Robotic nano-manipulation of MWCNTs on optical fibers for flexoelectric measurements.

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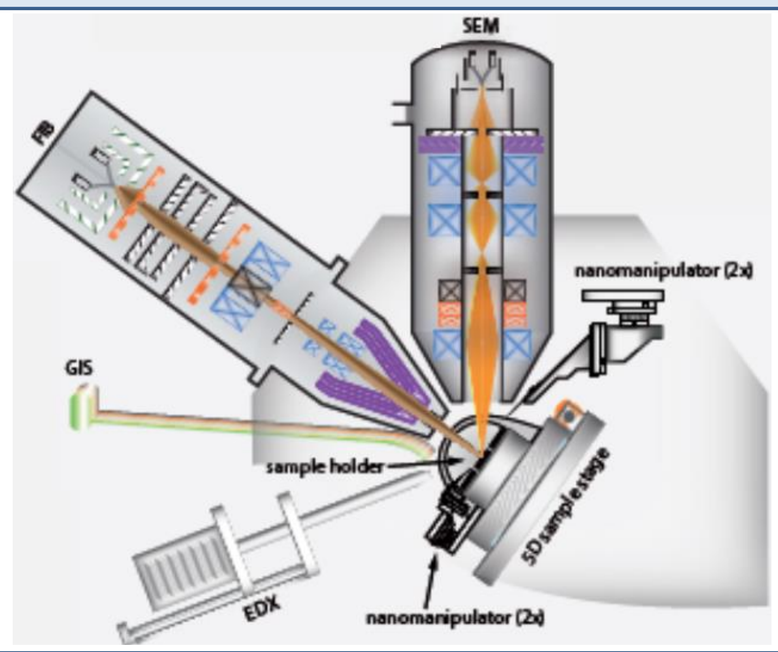
We report on a new generation nanofactory able to produce 3D nano-structures under vacuum by functionalizing and/or patterning and/or assembling materials on top of optical fibers, with very high accuracy. This nano-factory, called µRobotex, consists in a Zeiss Auriga 60 dual beams SEM/FIB, a GIS (Gas Injection System) and two microrobotic arms (from Kleindick and SmarAct).
It allowed us to manipulate Multi-wall Carbon Nanotubes (MWCNTs) one by one in order to measure flexoelectric properties.

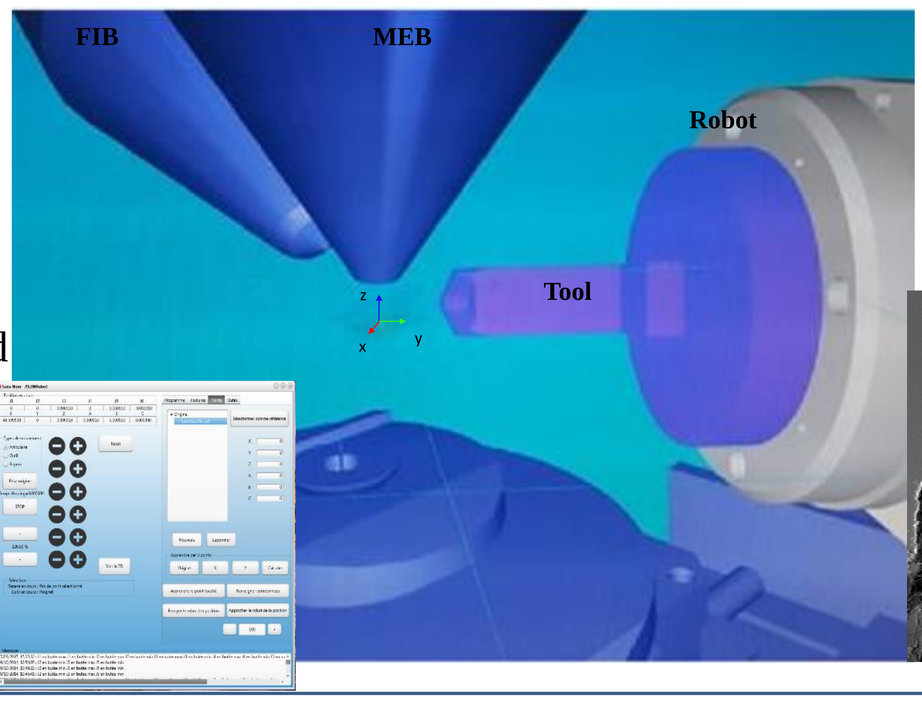
I – The platform

- Auriga 60 from Zeiss with dual MEB/FIB beams.
- Sample holder stage 5 DoF: X, Y, Z, Z' for eucentric point, and Θ and smarAct Θ'.
- SmarAct micro robot with 6 DoF : X*Y*Z: 150*70*70 mm±10 nm, Θx (tools) 360°±0,001°, Θy, Θz : 7°±0,001°.
- Gas Injection System with: XeF_2 for etching and patterning materials, $W(CO)_6$, Cyclopentadienyl Pt, and naphtalen gas for CVD thin layer.
- Kleindick tip with 3 DoF,
- Working space of $(0,5\ mm)^3$ for assembly of the MWCNTs.

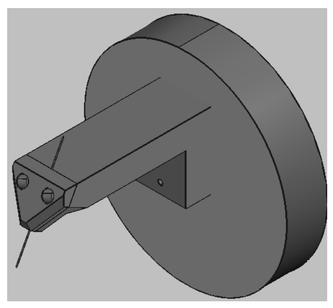


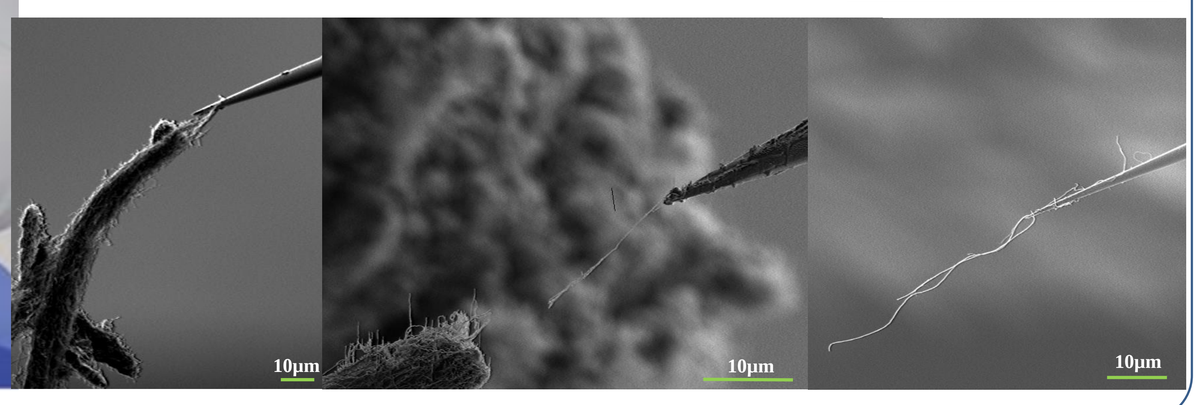
II –The robotic system

- Specific tools for holding optical fibers.
- Assembly area near the eucentric point (SEM/=/FIB).
- Assembly area around $0.5*0.5*0.5mm^3$.
- HMI for the stage of the SEM by the API function of Zeiss.

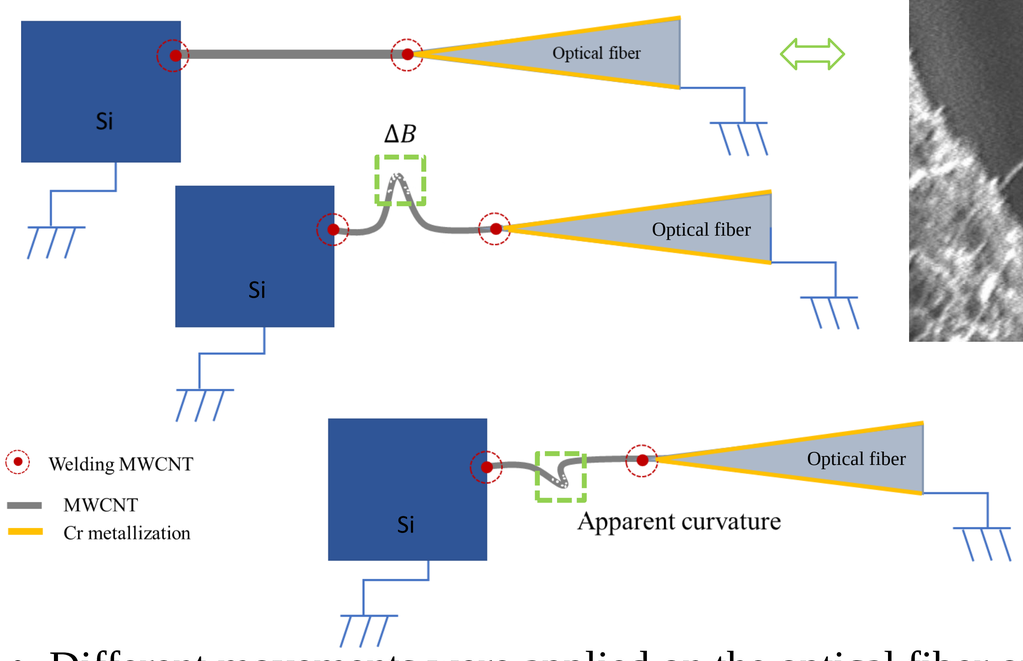


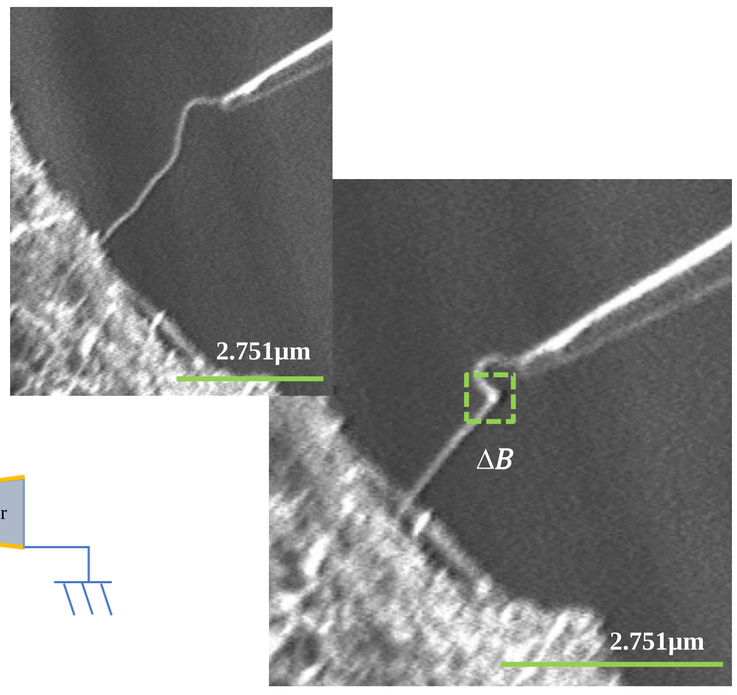
- Streched optical fiber = diameter of the tip around 100 nm.
- Metallized in PVD with Cr.
- Welding the MWCNT on fiber by EBAD and IBAD.





III – The manipulations

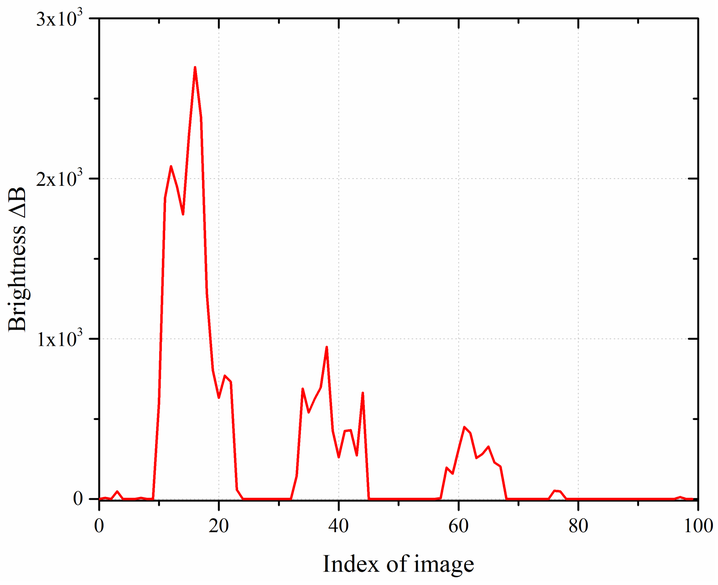




Polarization variation $\Delta P \sim \frac{\mu}{R}$

Surface density of charge $\overrightarrow{\Delta P} \cdot \vec{n} = \sigma$

Link brightness variation $\Delta B \overset{?}{\propto} \Delta\sigma \sim \frac{\mu}{R}$
⇔ flexoelectricity



- Different movements were applied on the optical fiber or on the silicon cantilever.
- These movements bend the MWCNT welded between a tip and a silicon cantilever.
- Difficulties to bend the NTC always in the observation plane for measurements.

Important projects in the field of nano-manipulation and assembly are on the way in µRoboteX station, in order to build 3D nano- or micro-structures on top of optical fibers or tips. Using this facility, we can bend individual MWCNTs welded between two tips or between a tip and a silicon cantilever, in order to study flexoelectricity effects in a single MWCNT by measuring the variation of brightness.

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