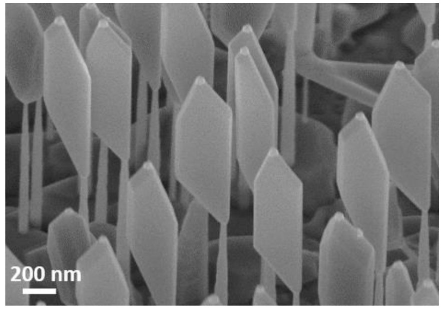
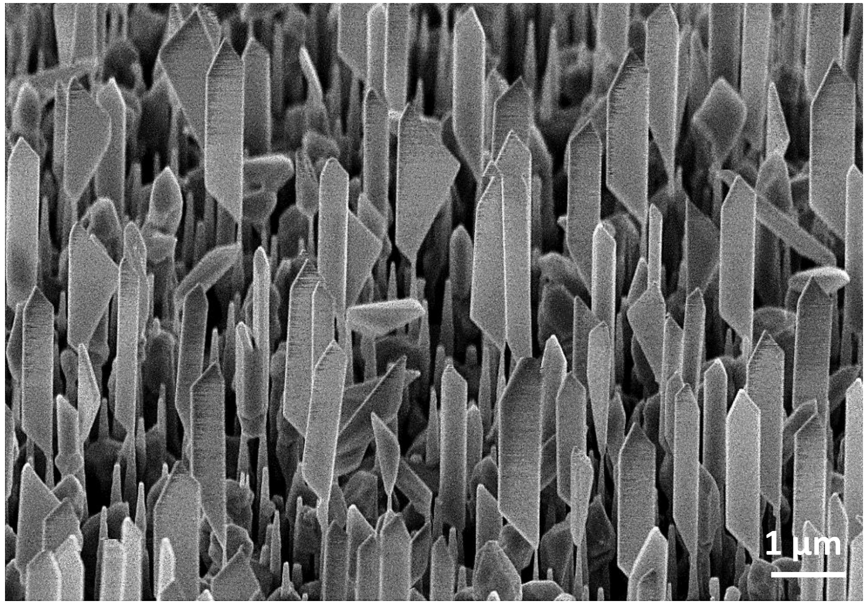




InSb nanostructures : Growth via chemical beam epitaxy and their transport properties

PhD. in Nanoscience (Third year)

Candidate:

Isha Verma

Supervisor:

Prof. Lucia Sorba

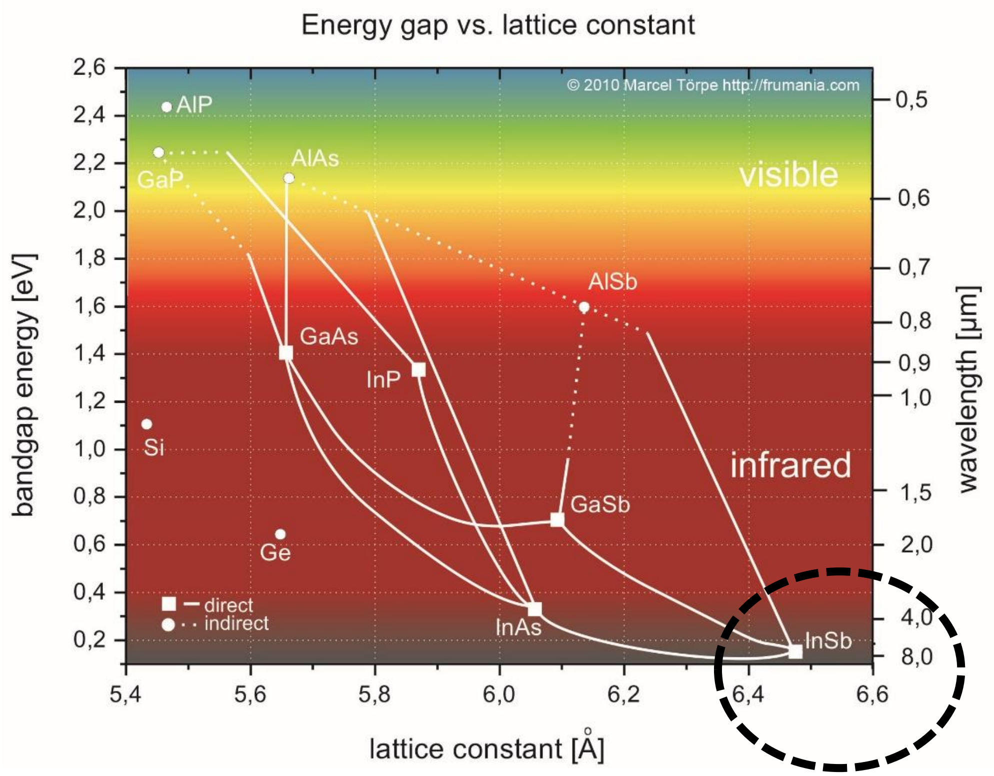
NEST

SCUOLA NORMALE SUPERIORE

INTRODUCTION

Indium antimonide (InSb)

- Energy band gap $E_g = 0.17$ eV at 300K
- Low effective carrier mass
- High electron mobility
- Large Landé g factor

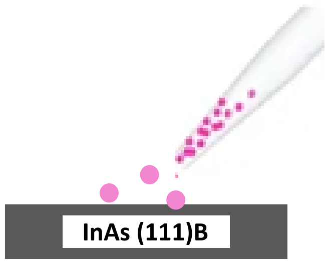


Large lattice constant
High lattice mismatch
Integration possible: Nanostructures

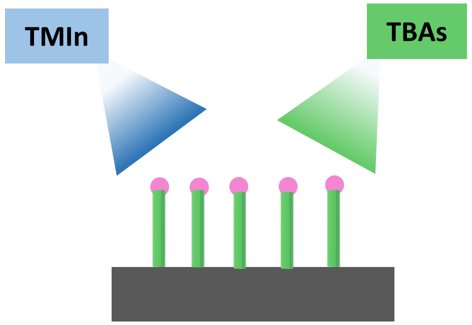
Perfect system for:

- Detection exotic bound states at the superconductor/semiconductor interface (Activity in the framework of European project SuperTOP).
- General applications: terahertz radiation source, infrared detectors, including FLIR systems, thermal imaging cameras.

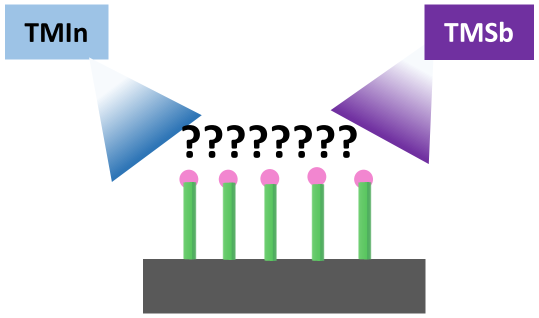
Growth Approach I: Au assisted CBE



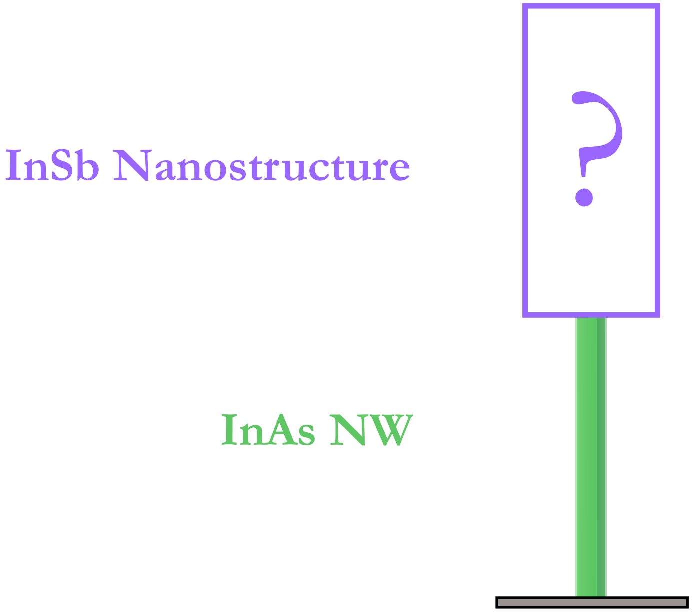
STEP 1
Drop-cast 30 nm Au colloids



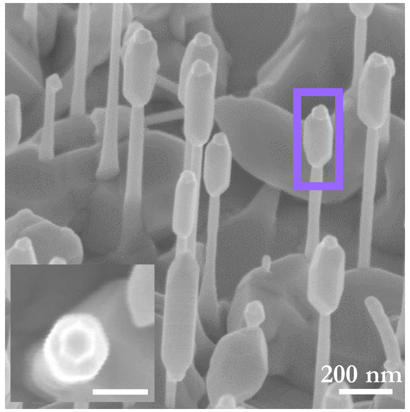
STEP 2
Growth on InAs NWs



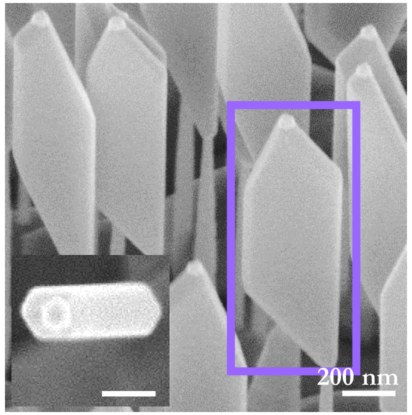
STEP 3
Growth on InSb nanostructures



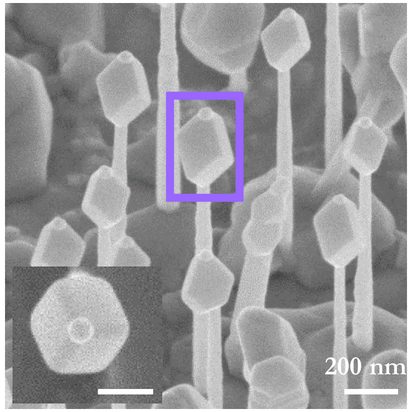
InSb Nanowires (1D)



InSb Nanoflags (2D)



InSb Nanocubes (3D)



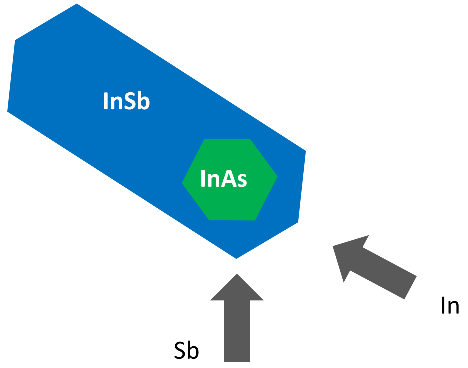
Morphological control by tunning growth parameters

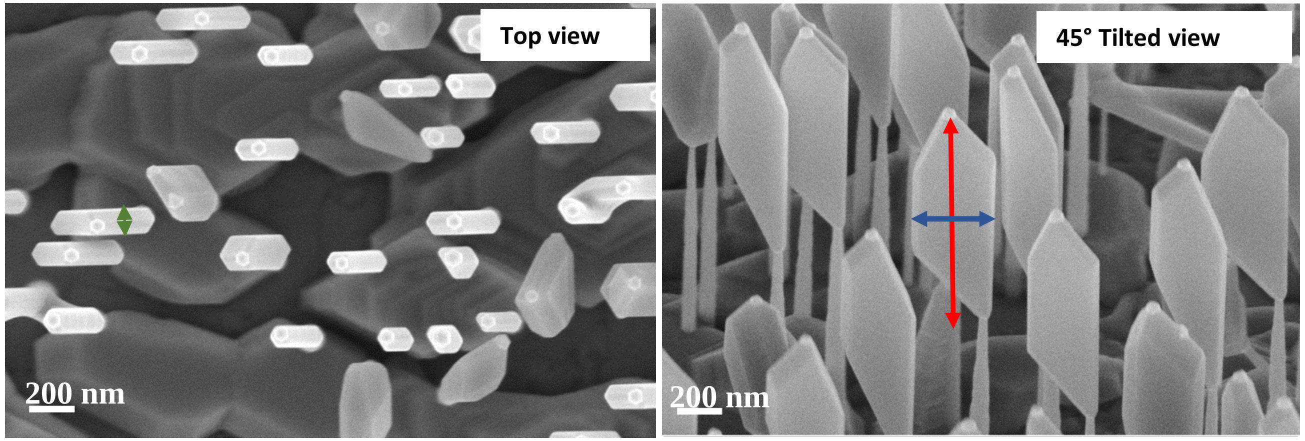
Inset scale: 100 nm

I. Verma, V. Zannier, F. Rossi, D. Ercolani, F. Beltram and L. Sorba, Morphology control of single-crystal InSb nanostructures by tuning the growth parameters. *Nanotechnology* **31** 384002 (2020)

InSb NFs on InAs stem

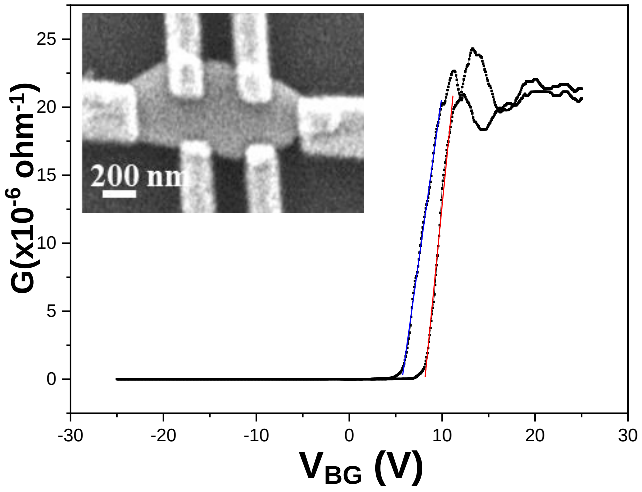
InSb growth without sample rotation
Elogantion toward In beam
Top view





InSb dimensions:
Length= (1.3 ± 0.1) µm Width= (282 ± 86) nm Thickness= (104 ± 17) nm

Four Probe measurements

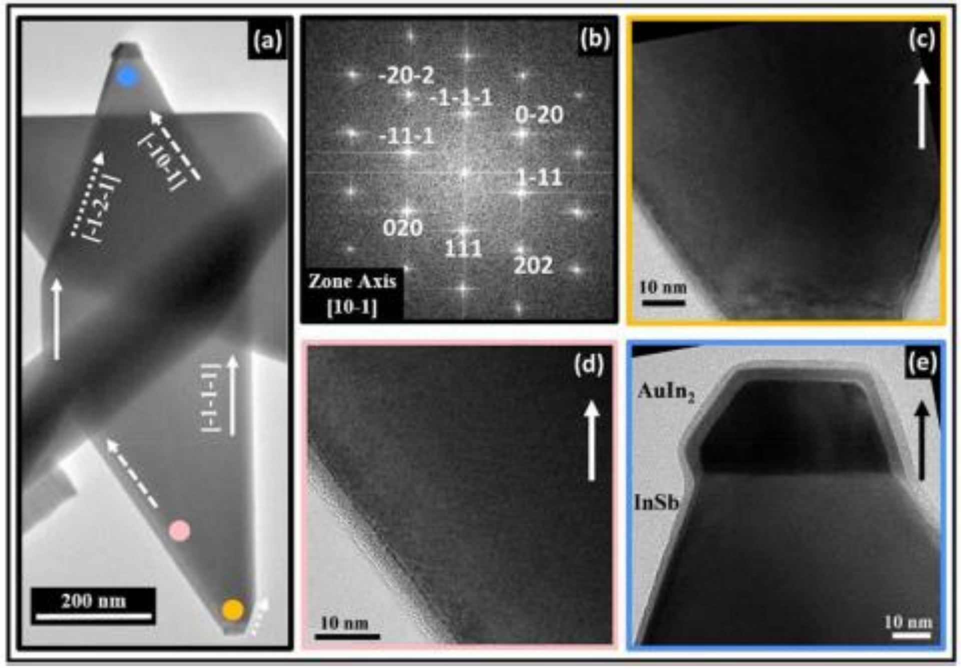


Transport Measurements at 4.2 K

Hall measurement: There's intermixing of longitudinal and hall voltage due to small dimension of InSb flags. Hence an appropriate value of mobility could not be extracted.

Solution:- Size up!

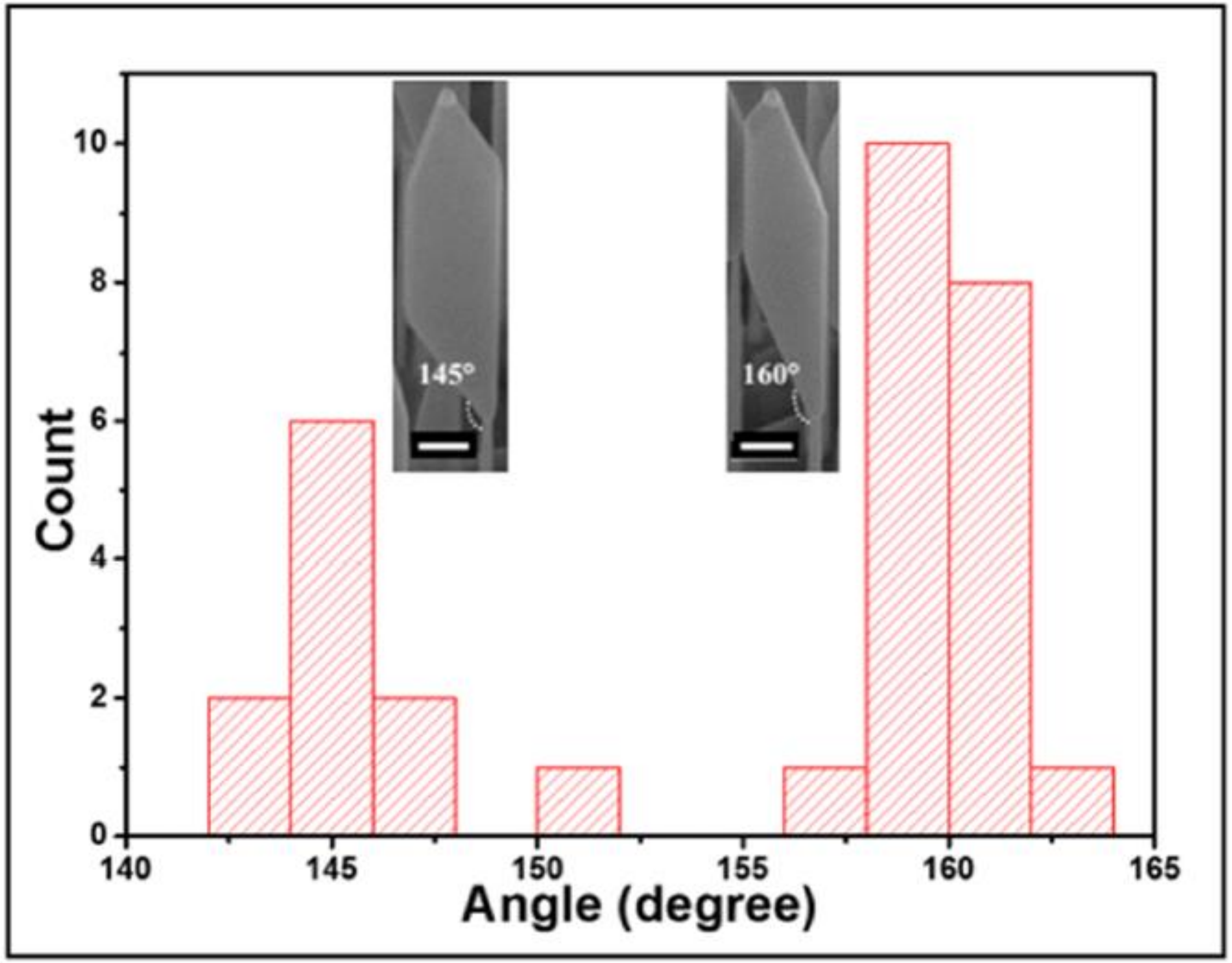
TEM Analysis



Perfect ZB crystal structure free from any stacking faults or twinning defects.

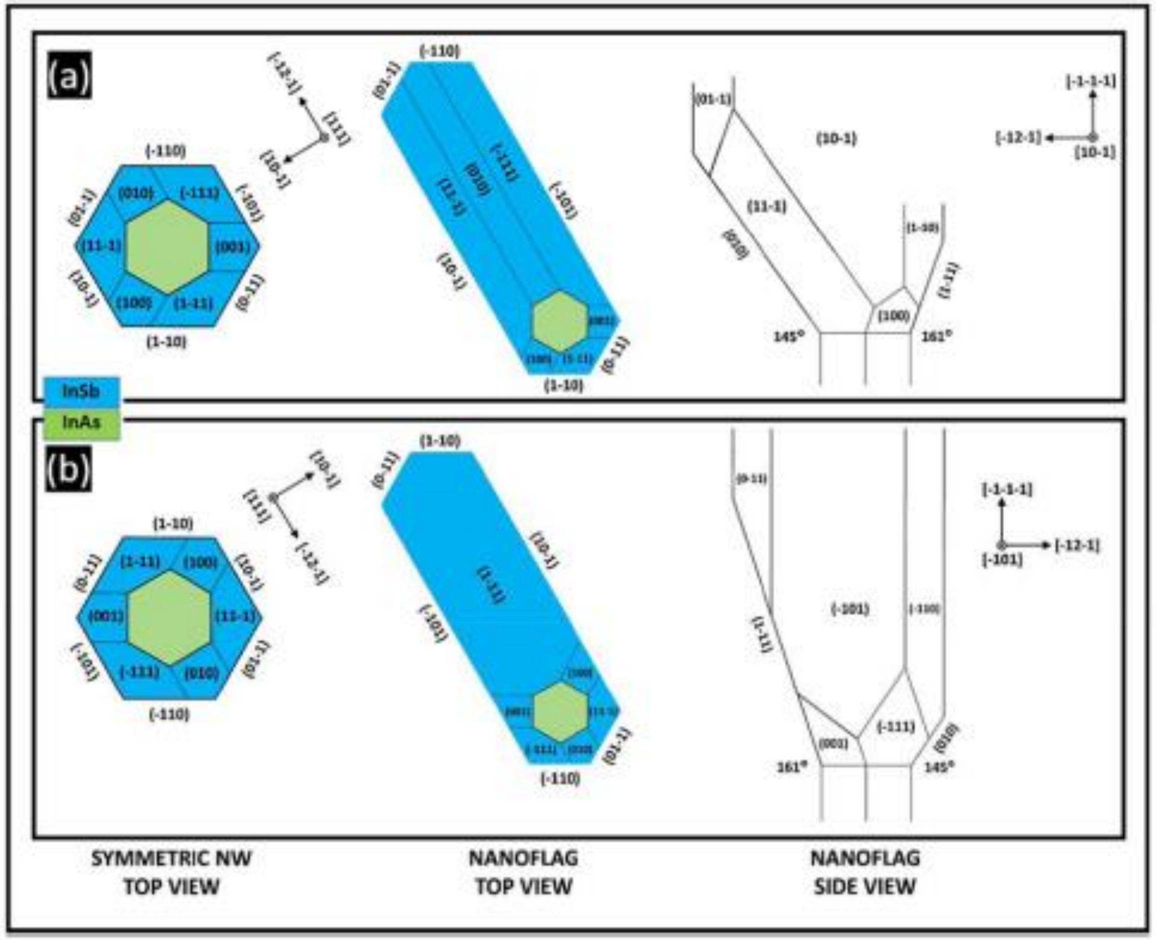
Both NFs have a major **(10–1)** and **(−101)** flat facet, bordered by 6 sides, parallel to 3 pairs of directions: **[−10–1]**, **[−1–2–1]** and **[−1–1–1]** , aligned with the growth axis.

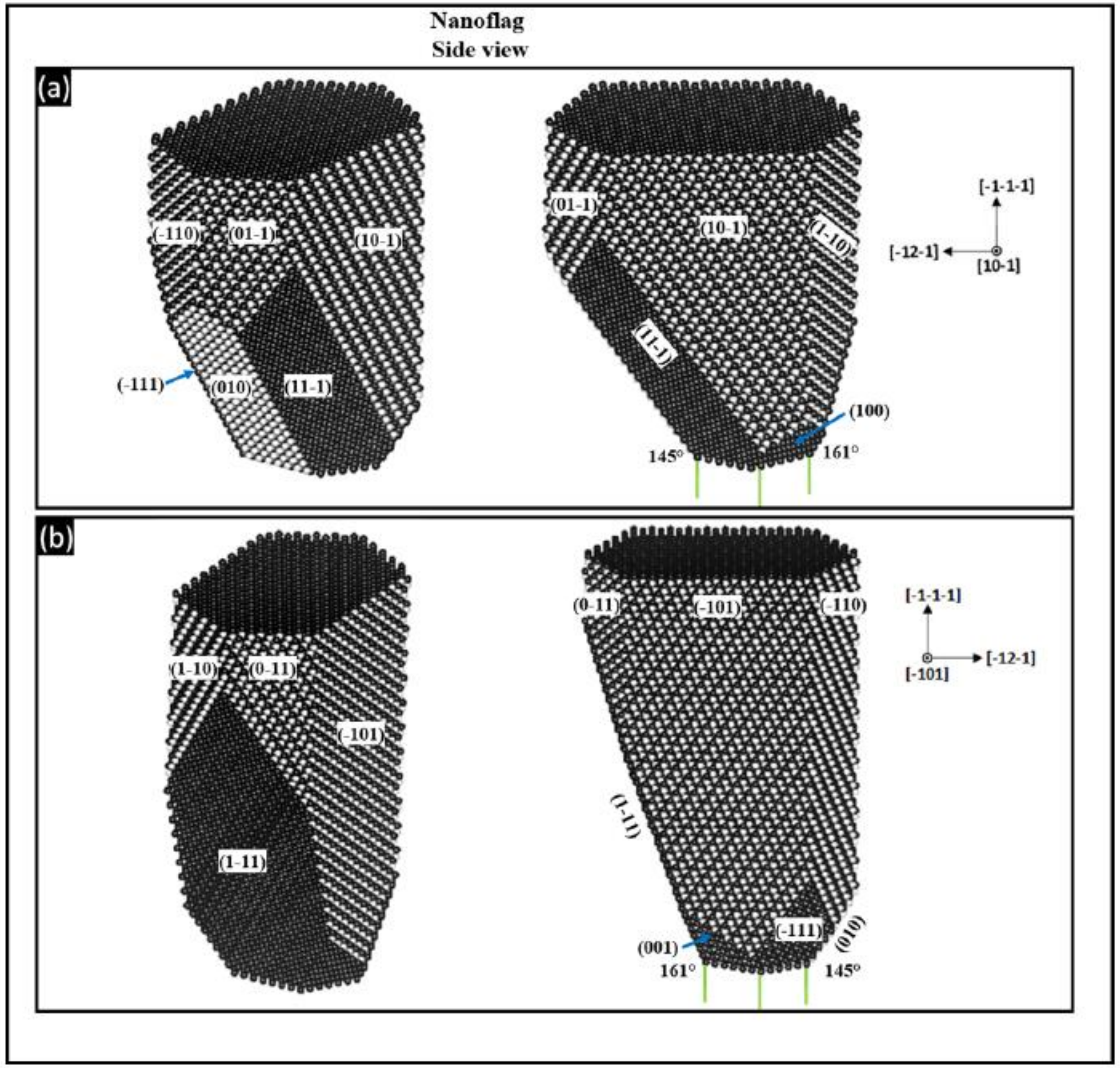
Existence of 145° and 160° aperture angle NF is explained by intrinsic **InSb lattice rotation**.



I. Verma, V. Zannier, F. Rossi, D. Ercolani, F. Beltram and L. Sorba, Morphology control of single-crystal InSb nanostructures by tuning the growth parameters. *Nanotechnology* **31** 384002 (2020)

MODELLING

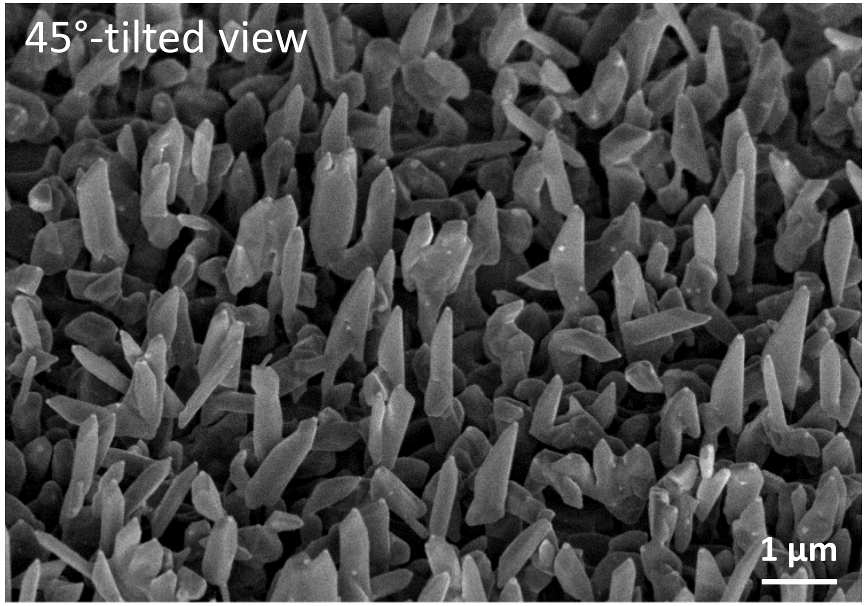




I. Verma, V. Zannier, F. Rossi, D. Ercolani, F. Beltram and L. Sorba, Morphology control of single-crystal InSb nanostructures by tuning the growth parameters. *Nanotechnology* **31** 384002 (2020)

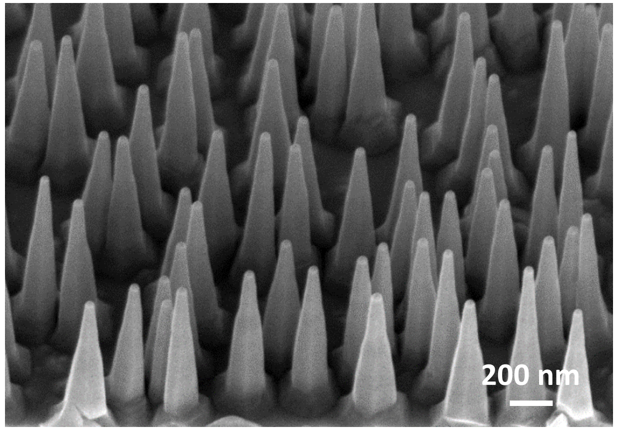
InSb Nanoflakes

Bigger InSb flakes on **thin untapered InAs NWs** stems are not achieavable!
The InAs stem bend and/or is etched → orientation lost, 3D InSb growth

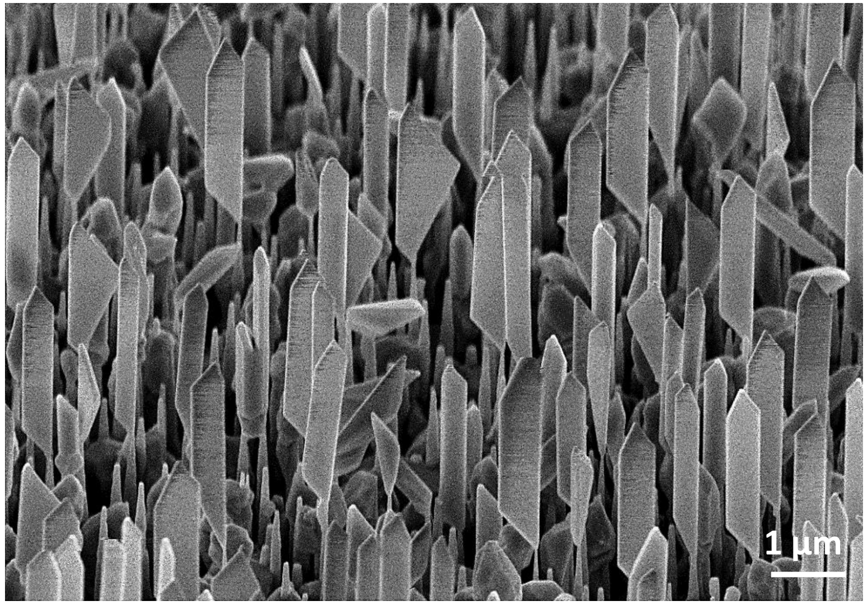


InAs NW with InSb NF

InP NWs grown on InP (111)B are strongly tapered
D_{tip} 40 nm (Au colloids of 30 nm)
D_{bottom} 150 nm



InSb NFs on InP NWs



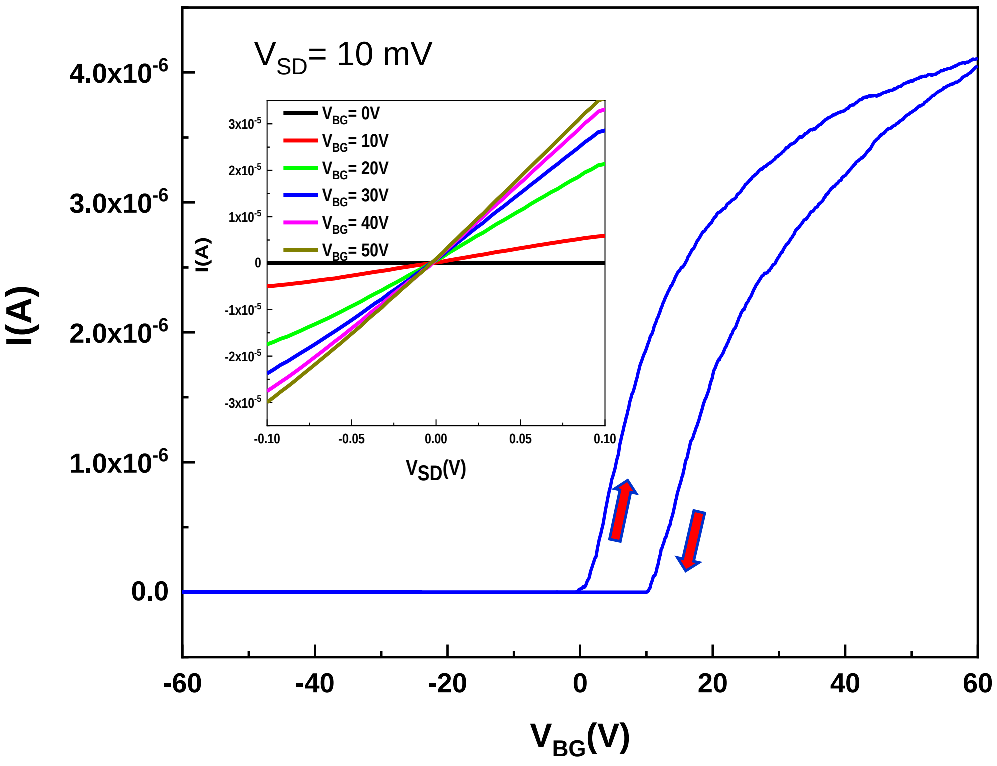
L: 3000 nm
W: 500 nm
T: 100 nm

InP NW with InSb NF

Possible solution: more robust NW stems (for example tapered NWs)

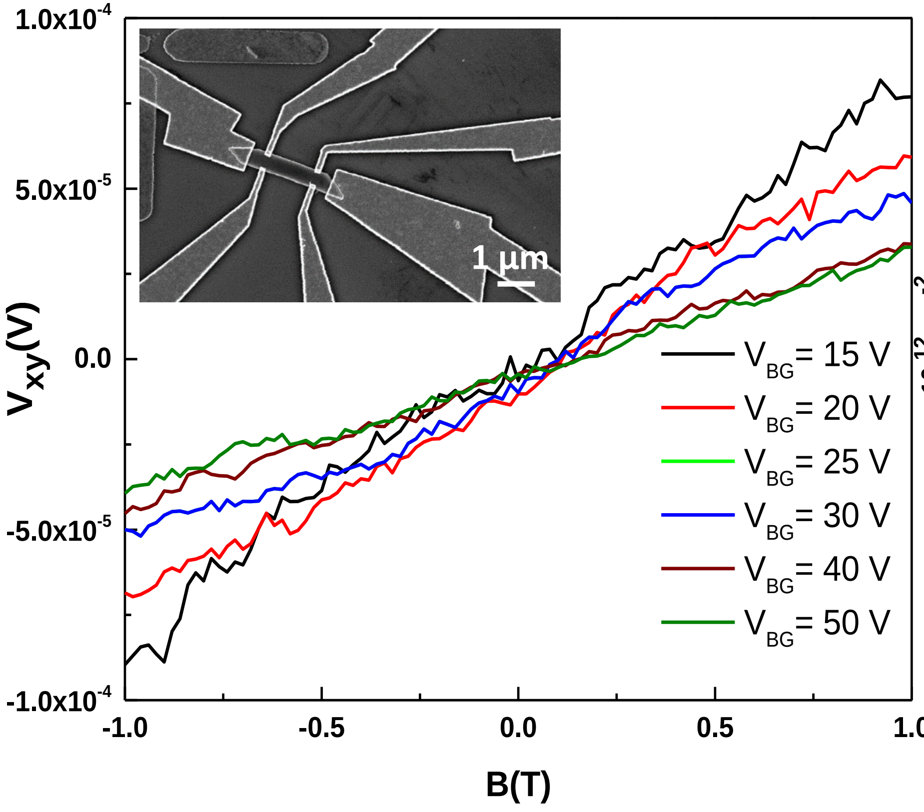
TRANSPORT MEASUREMENTS: INSB NANOFLAKES ON INP NW STEMS

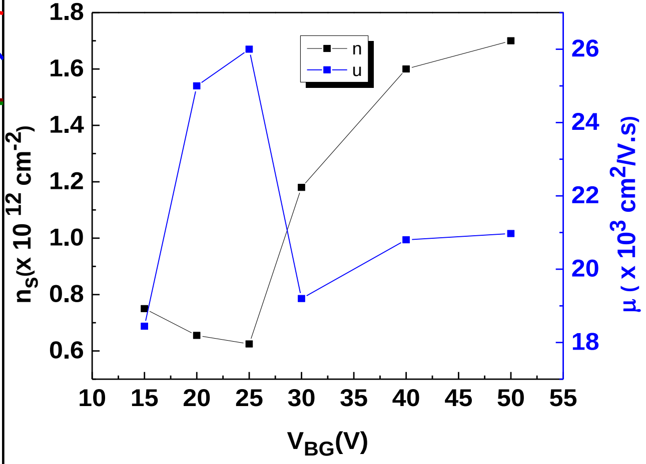
n- type characteristics of InSb NFs under BG modulation



R_{SD}(RT, VBG=0 V) = 11 KΩ
R_{SD}(4K, VBG=50 V) = 2.5 KΩ
μ_{FE} = 25000 cm^2/ V.s

Hall effect vs BG bias



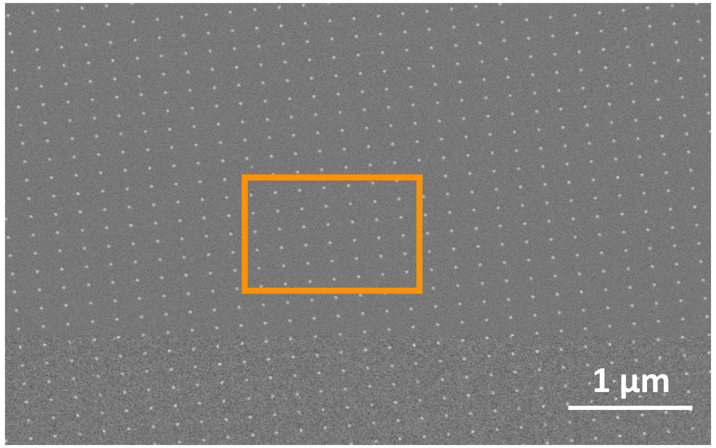


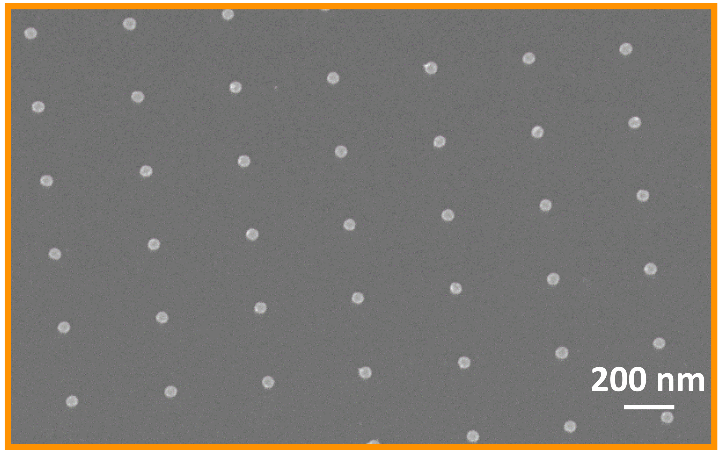
Mean free path λ_e up to 250 nm

FUTURE PLANS increasing InSb flake dimension

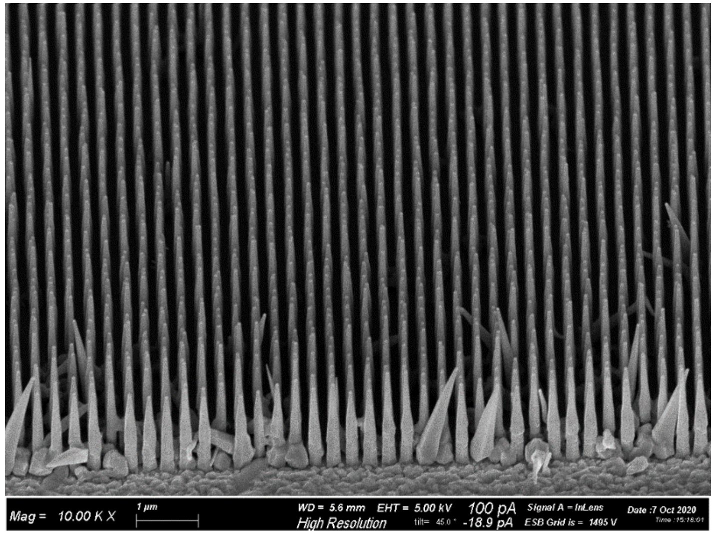
Growth Approach II: EBL patterened Au-assisted VLS

Before growth



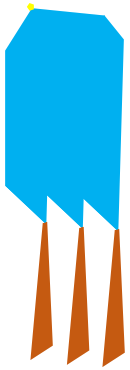


After growth



Future plans

- Growth optimization in order to achieve merging InSb NFs.
- To fabricate the device and perform hall measurements on as grown InSb NFs.

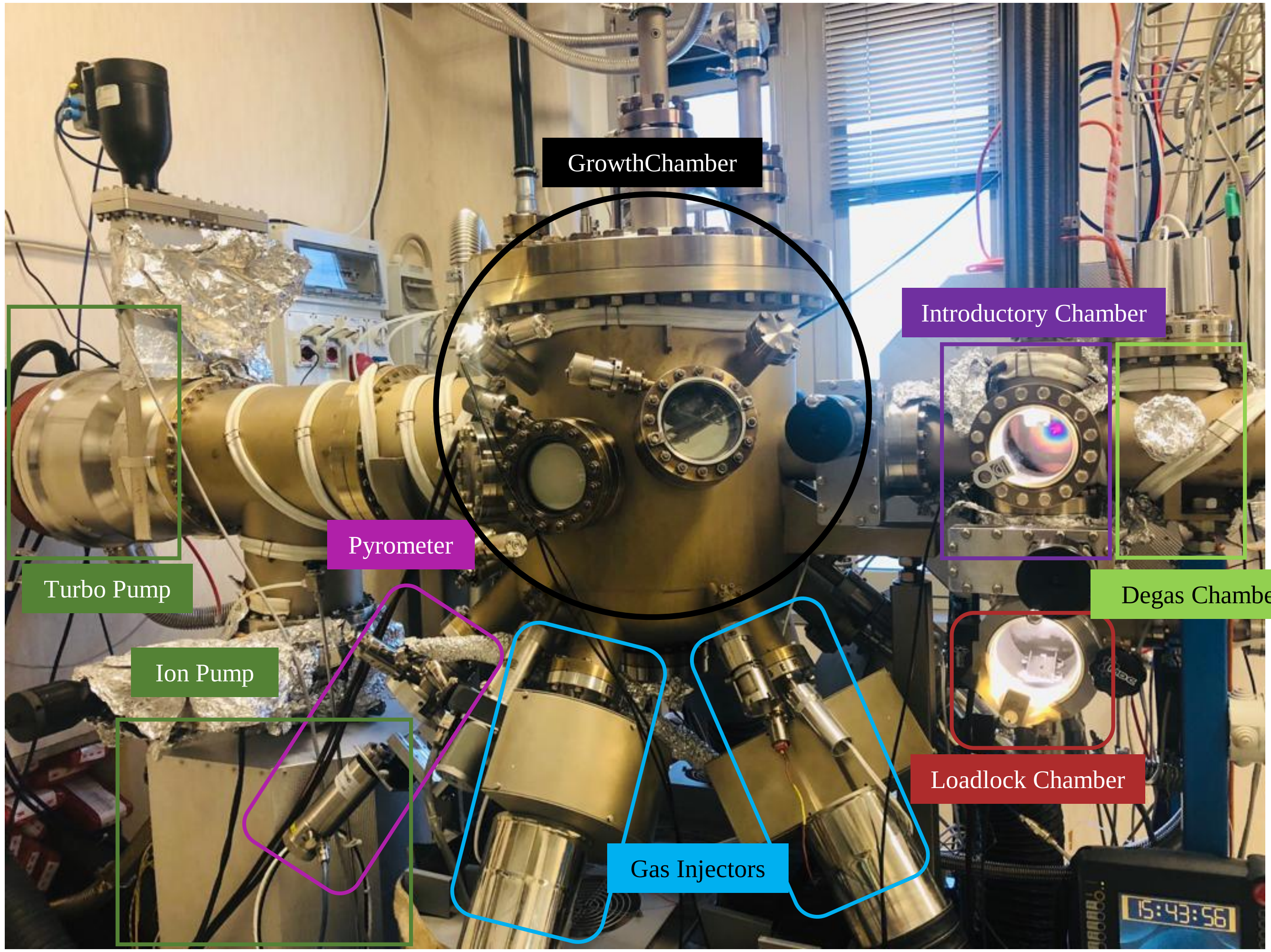


Merging InSb NF on InP NWs

Thank you for your attention

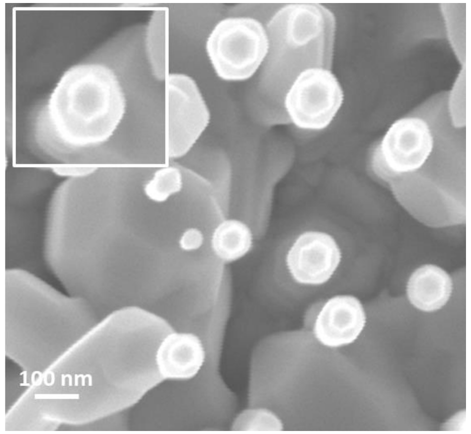
Supporting Slides

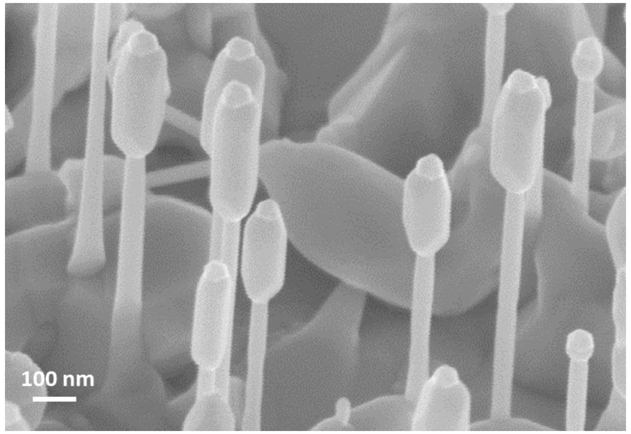
CHEMICAL BEAM EPITAXY (CBE)



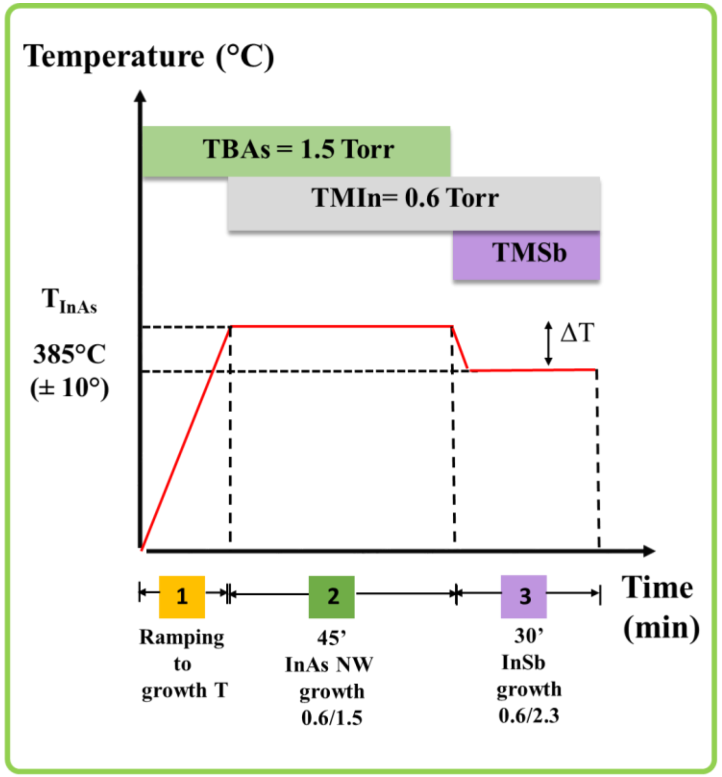
- UHV (10^{-9} mbar)
- Epitaxial growth of nanostructures
- Metal organic gaseous precursors

Nanowire to Nanocubes

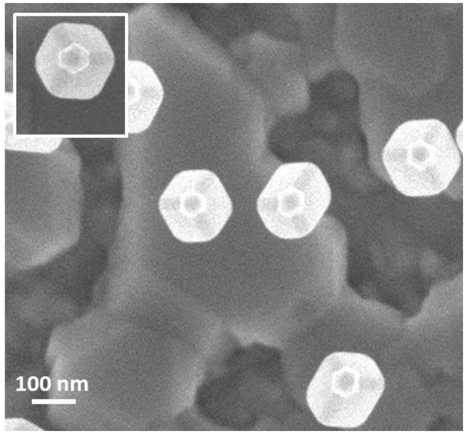


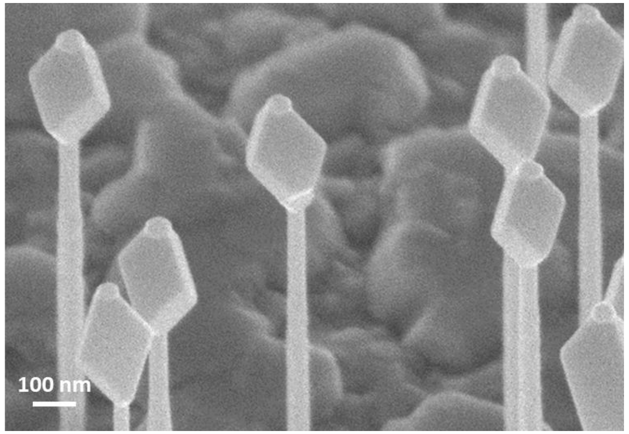


ΔT= -30°C



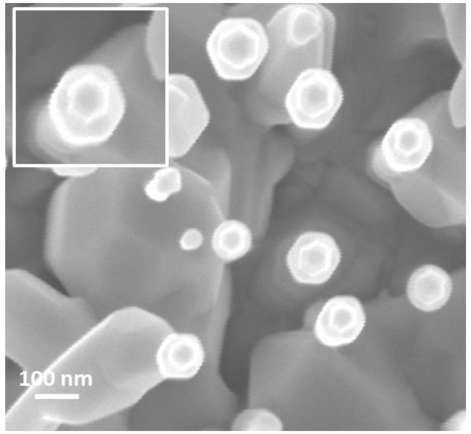
By changing the InSb temperature ΔT
NW → NC

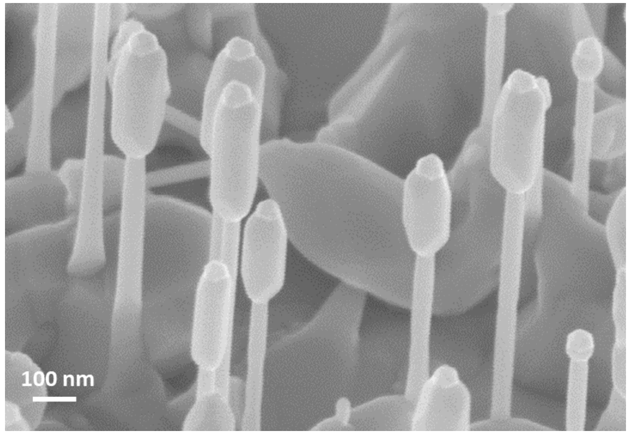




ΔT= -40°C

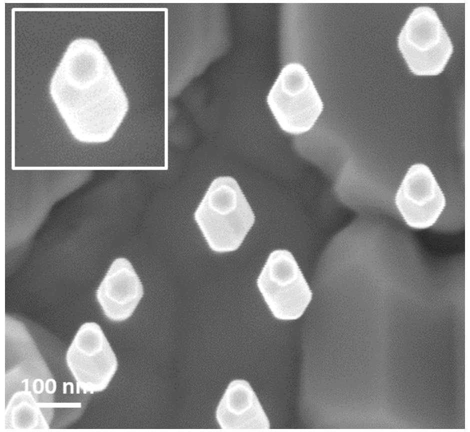
Morphological control by Rotation

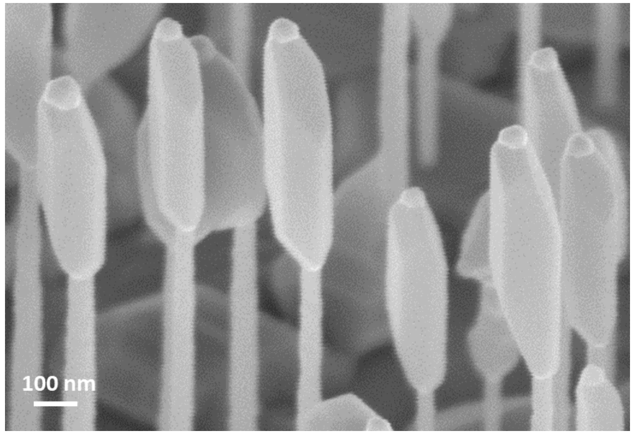




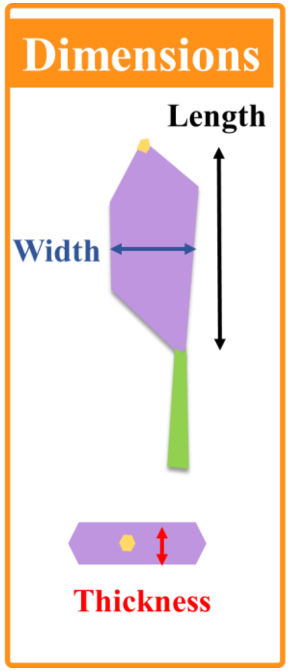
With Rotation

Asymmetry triggered by stopping rotation

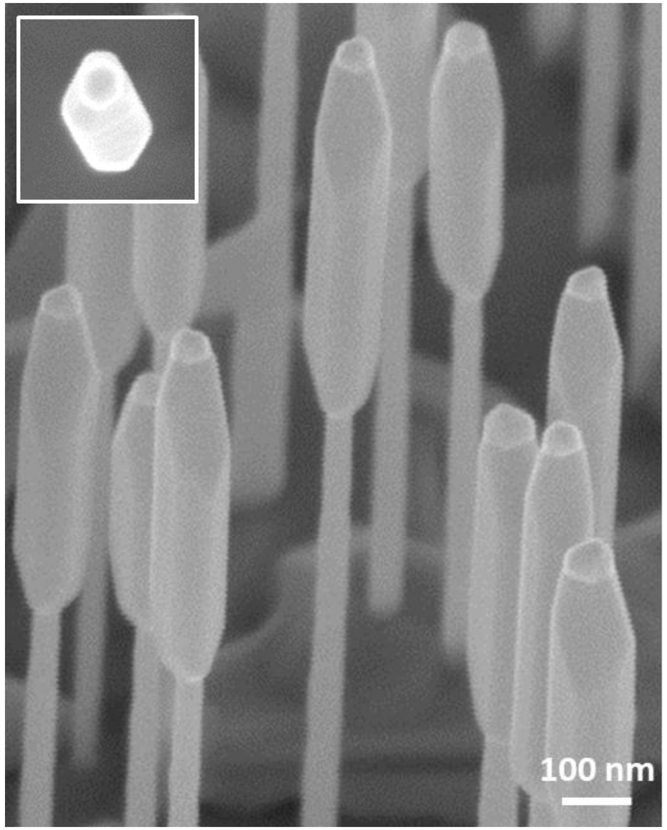




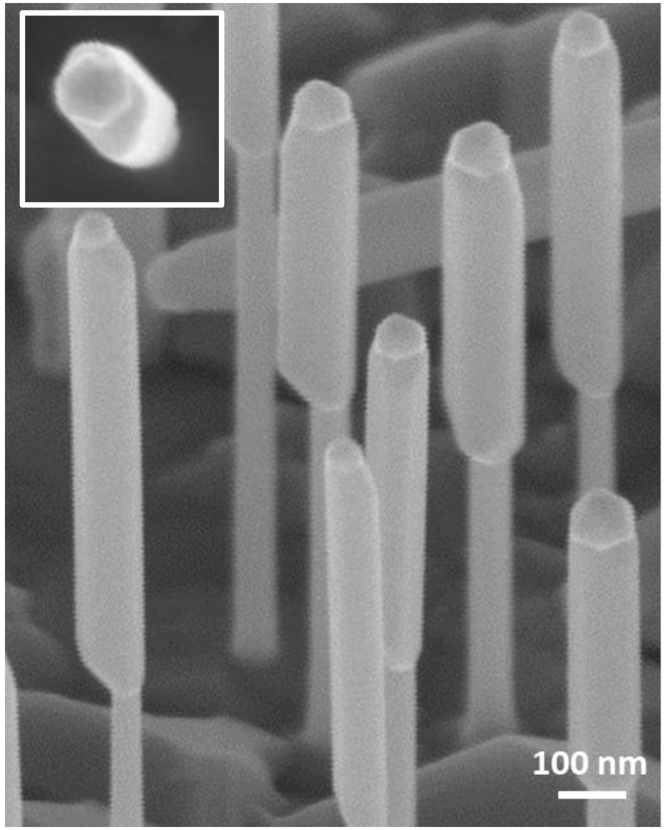
Without Rotation



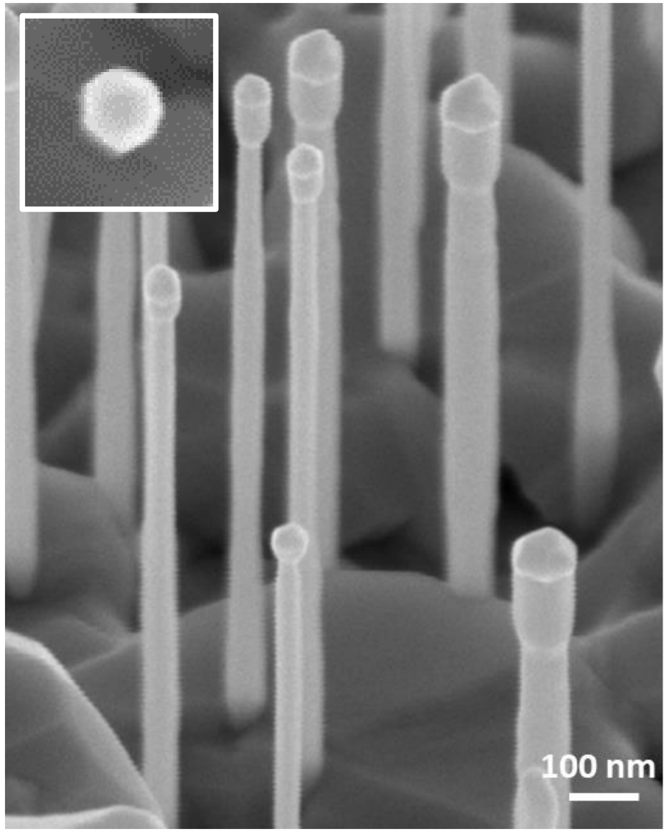
OPTIMIZING InSb TEMPERATURE



ΔT= -30°C



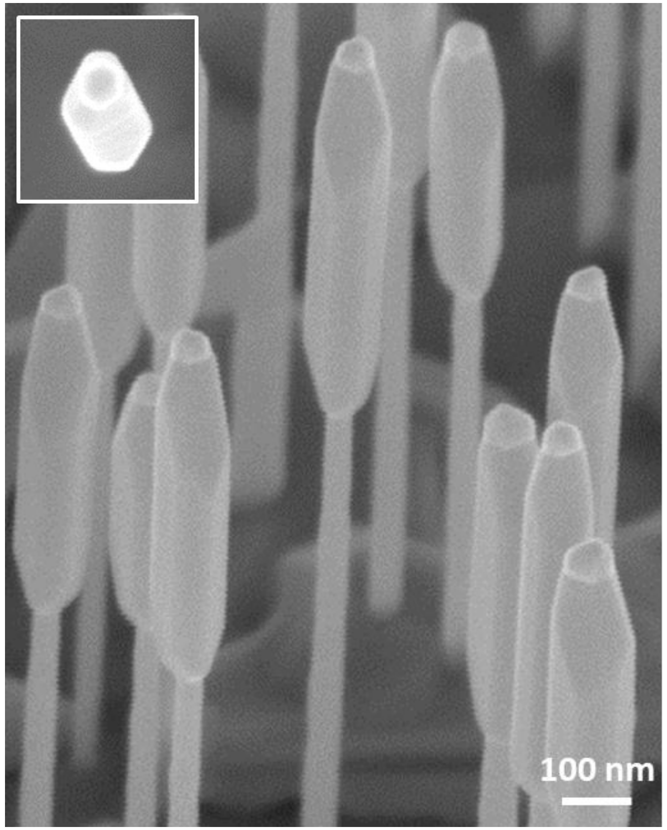
ΔT= -20°C



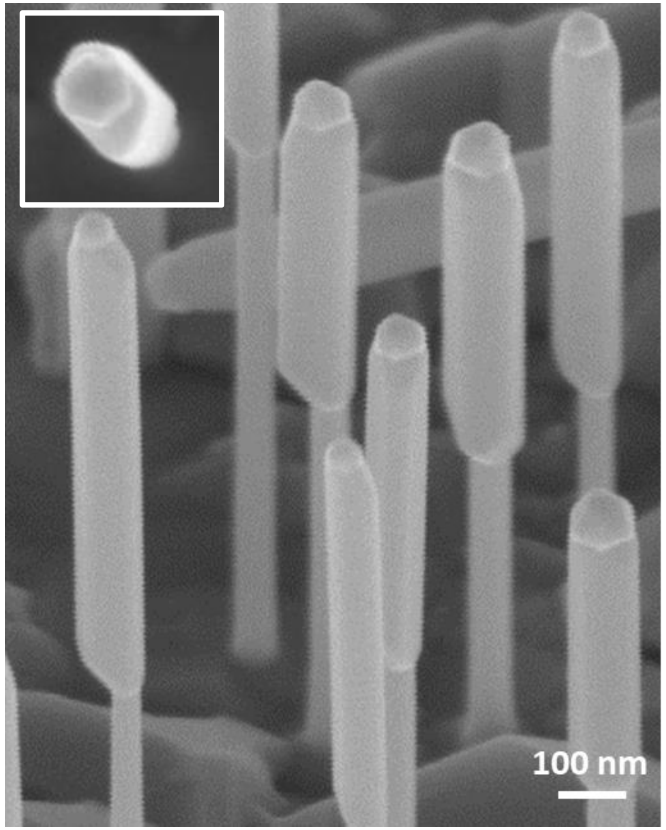
ΔT= -10°C

ΔT= -20°C is a good compromise

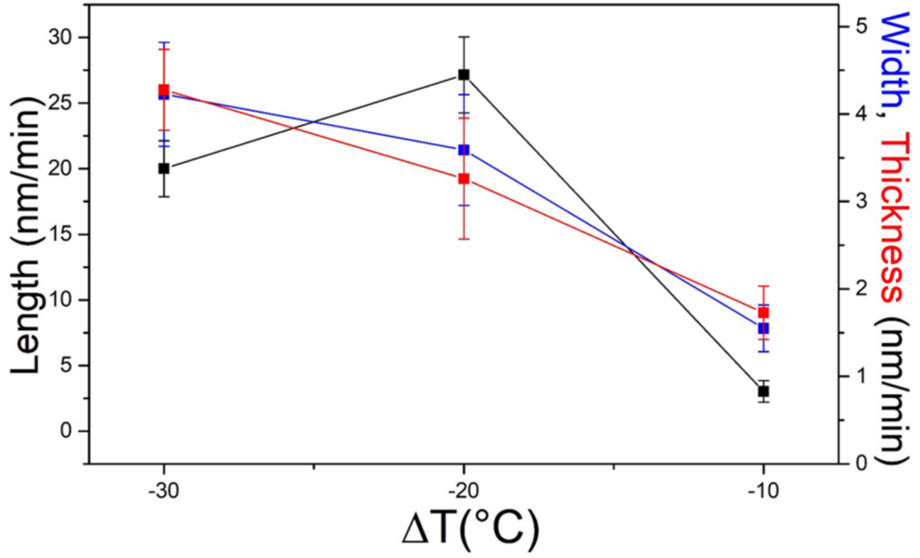
Optimizing InSb Temperature



ΔT= -30°C

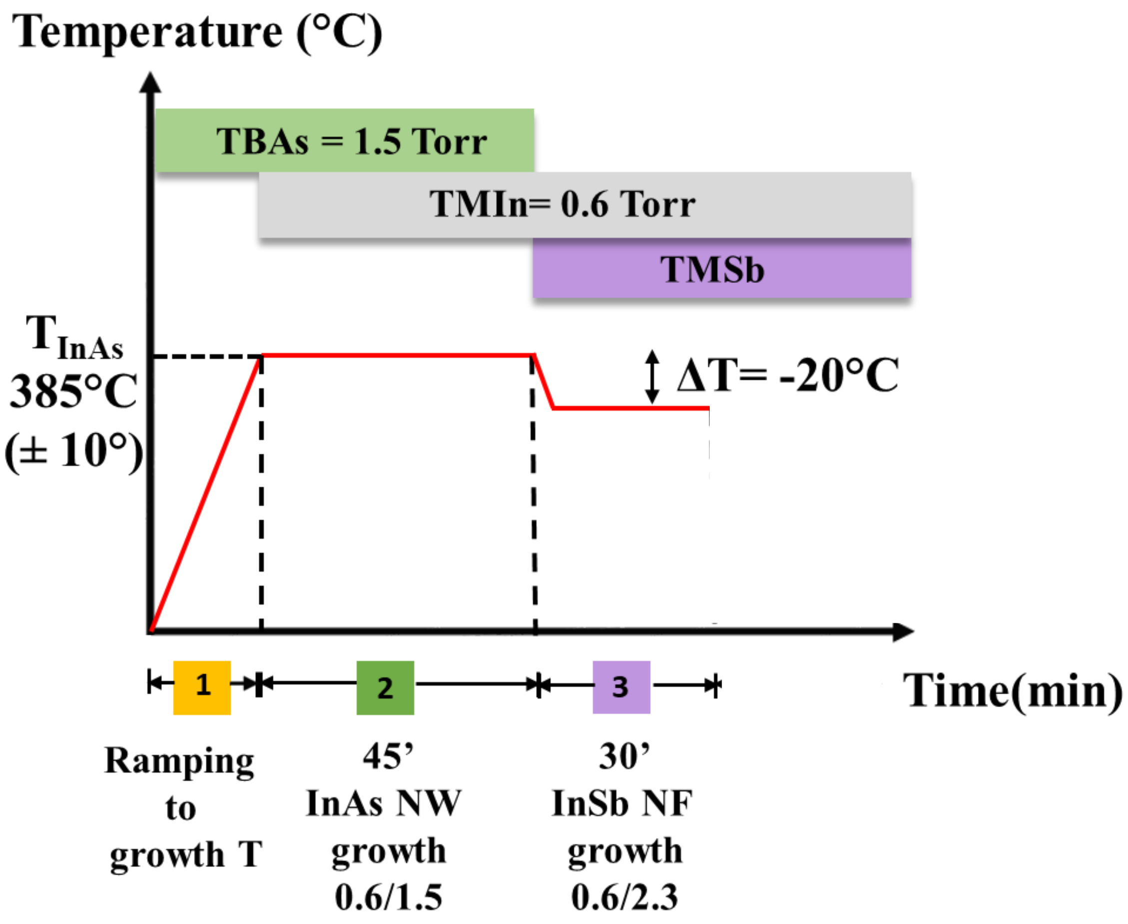


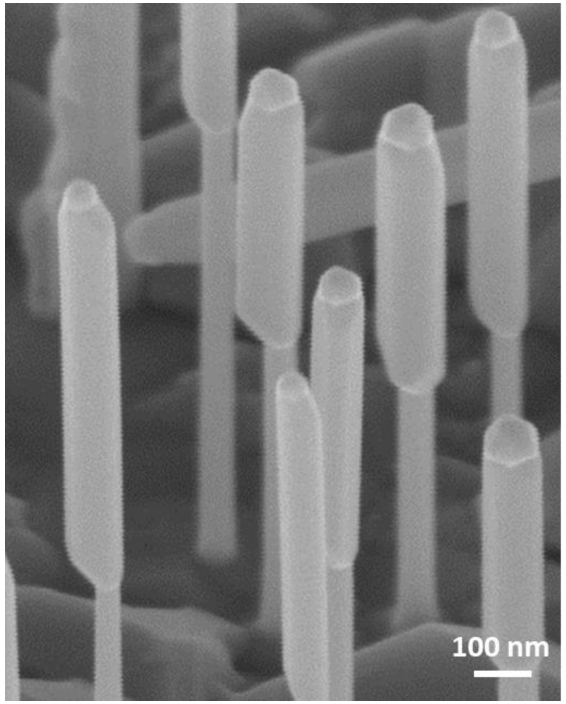
ΔT= -20°C



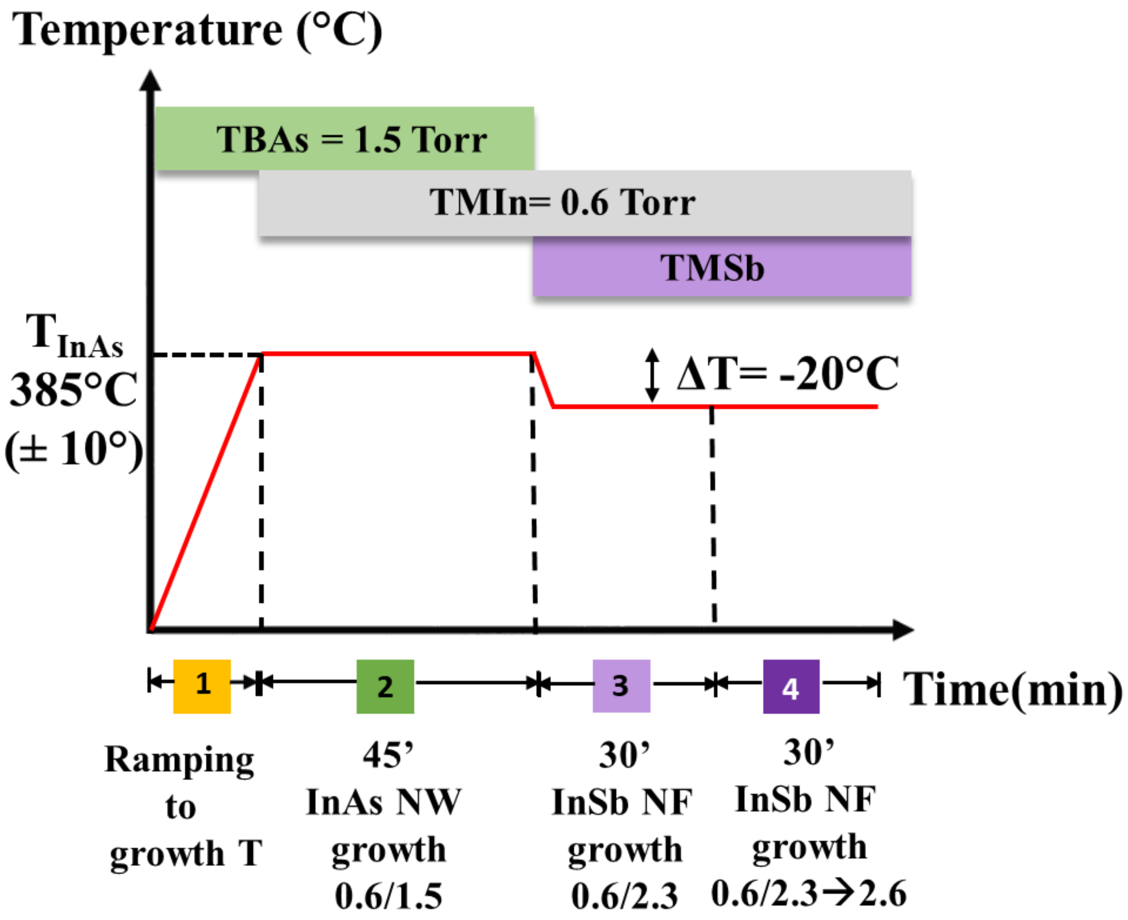
ΔT= -20°C is a good compromise

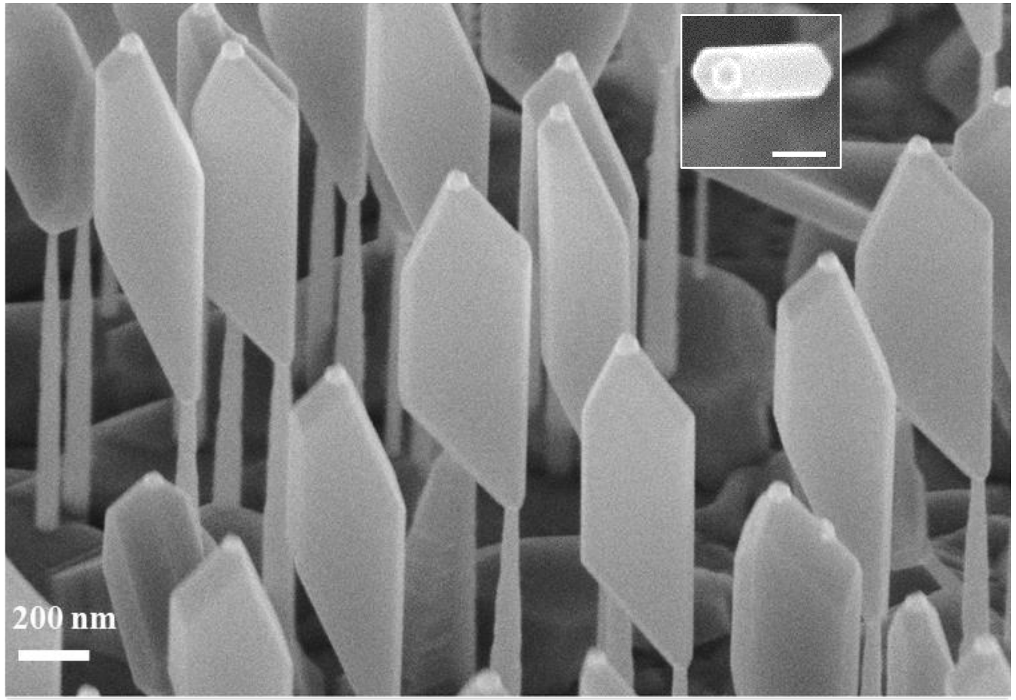
MORPHOLOGICAL CONTROL BY Sb FLUX





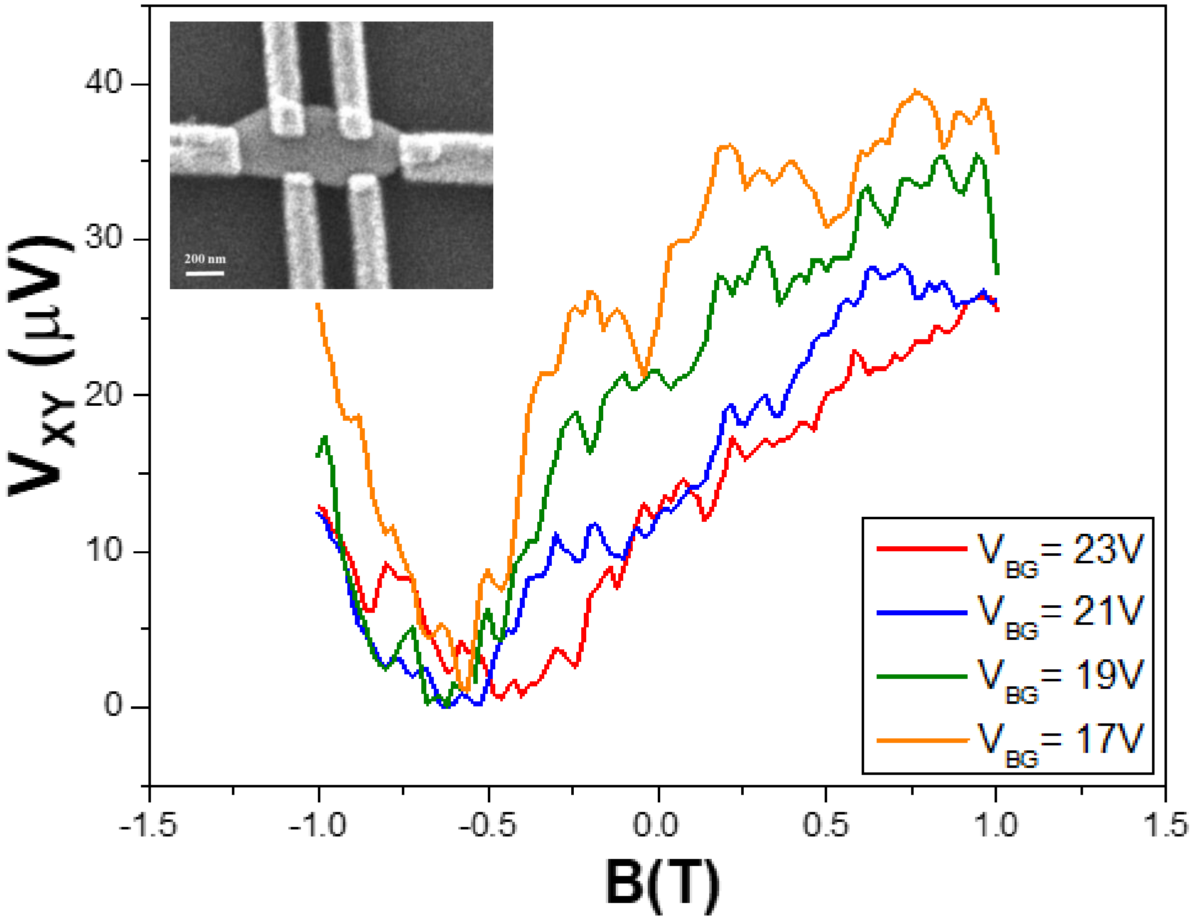
InSb Nanoflakes on InAs NW stems

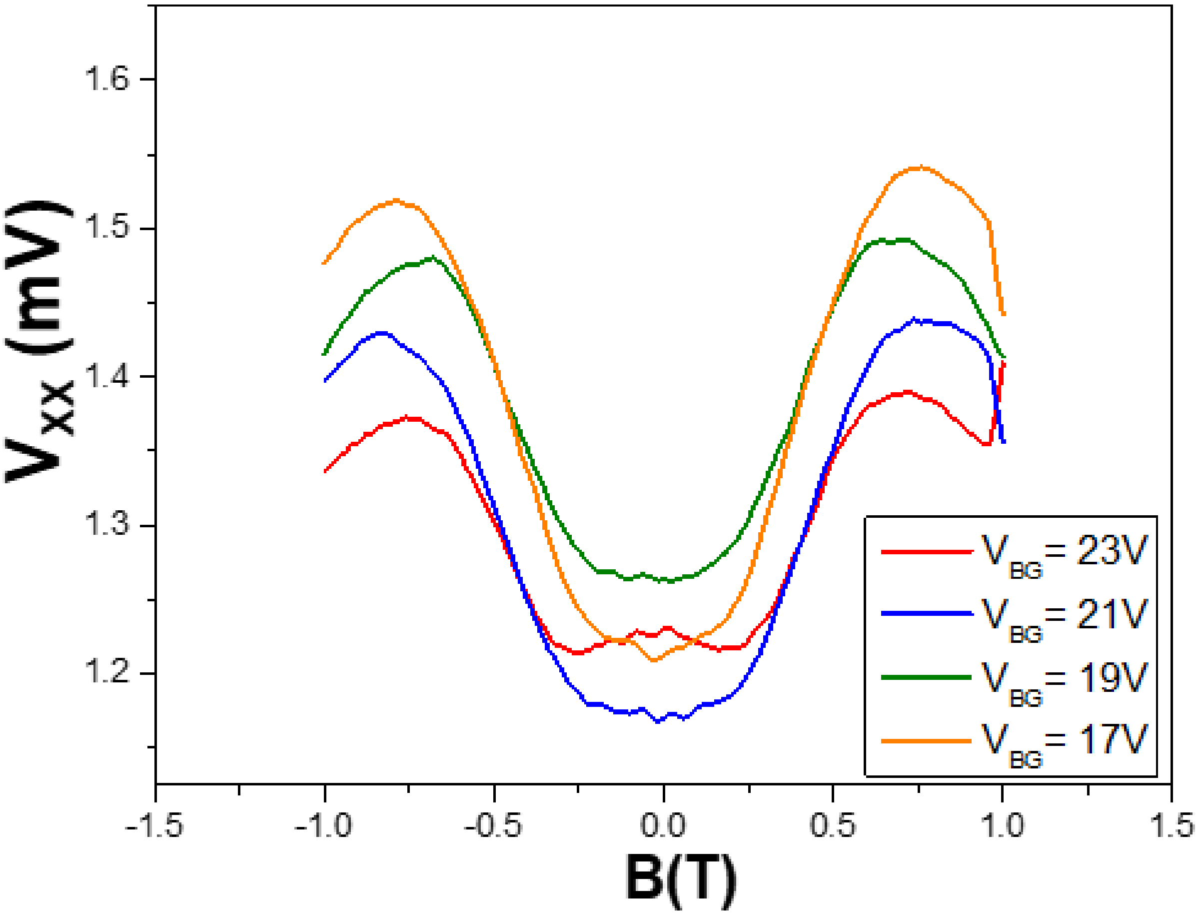




Length= (1.28 ± 0.14) µm
Width= (282.35 ± 86.48) nm
Thickness= (103.81 ± 17.18) nm

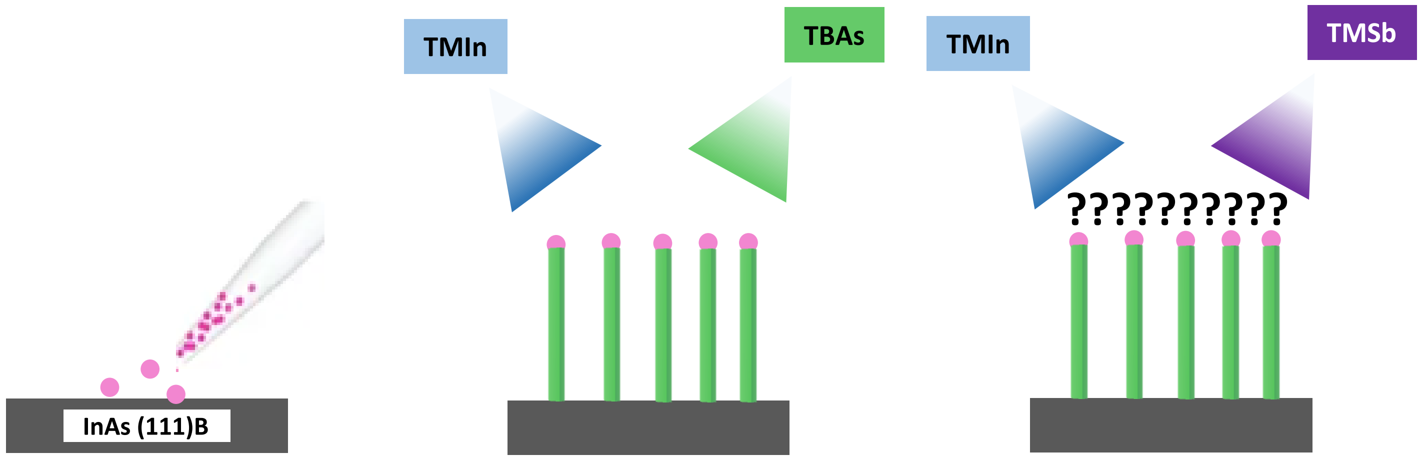
InSb Nanoflags: Hall Measurements at 4.2 K





There is a mixing of the V_{XX} and V_{XY} components due to the reduced size of the NF, and hence correct value of electron carrier and mobility cannot be determined.

Solution: Size Up!!


InAs (111)B
TMIn
TBAs
TMIn
TMSb
??????????