Internship Proposal for a First-year Master's student

Fabrication of Nanofluidic TEM Cells Incorporating Carbon Nanotubes

Duration: 3 months, starting as soon as possible in 2026
Salary ~660 EUR/month
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Context of the project: Nanofluidic channels impose extreme confinement on water and ions, giving rise to non-classical transport phenomena that deviate fundamentally from microfluidic behaviour.[1] One of the most intriguing observations is the unexpectedly high flow velocity of water through carbon nanotubes (CNTs), which deviates from classical hydrodynamics.[2] A recent theoretical study has proposed a new source of friction—beyond static roughness of interfaces—the resonance between the charge fluctuations in liquid water and plasmons at graphite surfaces.[3] This quantum friction exhibits strong coupling on multilayer carbon structures but decoupling on monolayer graphene. A second striking observation is the ultrafast proton conduction through water confined within CNTs.[4, 5, 6] Water molecules are predicted to self-organise into ice-like chains and shells in sub-5-nm CNTs[7], facilitating concerted proton hopping via the Grotthuss mechanism.[4, 6, 1] These phenomena have stimulated intense interest, both for their theoretical challenges and for their potential applications in filtration, desalination, and energy conversion.[8] However, direct experimental characterisation of nanofluidic behaviour at the molecular scale remains limited. Existing techniques average over space and time, thereby obscuring the molecular-scale dynamics underlying these phenomena. Electron beam with high acceleration energy has picometre-scale Broglie wavelengths. Transmission electron microscopy (TEM) enables visualization of crystalline structures and phase transitions down to the atomic scale.[9] Liquid TEM further afford observation of processes in liquid with high fidelity[10], with temperature and flow rate control. **The goal of this project is to develop fabrication strategies to incorporate CNTs into TEM liquid-cells for measuring nanofluidic transport**.

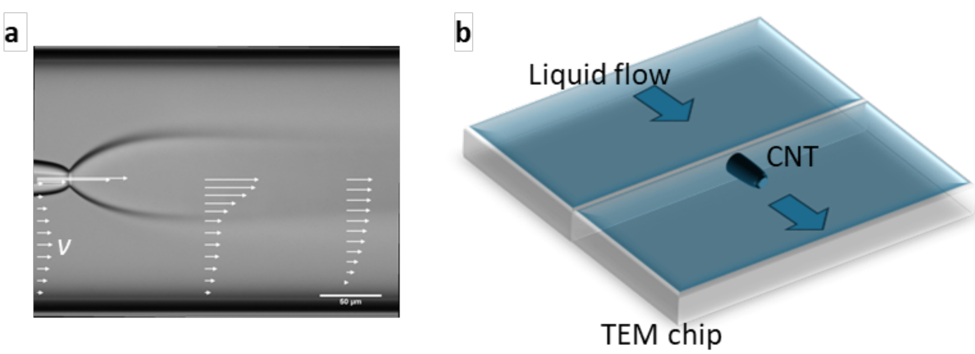

Figure 1. From microfluidics to nanofluidics. (a) Velocity profile in a microfluidic capillary. **(b)** Schematic of a CNT-based nanofluidic TEM liquid-cell.

Master 1 internship: The intern will participate directly in the device fabrication experiments. The fabrication will be carried out in the clean room at C2N. The fabrication will take 4 stages. First, disperse CNTs onto a SiN membrane used for liquid-cell TEM. Second, deposit a SiN or SiO_2 layer to embed the CNTs. Third, use lithography to pattern a SiN or SiO_2 wall that divides the cell into two compartments, ensuring that fluidic communication occurs solely through the CNT. Finally, connect the liquid cell to fluidic pumps and examine the performance under optical microscopy and electron microscopy.

This work could be extended to a Ph.D. on the observation of liquid dynamics through CNTs.

Candidate profile: Highly motivated candidates enrolled in a master's degree or equivalent, with a background in physics, materials science or engineering. Prior experience in lithography, vapor deposition, and cleanroom work would be a strong plus.

Application procedure: Please email your CV to Zhengyu ZHANG (zhengyu.zhang@centralesupelec.fr) and Federico PANCIERA (federico.panciera@c2n.upsaclay.fr).

References

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