InSb Nanoflags: Growth and Transport Study

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Introduction and Motivation

▪ **InSb**, owing to its low electron effective mass, high electron mobility, small bandgap and strong spin-orbit interaction, appears to be a promising material to investigate emerging exotic bound states at superconductor/semiconductor interfaces.

▪ **Nanoflag (NF) geometry** simplifies the device fabrication process and enables to work with more advanced device geometries with respect to nanowires.

▪Therefore, it is important to understand the growth mechanism so as to have a better control of morphology and quality.

▪InSb nanosails (twin induced)[1] and InSb nanosheets (Ag-assisted)[2] have been already grown by employing MBE and MOVPE. We have synthesized InSb nanoflags (NFs) by Au-assisted Chemical Beam Epitaxy (CBE) for the first time.

Experimental Details

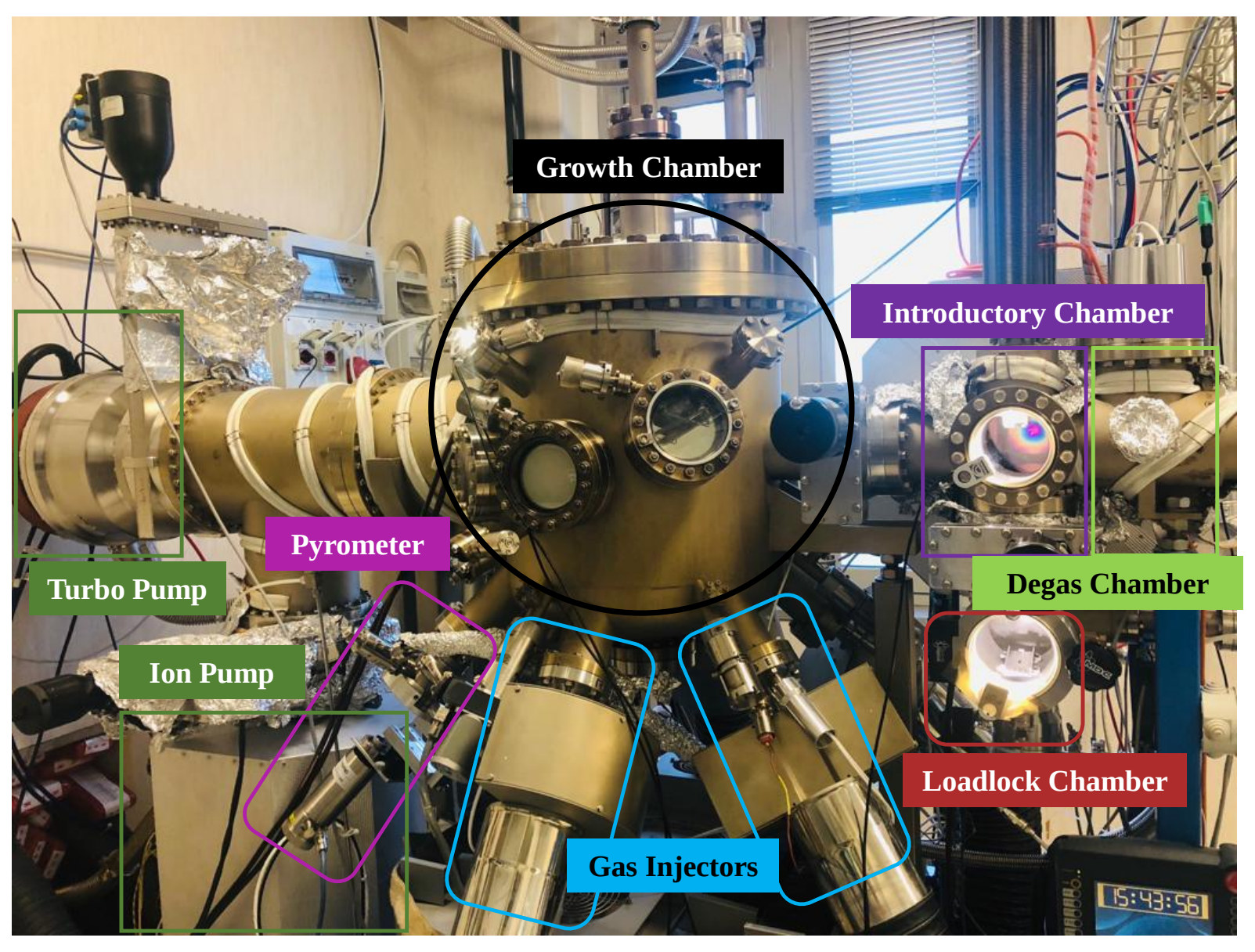
▪**Au-assisted Chemical Beam Epitaxy (CBE)**.

▪**MO precursors**: Trimethylindium (TMIn), Tertiarybutylarsine (TBAs) and Trimethylantimony (TMSb)

▪ **Substrates:** InAs(111)B

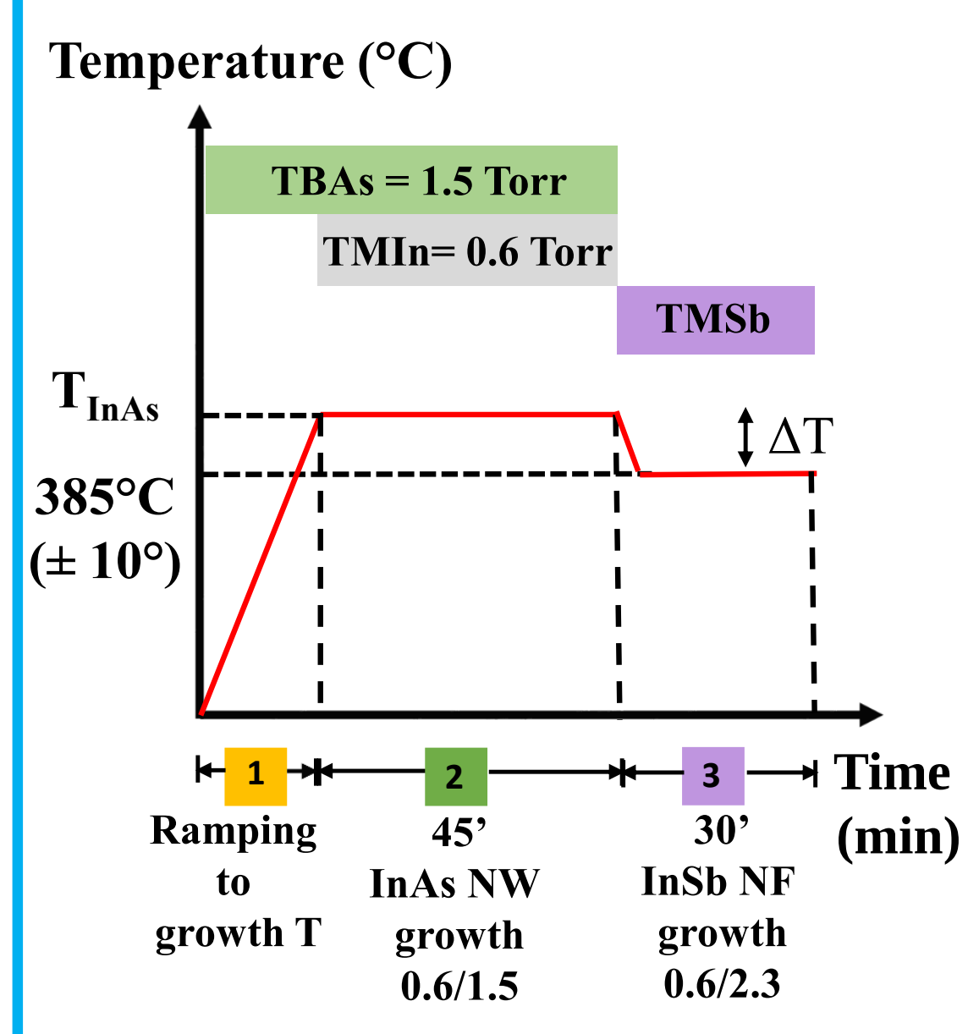
▪ **Catalyst:** 30 nm Au colloids (Density ≈ 5 per μm^2) deposited on the substrate at RT.

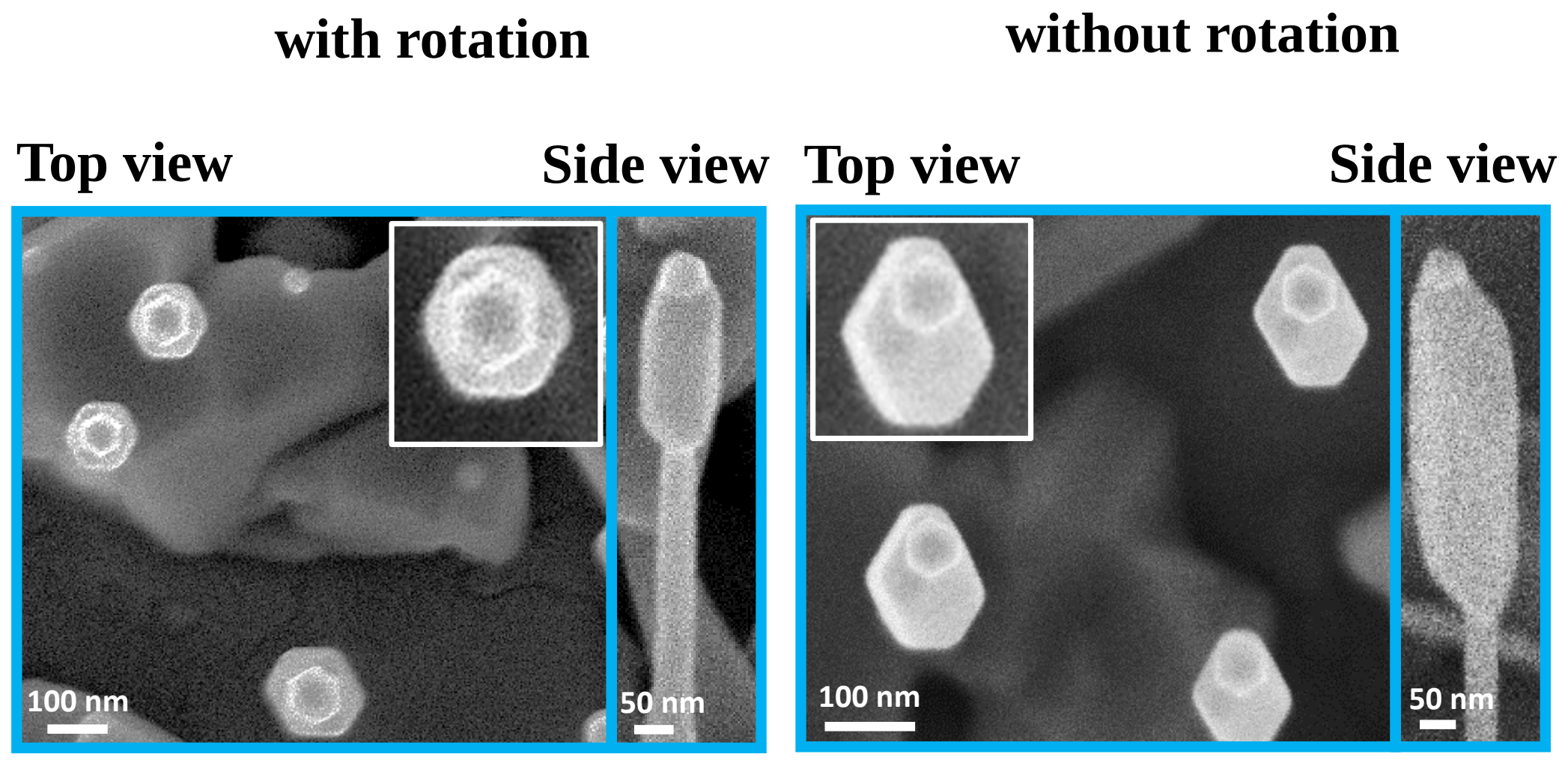
▪InSb growth temperature (ΔT) is referenced to InAs growth temperature (T_{InAs}).



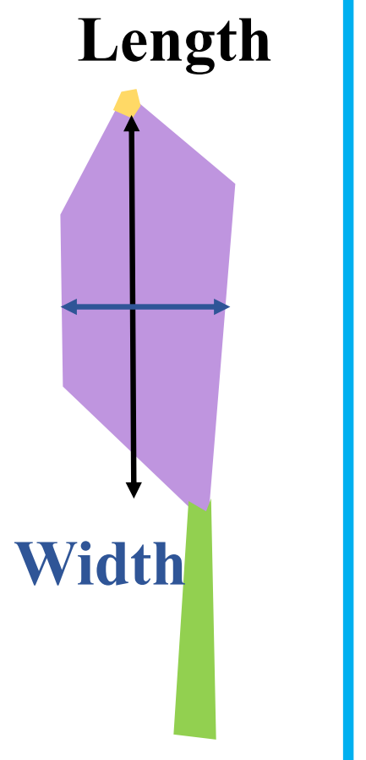
Riber C-21 CBE

(1) Rotating substrate

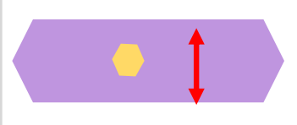




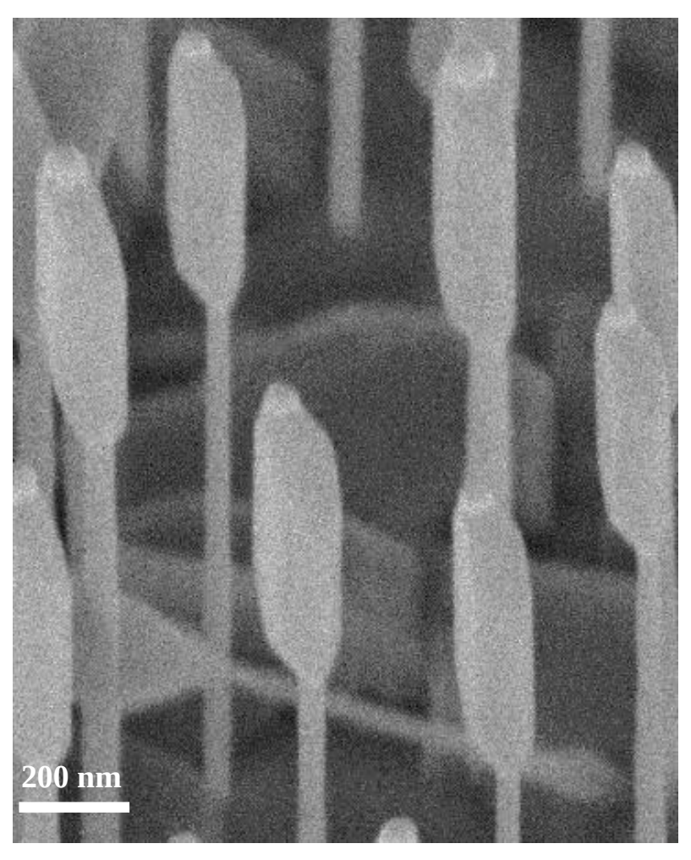
Dimensions



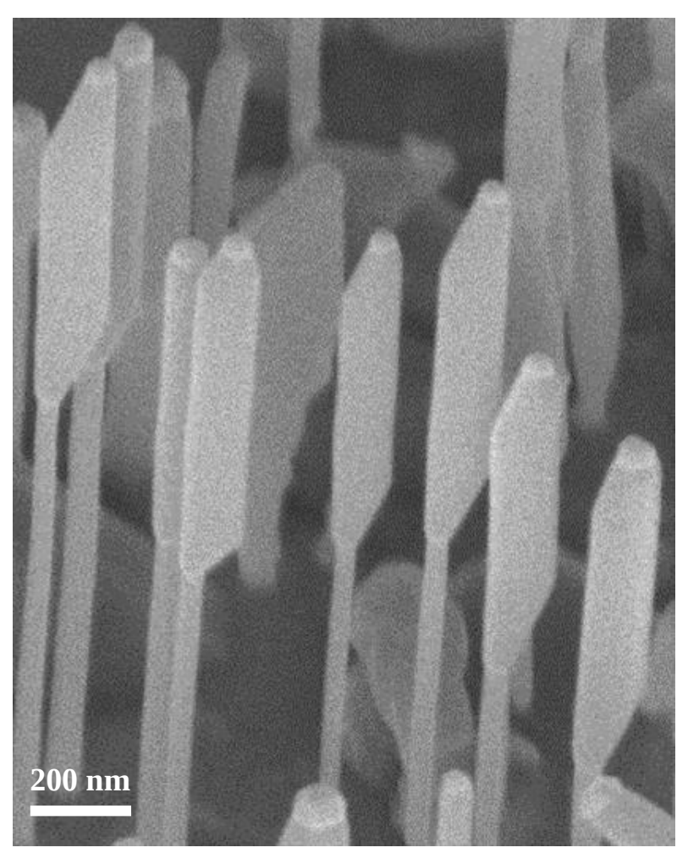
- ☐ Growth of InSb is uniform and symmetric when the substrate is being rotated. (5 rotations per minute)
- ☐ While with stopping the rotation, asymmetry appears in the growth of InSb.
- ☐ Rotation of the substrate is a crucial parameter because it imparts symmetry or asymmetry which is necessary for the growth of InSb NF .



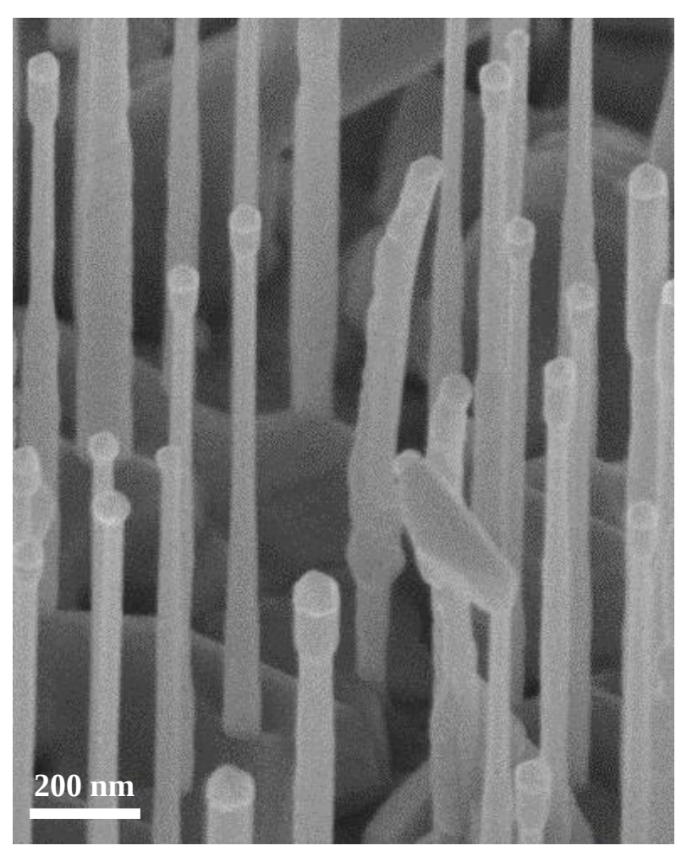
(2) Temperature of InSb (ΔT)



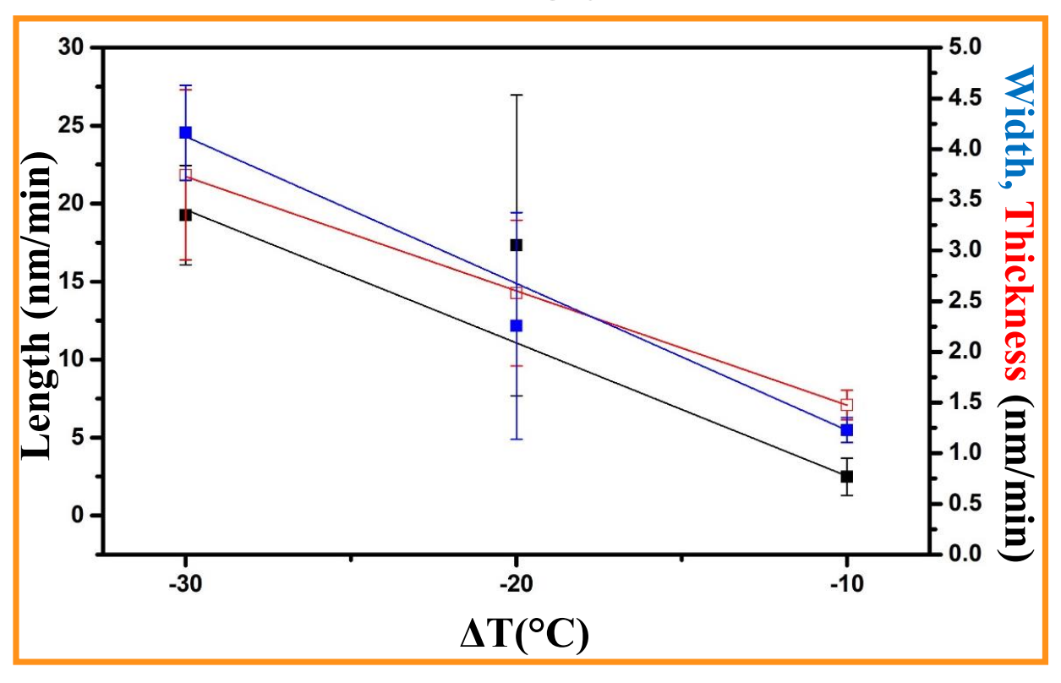
ΔT= -30°



ΔT= -20°

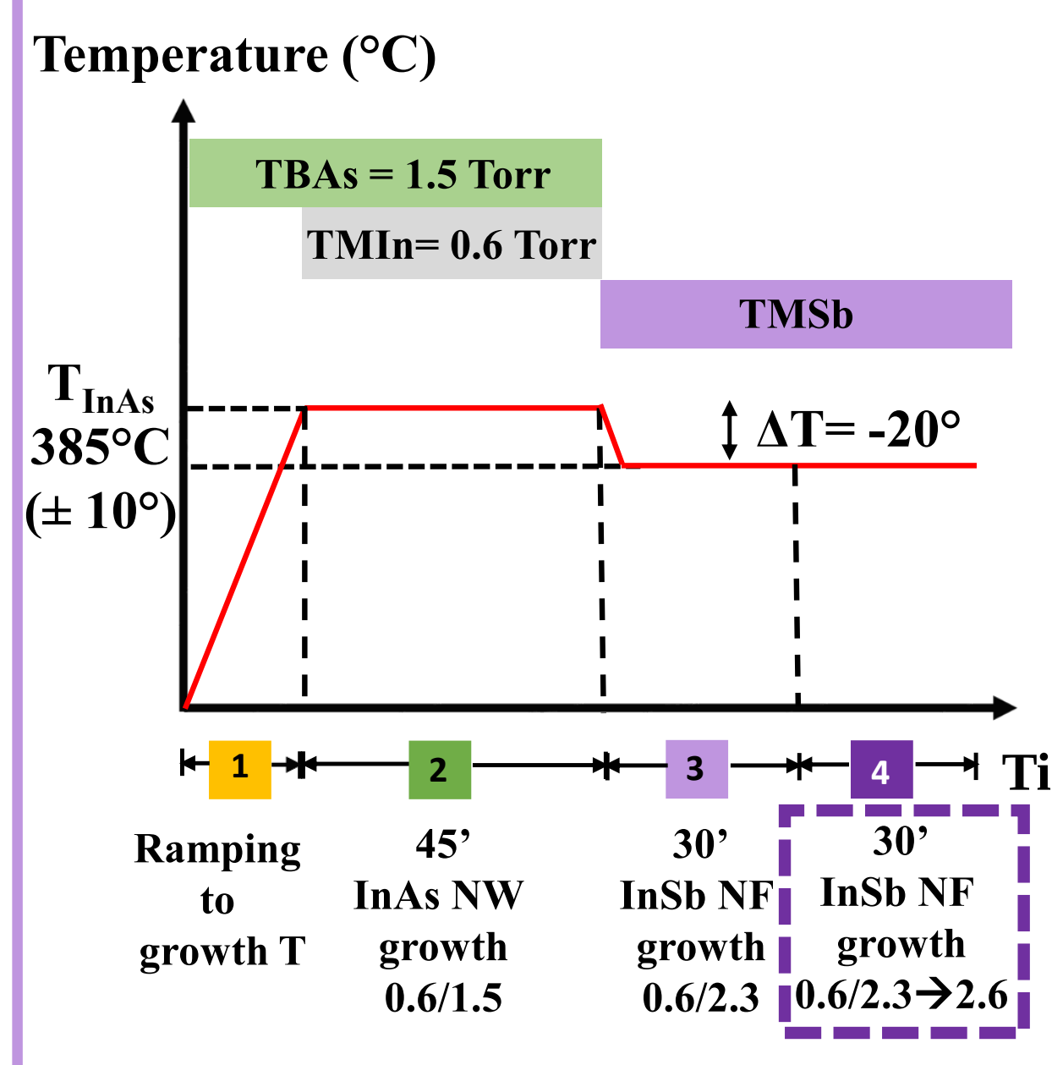


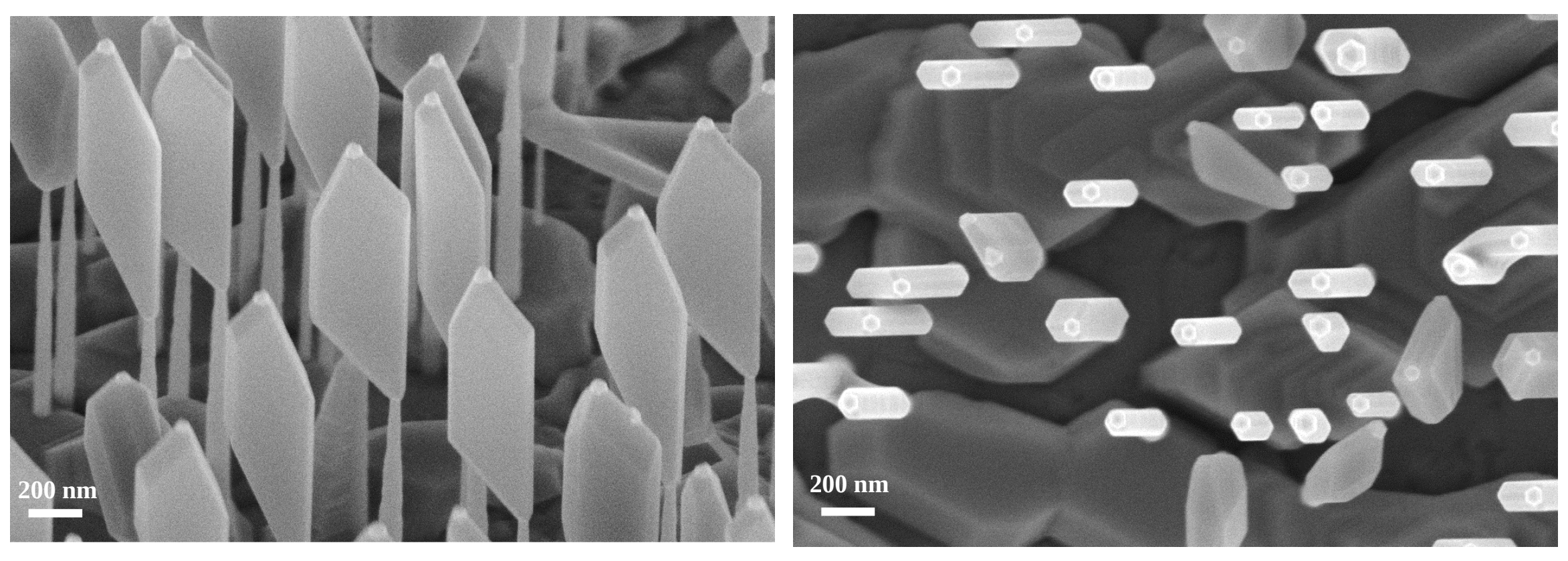
ΔT= -10°



- ☐ Growth rates for **length, width and thickness** linearly decreases with increasing in ΔT.
- ☐ For InSb NF, ΔT= -20° is the optimized temperature.

(3) Increasing Sb flux

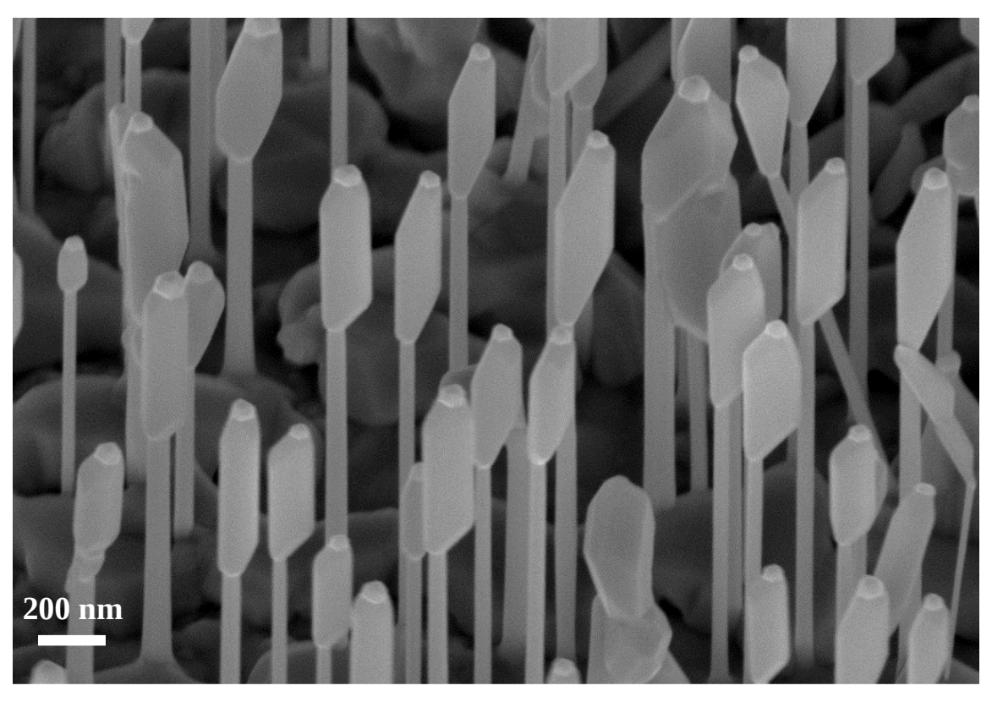




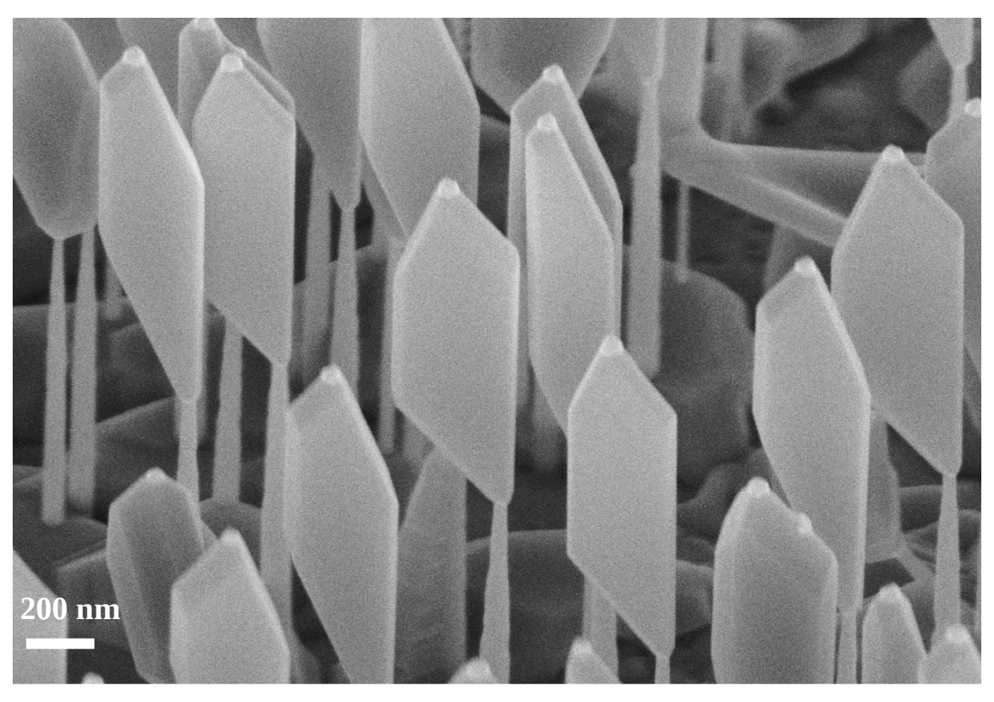
Length= (1.28 ± 0.14) um
Width= (282.35 ± 86.48) nm
Thickness= (103.81 ± 17.18) nm

- ☐ The sample is grown by adding an additional step of increasing Sb flux from 2.3 torr to 2.6 torr while keeping the In flux constant at 0.6 torr at ΔT= -20° with non rotating substrate.
- ☐ The cool down protocol is done in absence of group V flux to avoid growth at sidewalls of NWs.

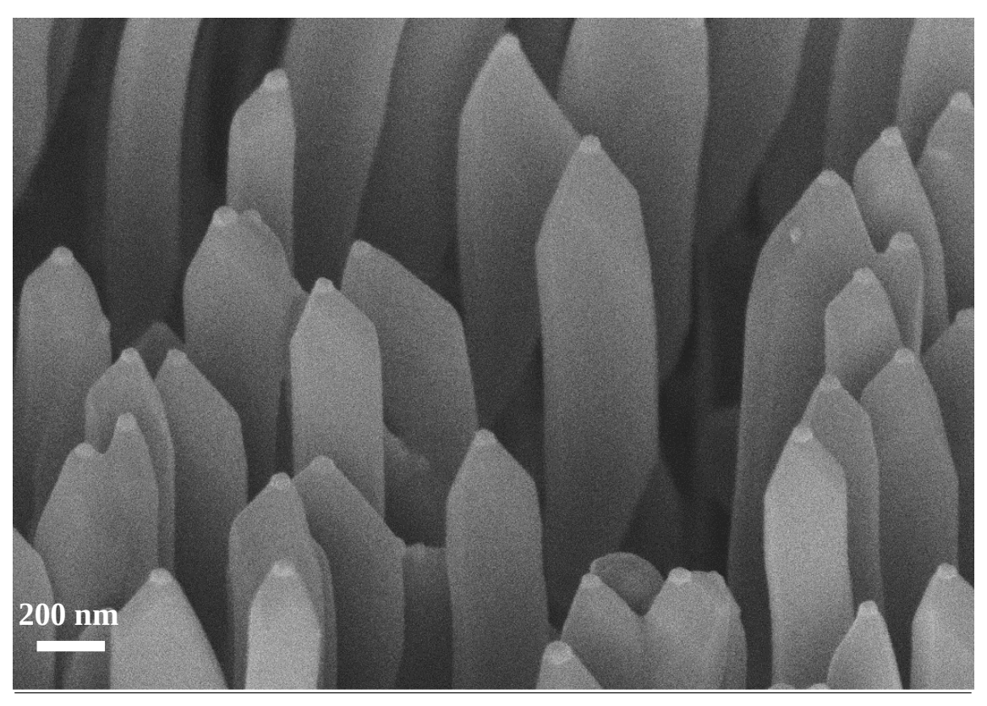
(4) Growth time



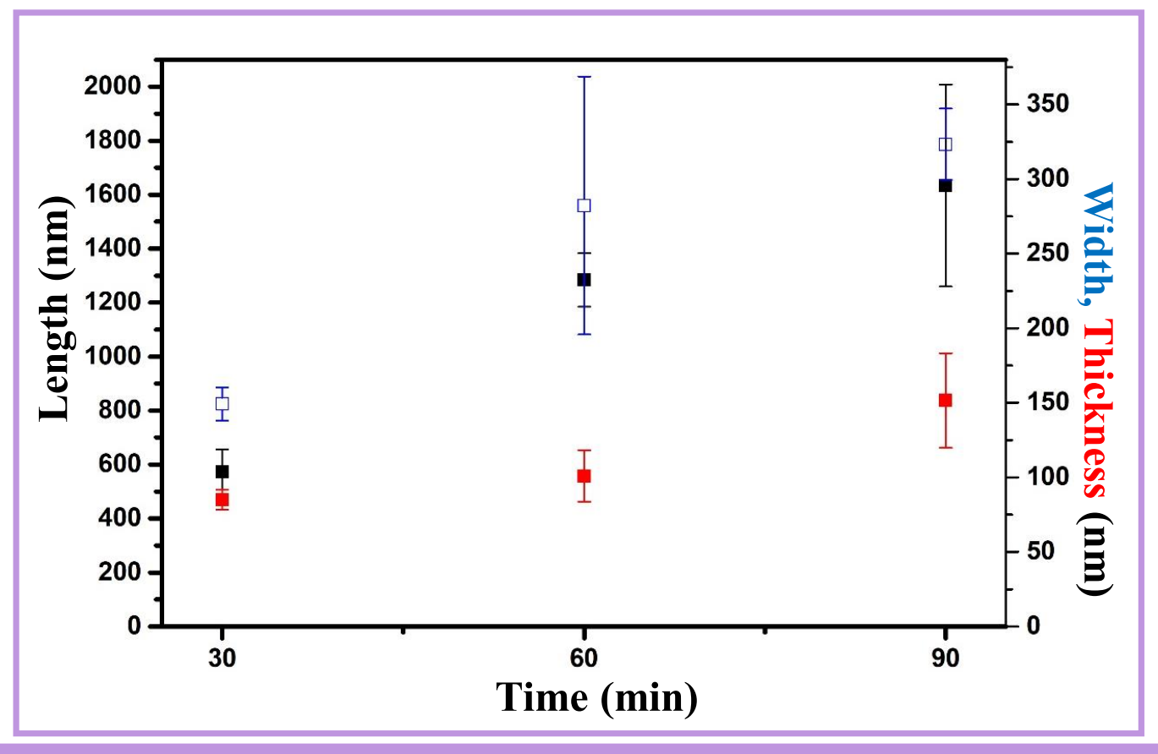
15' 3 +15' 4



30' 3 +30' 4



30' 3 +60' 4



- ☐ The growth rates of **length** and **width** are non linear with respect to growth time.
- ☐ The trend suggests that the growth rates of **length** and **width** starts to saturate with increasing InSb growth time.
- ☐ While the growth rates of **thickness** linearly increases with respect to the growth time.

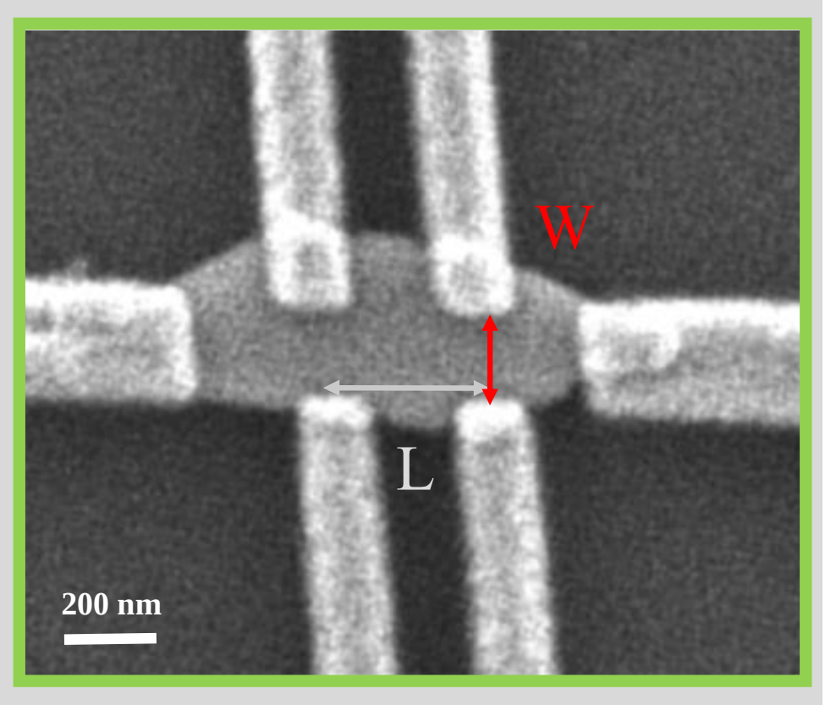
(5) Transport Measurements

- ☐ To assess the electronic quality of InSb NF, preliminary electrical measurements are performed in Hall bar configuration at low temperature (T = 4.2 K).
- ☐ For the device fabrication, the as-grown InSb NF are first mechanically transferred to a SiO_2/Si^{++} substrate.
- ☐ In a four-probe measurement, by sweeping the back gate (BG) voltage, we can modulate the carrier density in the NF channel – from a region of low conductance / high resistance, i.e. depletion region, to a region of high conductance / low resistance, i.e. accumulation region. These measurements show that the sample is intrinsically n-type doped and that we are in electron transport regime.
- ☐ For mobility extraction:

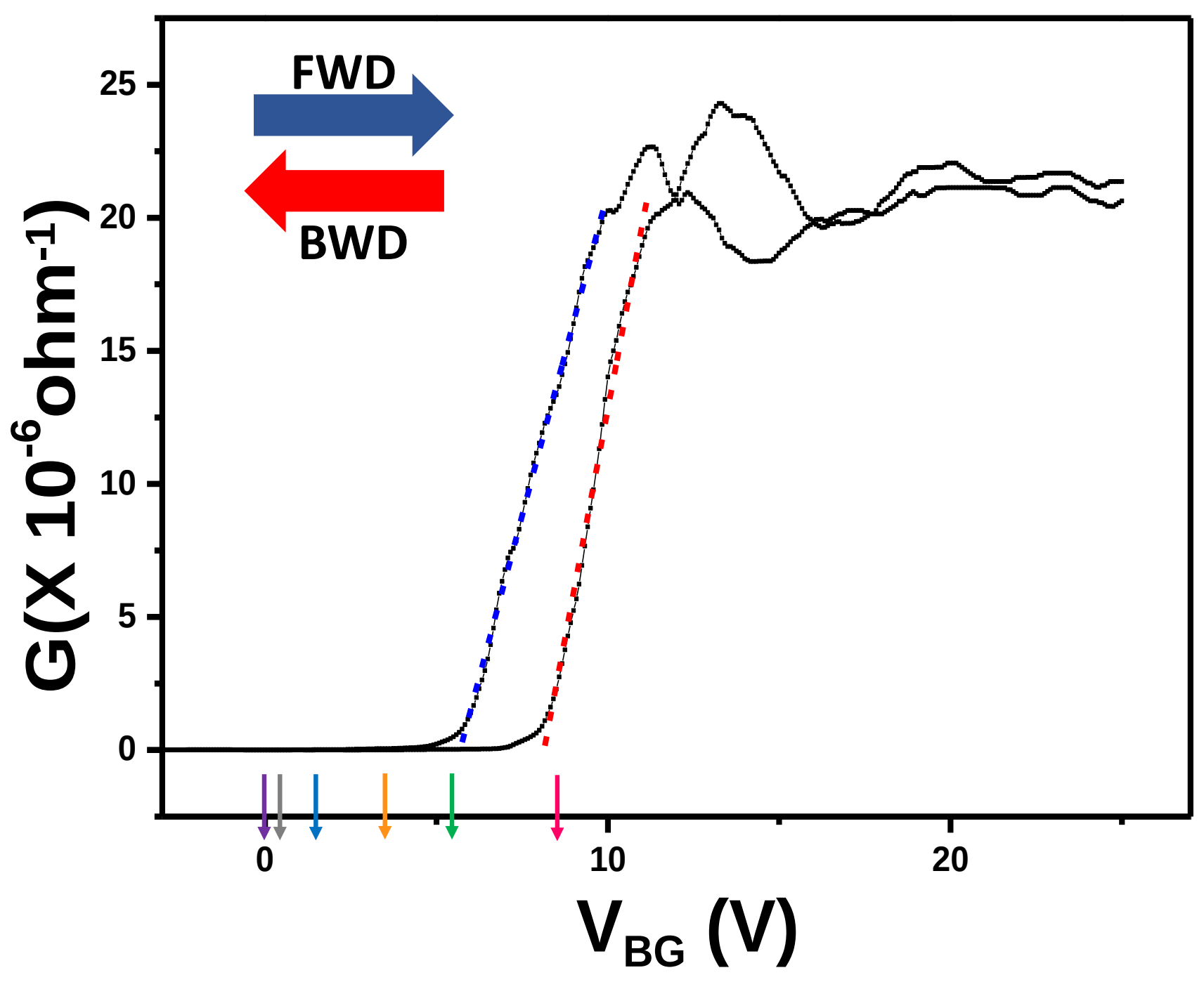
$$\mu_{FE} = \frac{L}{WC_{ox}}\left(\frac{dG}{dV_{BG}}\right) \qquad C_{ox}\ (300\text{nm } SiO_2) = 11.6\ \text{nF/cm}^2\ ;\ \frac{L}{W} = 1\ ;\ \frac{dG}{dV_{BG}} = 6.89 \times 10^{-6}\ \frac{A}{V^2}$$

$$\mu_{FE} = 594\ \text{cm}^2/\text{Vs}$$

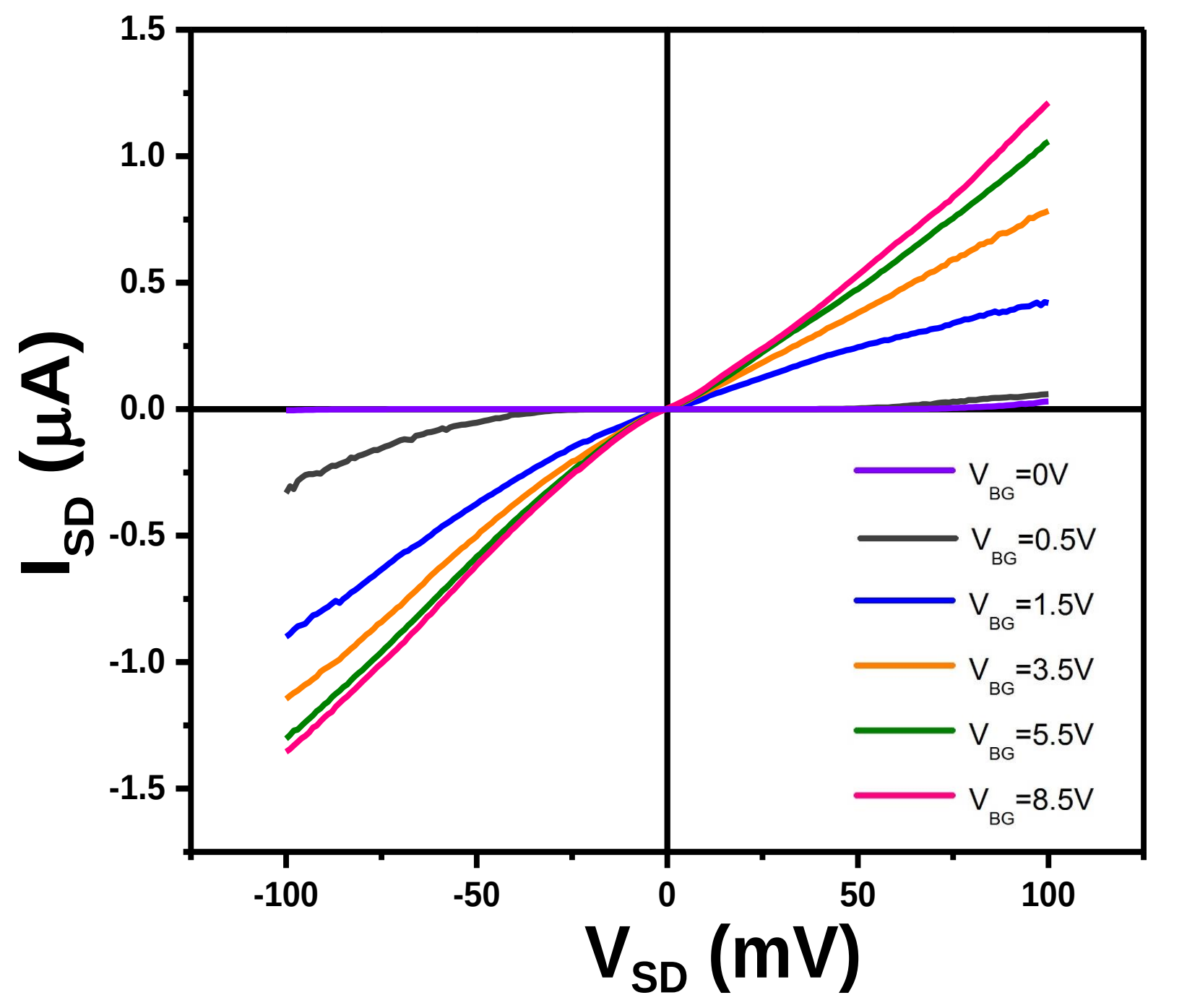
- ☐ From a Hall measurement, the carrier concentration is found to be $3\text{x}10^{16}$ cm^{-3} at V_{BG} = 11 V.
- ☐ The two-probe I-V curves shows modulation for positive BG.



SEM image of InSb NF Hall bar device



Four-probe conductance G as a function of V_{BG} at T=4.2 K.



Two probe current−voltage characteristics at different back gate voltages in the electron transport region.

Acknowledgement

This work is financially supported by QuantERA ERA-NET in quantum technologies through the project SuperTOP.

References

[1] María de la Mata, Renaud Leturcq, Sebastien R. Plissard, Chloé Rolland, Cesar Magén, Jordi Arbiol, and Philippe Caroff; " Twin-Induced InSb Nanosails: A Convenient High Mobility Quantum System"; Nano Letters 16, 825 – 833, 2016.

[2] D. Pan, D. X. Fan, N. Kang, J. H. Zhi, X. Z. Yu, H. Q. Xu, and J. H. Zhao; "Free-Standing Two-Dimensional Single-Crystalline InSb Nanosheets"; Nano Letters 16, 834 – 841, 2016.

Conclusions

- ☐ InSb NFs have been grown by **Au-assisted CBE**.
- ☐ By tailoring the parameters such as rotation of substrate**, InSb temperature**, **MO fluxes and proper choice of time**, we realized InSb NF with optimized morphology.
- ☐ The preliminary transport measurements depict that the as-grown InSb NF are **n-type.** Carrier density can be modulated with the help of a global back gate.