

In-situ TEM Growth of Chiral Tellurium Nanoribbons on Hexagonal Boron Nitride

Duration: 6 months starting from March
Salary ~650 EUR/month
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Context of the project: Tellurium (Te) is a chiral elemental semiconductor whose atomic structure consists of helical chains (space groups $P3_121$ or $P3_221$), imparting unique electronic, optical, and spin properties. Its quasi-one-dimensional nature yields strong spin–orbit coupling, anisotropic transport, and distinctive optical responses, including non-linear chiral effects such as second-harmonic generation circular dichroism (SHG-CD) in ultrathin nanowires [1,2]. Several growth approaches have been reported, including vapor transport, solution chemistry, and physical vapor deposition. These methods have produced Te nanoribbons or nanowire with good crystallinity and high mobilities of $\sim 400 \text{ cm}^2/\text{V}\cdot\text{s}$ and on/off ratios $\sim 10^5$ [3]. However, nanoribbon alignment is often partial and the substrates are non-insulating (limiting electrical probing). While some epitaxial relationships are known, atomic-scale insights into epitaxial growth mechanism remain scarce [3]. Using hexagonal boron nitride (hBN) as an insulating, atomically flat substrate is a promising route that remains underexplored for Te nanoribbons. Its ultrawide bandgap ($\sim 5.8 \text{ eV}$) and van der Waals surface minimize substrate-induced scattering or leakage, enabling clean electrical measurements, while its flatness and inertness make it ideal for epitaxy.

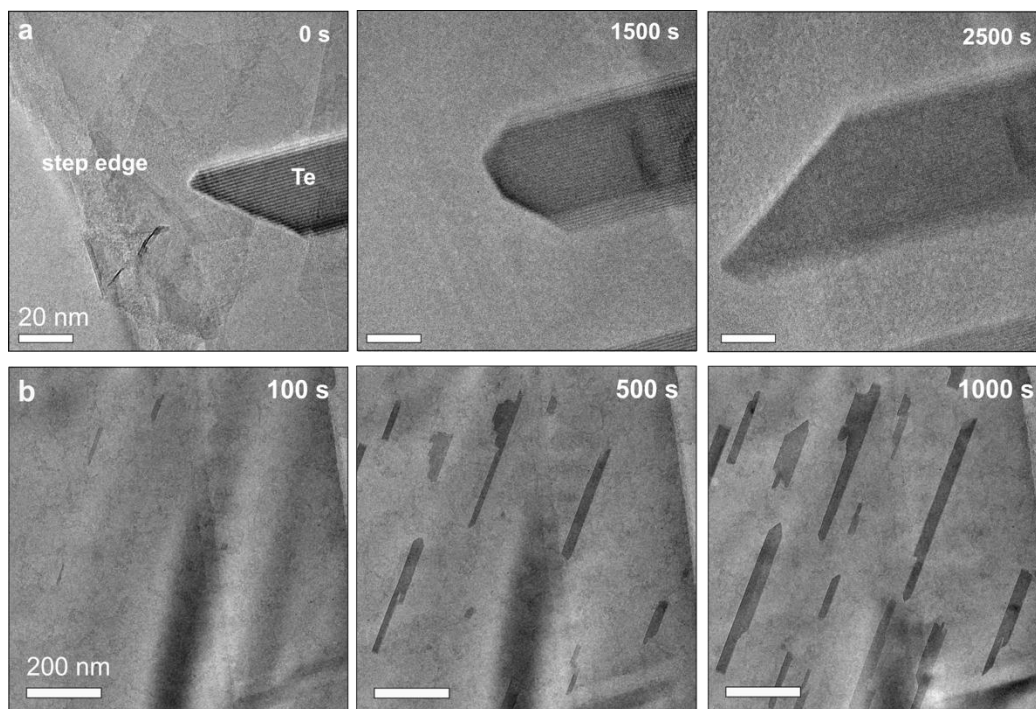


Figure 1. In situ growth kinetics [4]. a, Time series showing changing facets at the tip of a nanoribbon during growth over a substrate step. Note that the field of view changes as the nanoribbon grows. b, Video stills of nanoribbon growth at low-medium flux rate ($T_r = 355 \text{ }^\circ\text{C}$) and substrate temperature $180 \text{ }^\circ\text{C}$.

In this project, we will use in situ Transmission Electron Microscopy (TEM) to observe directly the nucleation, early growth, and interface formation of Te nanoribbons on hBN. *In situ* TEM provides unparalleled imaging resolution and allows the capturing of the growth dynamics [4,5] and the effect of growth parameters on the growth kinetics in real-time [Video]. Using this technique will allow us to understand the growth mechanism and how substrate, temperature, flux, and epitaxial registry control size, alignment, and chirality. Our goal is to develop a novel platform of aligned, epitaxially grown, chiral-selected Te nanoribbons on hBN, enabling both structural and electrical characterization. By combining high-purity epitaxial growth, in situ observations, and device fabrication, we aim to establish a reproducible system for spintronic devices exploiting the chiral degree of freedom of Te.

Master 2 internship: The successful applicant will prepare samples by transferring exfoliated hBN flakes onto TEM heating chips under the supervision of the MAT2D team, participate in in-situ growth experiments, and perform advanced image analysis of the resulting nanostructures. During the internship, the student will also interact with Thales (MBE growth of Te) and the LAF group (spintronics applications of Te). The *in situ* experiments will be conducted using the MBE growth method in the NanoMAX TEM. The analysis will be carried out by developing dedicated image-processing algorithms able to extract relevant geometric parameters from each image. The expected result of this work will be to correlate growth conditions with the resulting morphology and define strategies to align the nanoribbons and ultimately control their chirality in view of creating a novel spintronic platform. This internship provides hands-on training in nanomaterials synthesis, electron microscopy, within a multidisciplinary environment bridging growth, characterization, and device applications.

This work could be extended to a Ph.D.

Candidate profile: Highly motivated candidates enrolled in a master's degree or equivalent, with a background in physics, materials science or engineering. Prior knowledge in programming (possibly Python) would be highly appreciated.

Application procedure: For additional information about the project and/or the recruitment process, please contact Federico PANCIERA (federico.panciera@c2n.upsaclay.fr). The candidate should include a CV.

References

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- [3] Z. Zhang et al., *Oriented Tellurium Nanoribbon Arrays: From Controlled Synthesis to High-Performance Field-Effect Transistors*, ACS Nano 17, 2023. DOI: 10.1021/acs.nano.2c11759
- [4] K. Reidy, N. R. Ithzak, C. Wei, L. Houben, K. Rechav, P. Miller, P. Knight, F. Panciera, E. Joselevich, F. M. Ross, *In Situ Nucleation and Growth Mechanisms of Tellurium Nanoribbons via van der Waals Epitaxy*, Microsc. Microanal. 31(1), 2025. DOI: [10.1093/mam/ozaf048.907](https://doi.org/10.1093/mam/ozaf048.907)
- [5] M. Panciera et al., *Synthesis of Nanostructures in Nanowires Using Sequential Catalyst Reactions*, Nat. Mater. 14, 2015, 820–825. DOI: 10.1038/nmat4329
- [6] J. C. Harmand et al., *Atomic Step Flow on a Nanofacet*, Phys. Rev. Lett. 121, 2018, 166101. DOI: 10.1103/PhysRevLett.121.166101