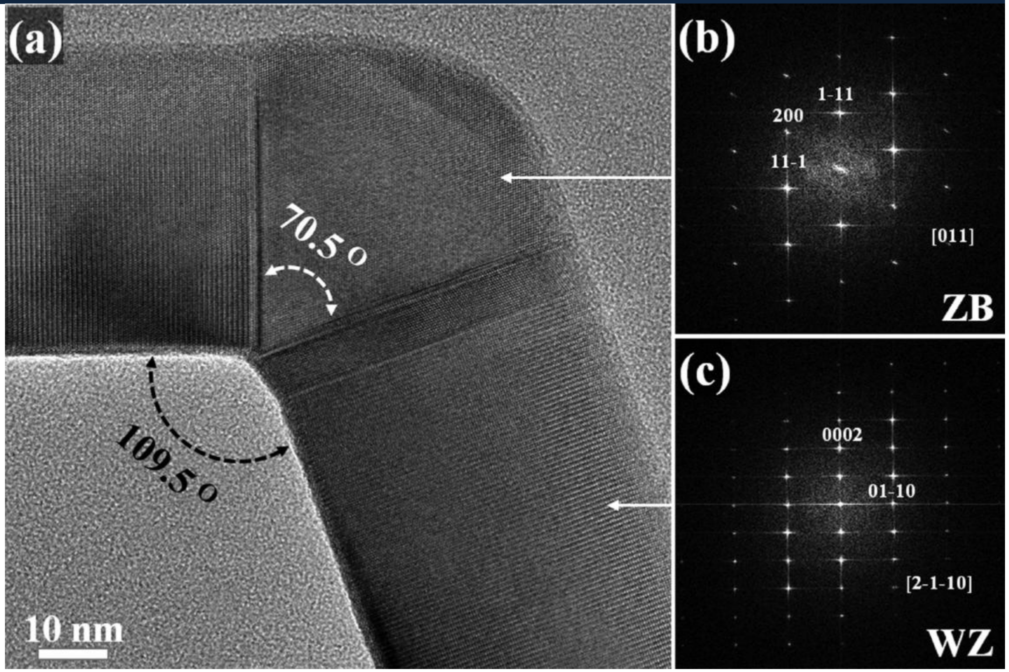
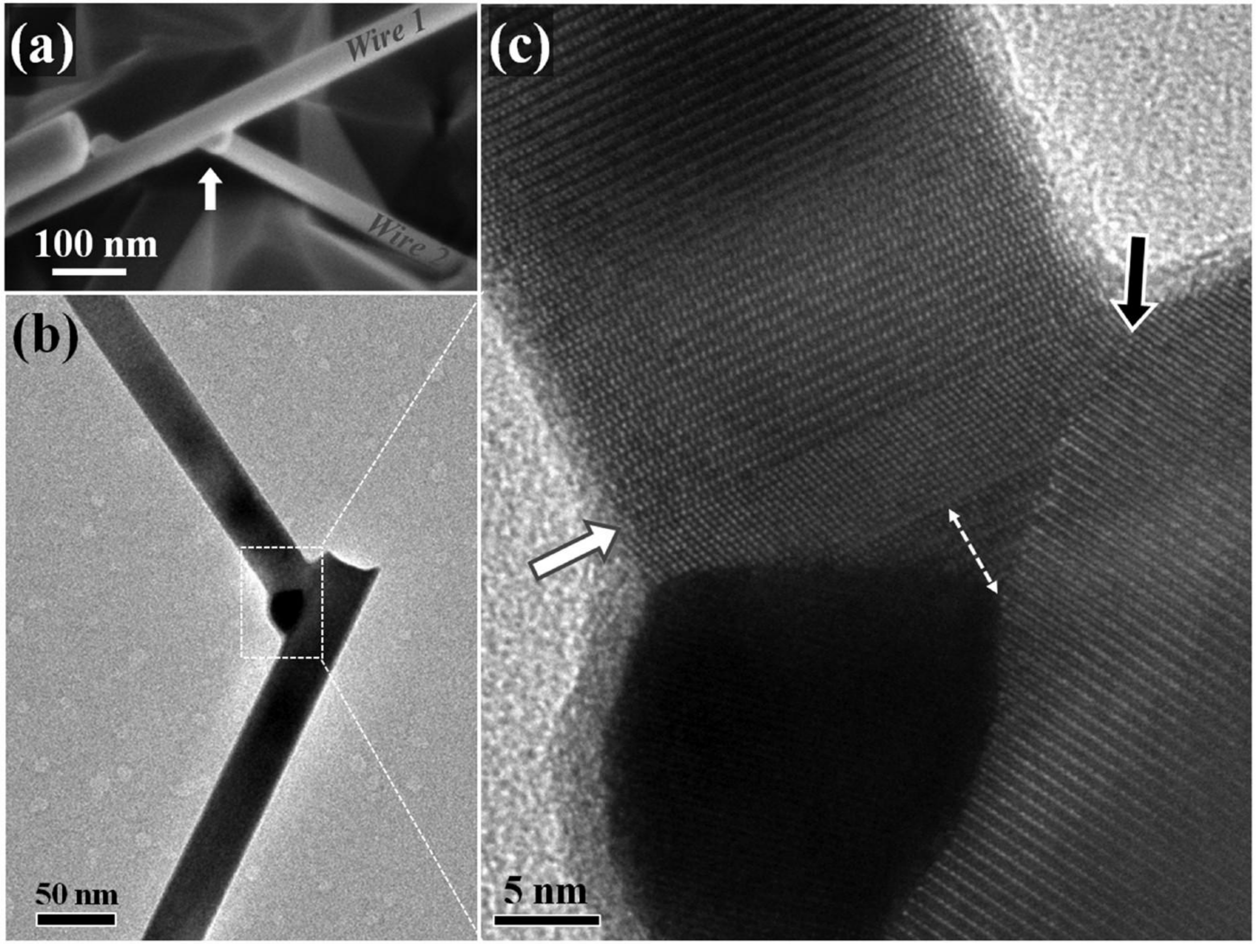


Figure 3. (a) HR-TEM image of an InAs NWs elbow resulting from a tip-to-tip merging. (b) FFT pattern of a perfect ZB and (c) FFT pattern of WZ.

Independently from the polarity the merging zone is perfect ZB with sharp transitions.

Tip-to-side 1



The golden droplet can't etch into the hit NW due to oversaturation. In case of same polarity instability occurs and the droplet etch into. (Black arrow)

Sharp transition (white arrow) between WZ of the wire and ZB of the junction.

Transition back to WZ at the double headed arrow.

Figure 4. (a) SEM image of two InAs NWs merging tip-to-side. (b) Low-magnification TEM picture of two such merging wires. (c) HR-TEM image showing early stages of WZ NWs merging. The transition into ZB at the merging intersection is marked with a white arrow and the etched interface with a black arrow.

Tip-to-side 2

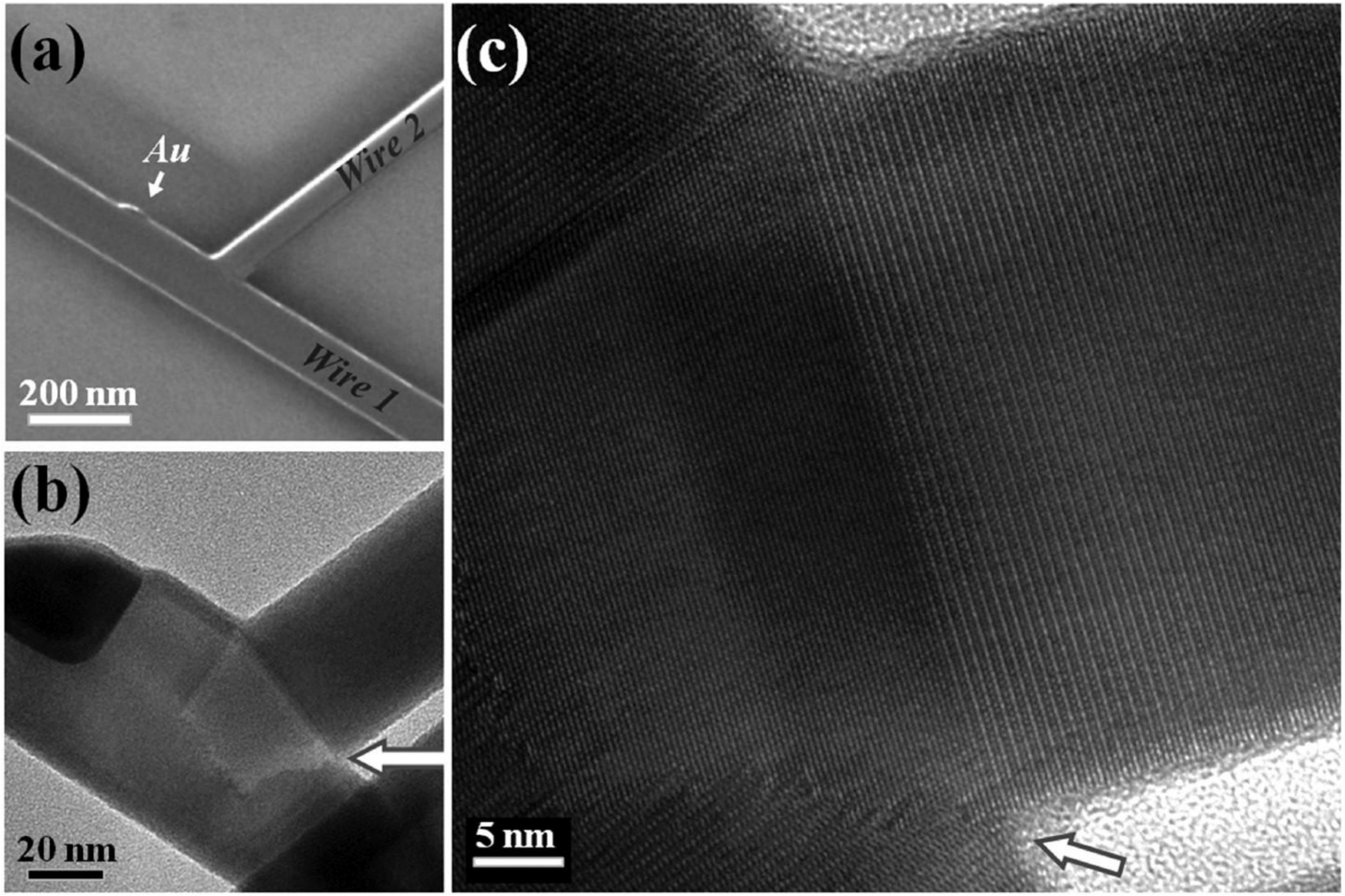


Figure 5. (a) FE-SEM image of two InAs NWs merging tip-to-side: (b) TEM and (c) HR-TEM images showing the initial stage of full merging of the hitting NW with the hit NW. The etching of the hitting NW into the hit wire can be clearly seen at the bottom of the HR-TEM image.

Tip-to-side 3

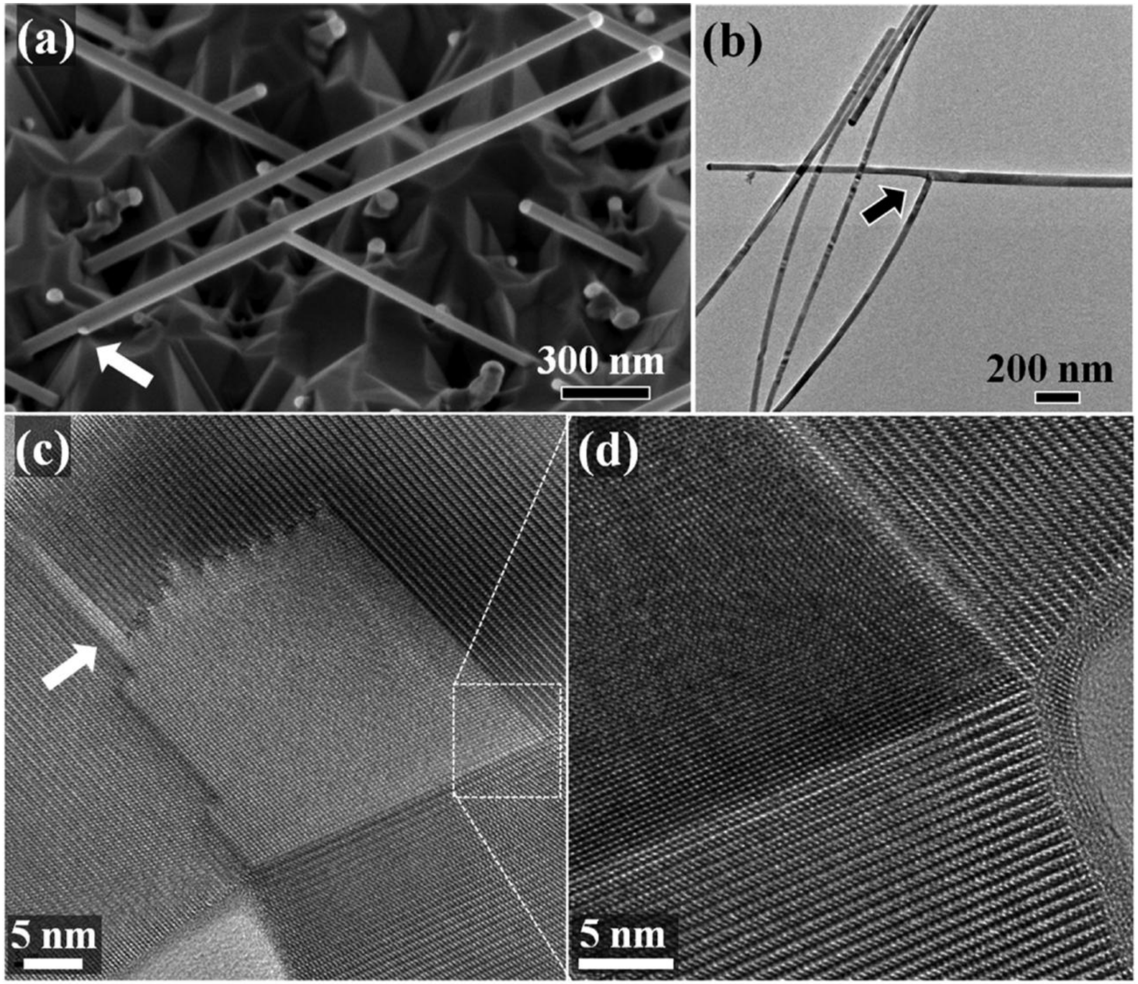


Figure 6. (a) FE-SEM and (b) TEM images of Y-shape InAs NWs merging with tip-to-side; (c) HR-TEM image of the details in the merging area, showing sharp and rough interfaces between the WZ and ZB structures. (d) HR-TEM image showing very sharp boundaries between WZ NWs and a ZB merged area at ~70° angle.

Tip-to-side 4

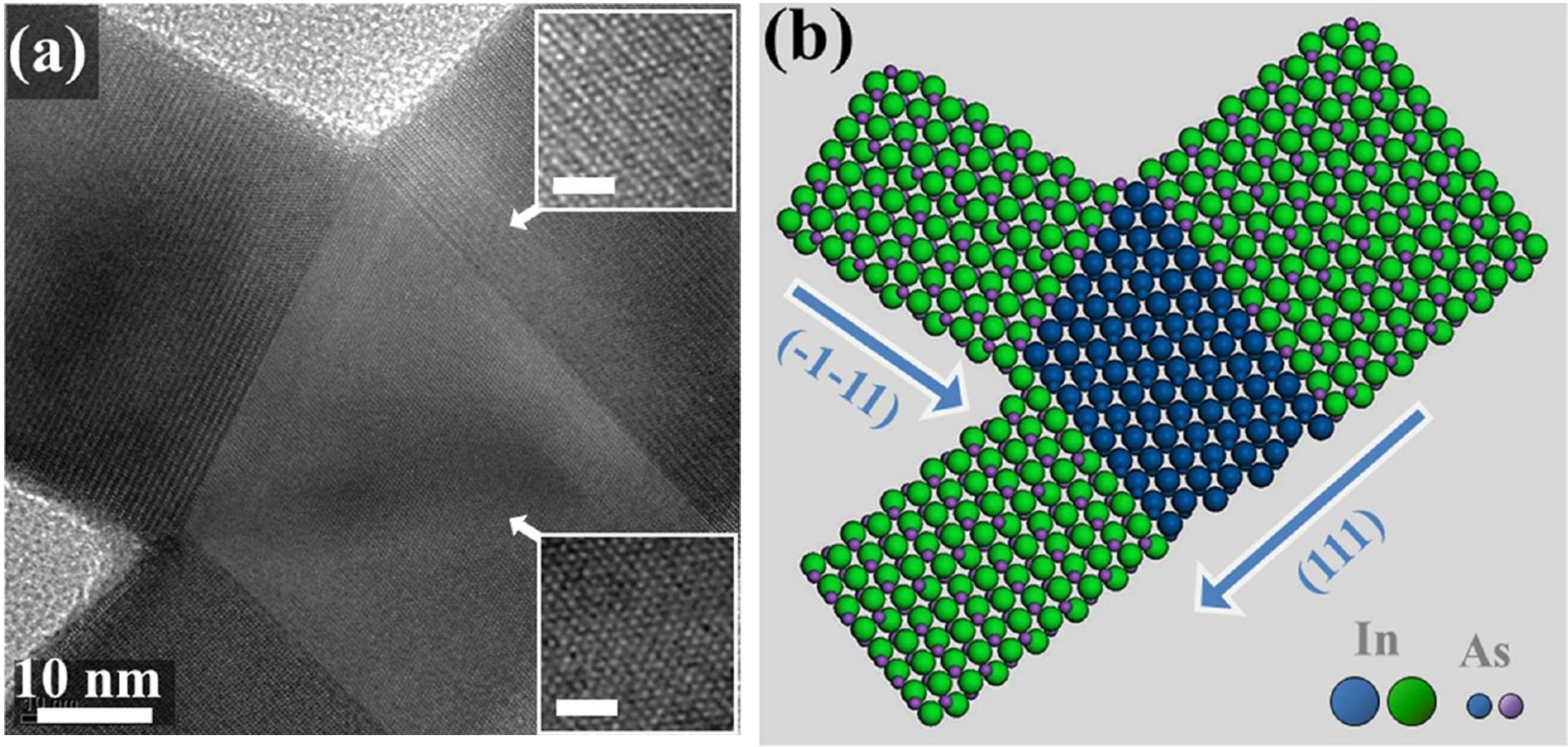


Figure 7. (a) TEM image and (b) the schematic model of two InAs NWs fully merged intersection, where the entire intersection has been transformed into ZB with three very sharp transitions; all scale bars of the in-set images are 2 nm.

K-shaped junctions

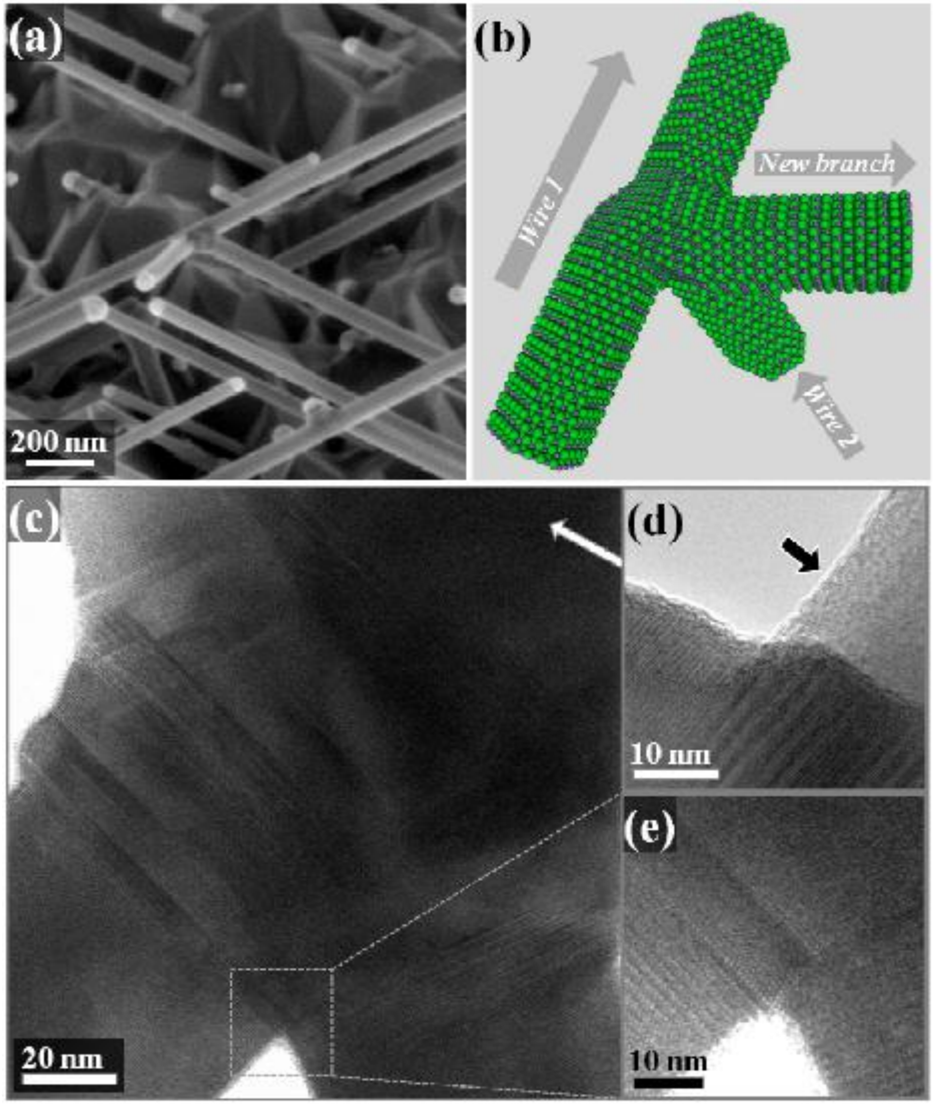


Figure S2 (a) FE-SEM image and (b) the atomic model of the quad-arms InAs NWs merging with tip emerging away from the original NWs plane; (c) TEM and (d)-(e) HRTEM images showing clear WZ structure of three arms with ZB structure of the merged area in the same view-plane and unclear branch out of view-plane (black-arrow).

2-point conduction measurements

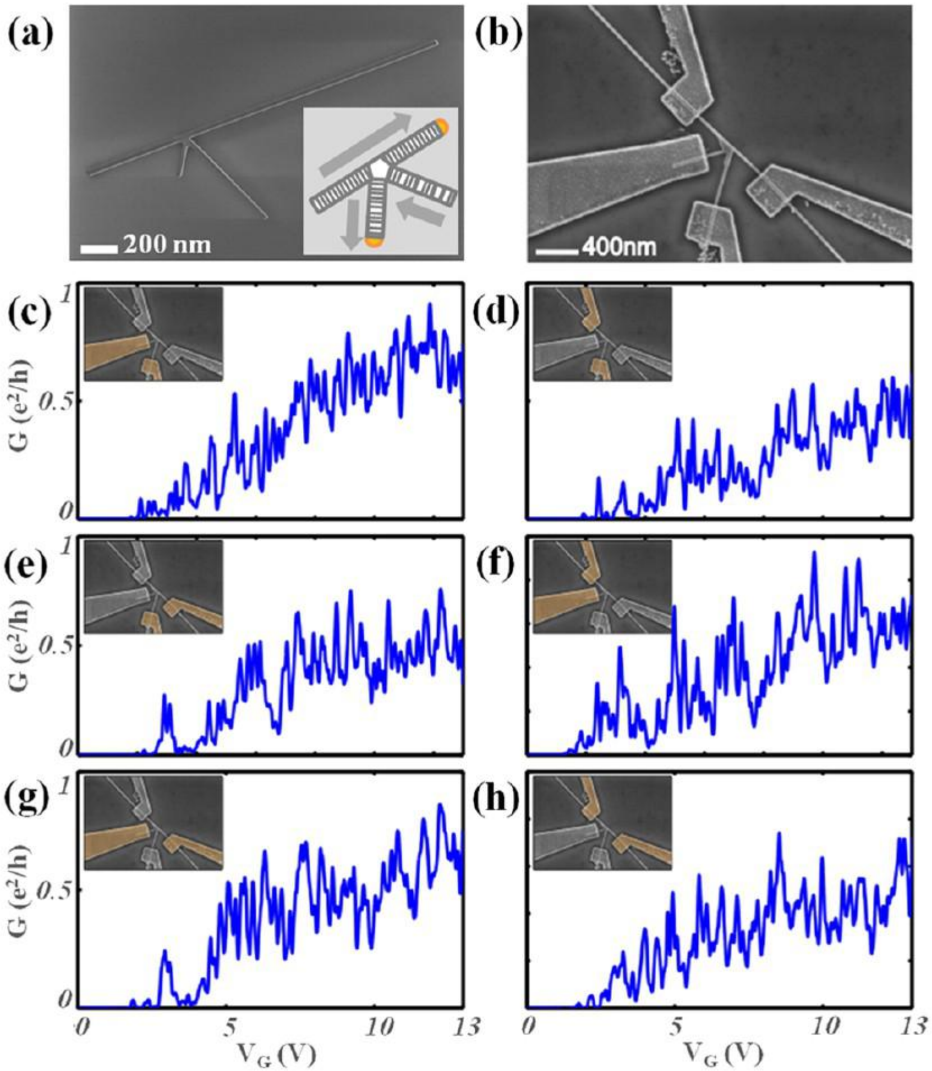


Figure 8. (a) An SEM and schematic (inset) images of the quad-arms InAs NWs (K-shape) merging of the tip-to-side type; (b) an SEM image of the device used for conductance measurements: contacts are placed on all branches of the NW junction. (c−h) Two terminal conductance versus gate voltage for all six permutations of the contacts. The SEM image of the device with the contacts (inset) used for the conductance measurement marked in orange.

The ZB-WZ transition can be expected to introduce a potential barrier.
Ultra clean MBE : contact dominated conductance
No visible dependence of the leads – no barrier and isotropic junctions.