

WP4
Scanning probe microscopy based
investigations of carbon nanotubes
and of carbon nanowalls

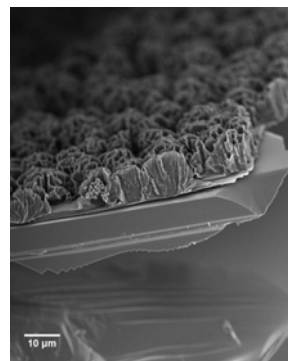
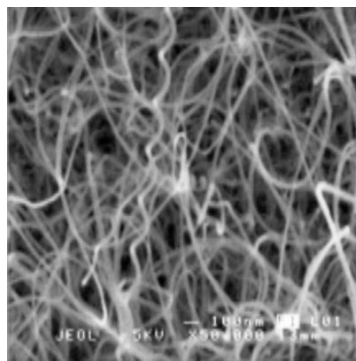
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A. Vanhulsel	VITO
A. Fonseca	UNamur
J. B. Nagy	UNamur
J. Piot	KULeuven
T. Moorkens	KULeuven
K. Schouteden	KULeuven
C. Van Haesendonck	KULeuven



Annual INPAC Meeting
La Foresta, Vaalbeek, November 29, 2007

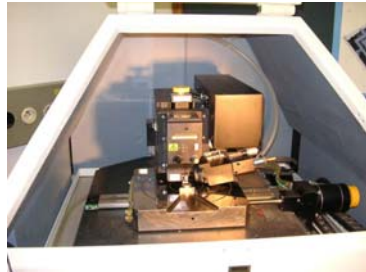
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Carbon Nanotubes and Nanowalls



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Our multifunctional SPM: AFM, EFM,...



SPM AutoProbe M5

Stage:

Z - travel range: 35 mm

X, Y -travel range: 200 x 200 mm

Resolution: 1.0 μm

Metrology Scanner:

x, y 100 μm

z 7.5 μm

Resolution: x, y 1 nm; z 0.1 nm



Vacuum SPM

Stage:

Z - travel range: 25 mm

X, Y -travel range: 20 x 20 mm

Resolution: 2.5 μm

Scanner:

x, y 80 μm

z 7.5 μm



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LT UHV STM "Omicron"

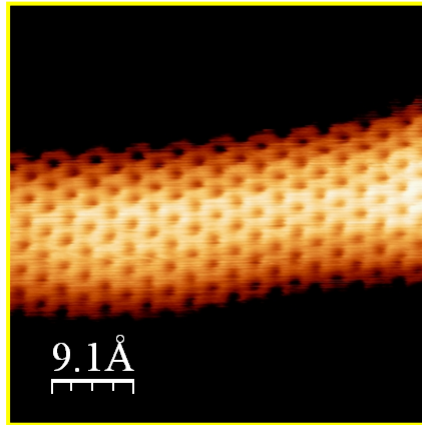
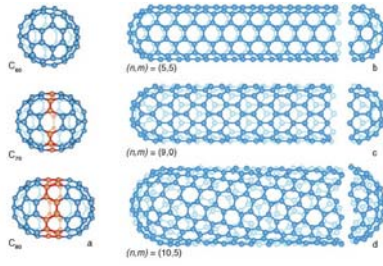
Specifications

Lowest temperature at the sample: < 5 K
Initial cool down time to 5 K: < 6 h
Time between LHe refills: > 15 h
Coarse movement: X/Y/Z = 5 x 5 x 10 mm
Scan range (and offset range) : X/Y/Z =
10x10x1 μm at 300 K
X/Y/Z = 1.8x1.8x0.2 μm at 5 K
Z-resolution: < 0.01 nm
Gap Voltage: ± 0.5 mV to ± 10 V
Tunneling current setpoint: 50 pA... 50 nA
Bakeout temperature: up to 150°C
Vacuum achievable: 10^{-11} mbar range



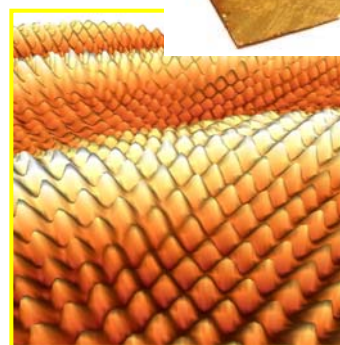
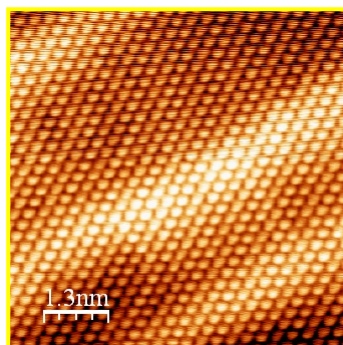
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Carbon nanotube: LT UHV STM image



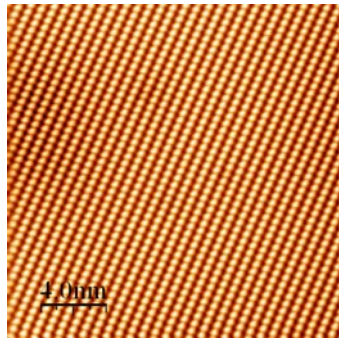
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CNT deposition: Au(111) substrate

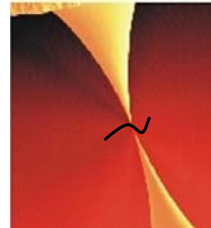


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CNT deposition by STM manipulation: InAs substrate cleaved in UHV

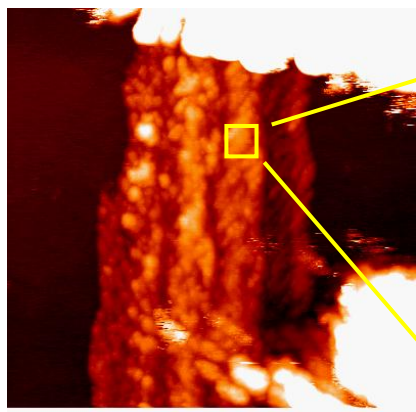


STM tip

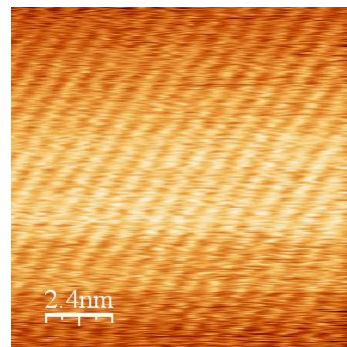


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CNT-bundle deposited on InAs substrate



180×180 nm² image



12×12 nm² image of the CNT-fragment

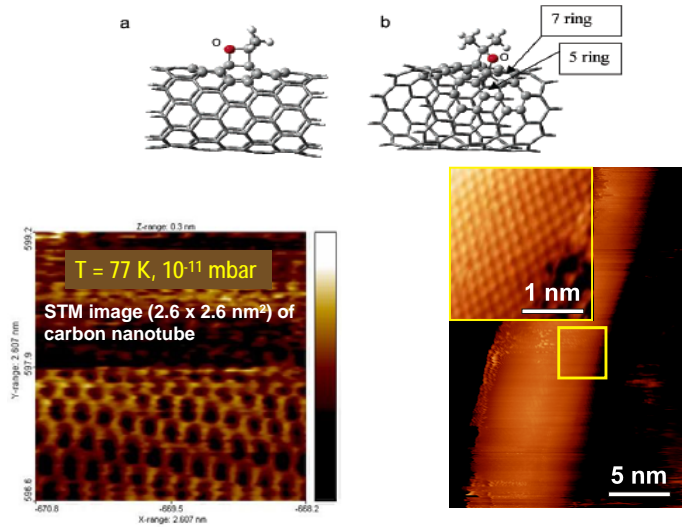


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Carbon nanotubes: where are the defects?

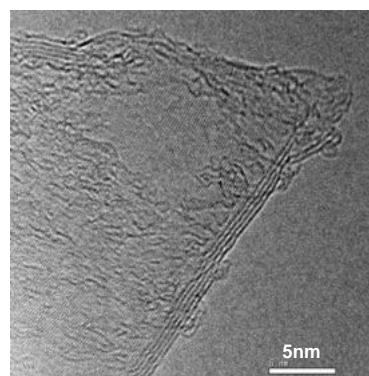
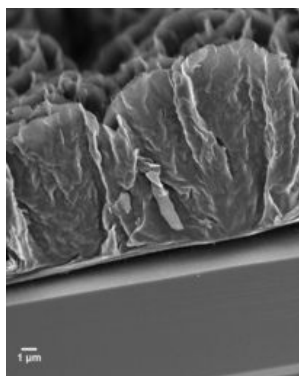
9310 *J. Phys. Chem. B*, Vol. 107, No. 35, 2003

Chakrapani et al.



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Carbon nano-walls (CNWs)

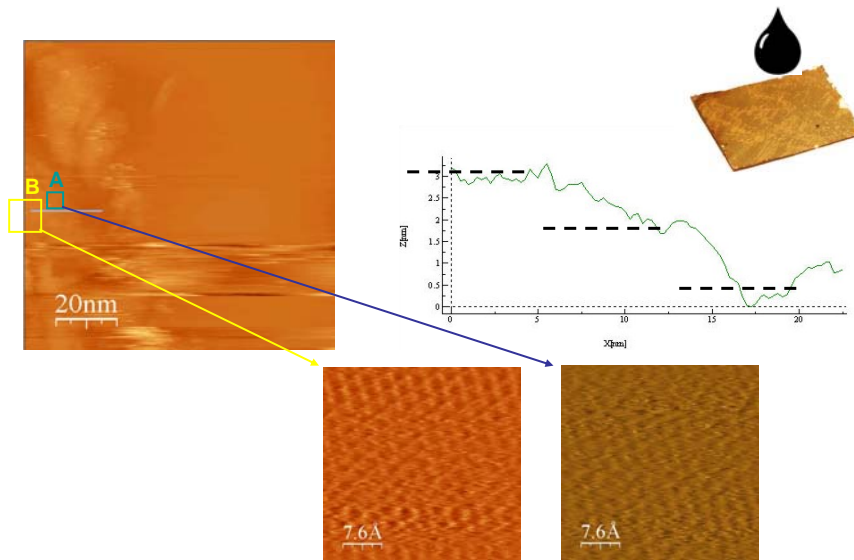


Freestanding CNW grown by means of microwave plasma-enhanced chemical vapor deposition (MW PECVD) in VITO



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CNW deposited on Au(111)/mica: STM imaging



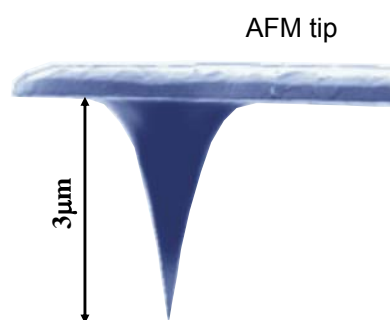
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Current-carrying nanostructures: how to measure voltage

cm-range

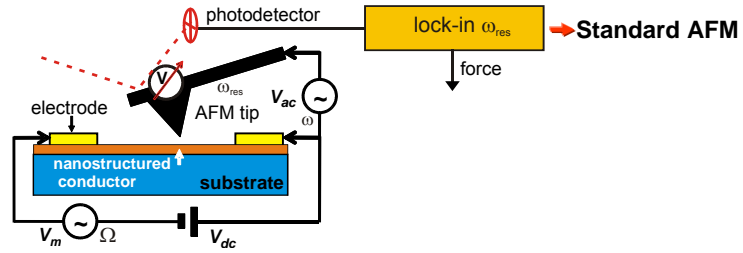


nm-range?



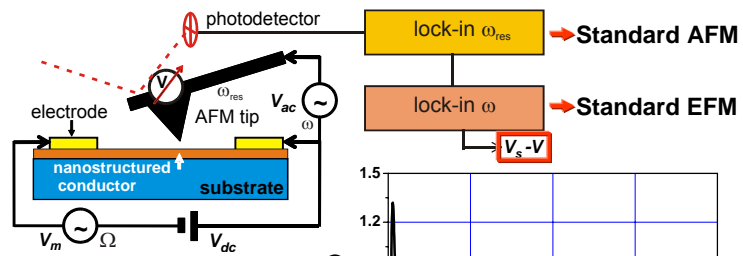
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Our new set-up for the EFM measurements

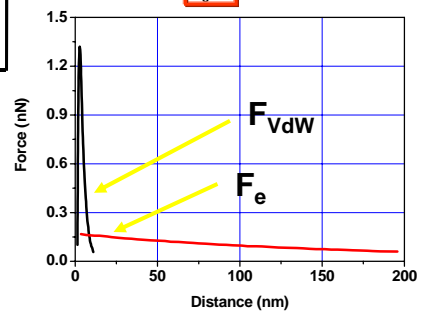


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Our new set-up for the EFM measurements

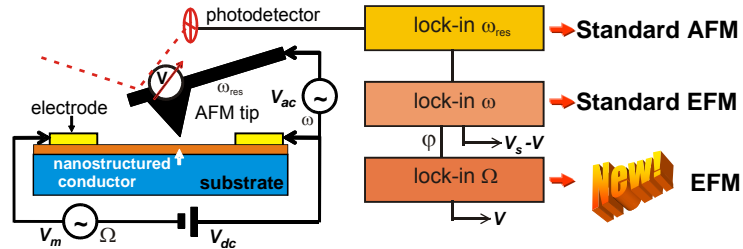


$V_s(x,y)$ – work function
 $V(x,y)$ – voltage drop



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Our new set-up for the EFM measurements



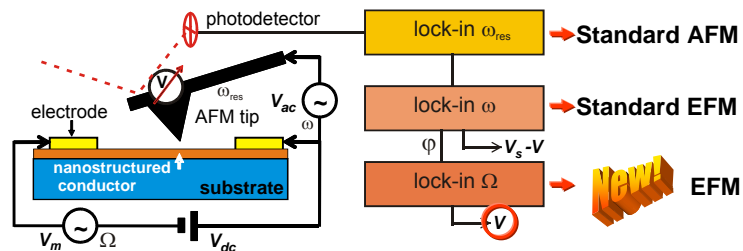
$$\nabla(F)_\omega \approx C''(z) \cdot V_{ac} \cdot (V_s(x, y) - V(x, y) \cdot (1 + m \cdot \sin(\Omega t))) \cdot \sin(\omega t)$$

$C''(z)$: second derivative of the capacitance of the tip-sample system
 $V_s(x, y)$: work function
 m : modulation coefficient



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Our new set-up for the EFM measurements



$$\nabla(F)_\omega \approx C''(z) \cdot V_{ac} \cdot (V_s(x, y) - V(x, y) \cdot (1 + m \cdot \sin(\Omega t))) \cdot \sin(\omega t)$$

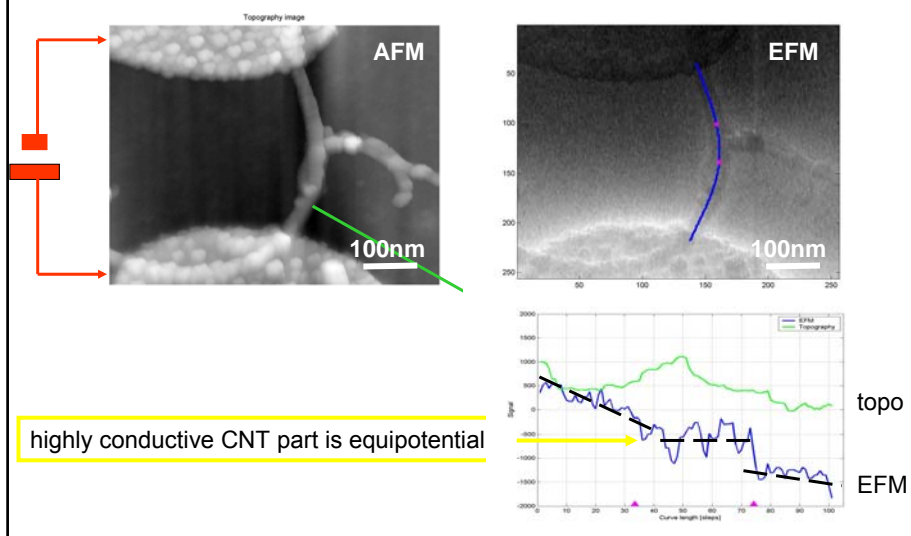
harmonic detection of the phase shift variations of the AFM cantilever oscillations at the frequency $\Omega/2\pi$ that is used to modulate the current flowing across the sample between the two electrodes

A. Volodin, et al., *Appl. Phys. Lett.* 91, 142111 (2007)



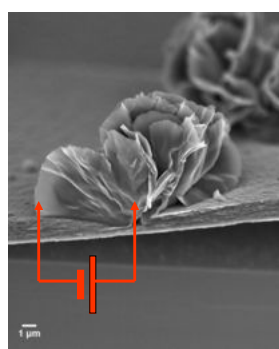
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EFM of contacted nanotubes

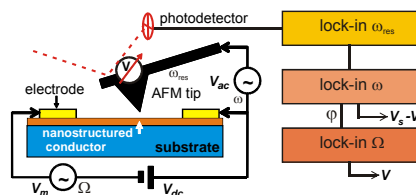


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Future plans: contacted CNW

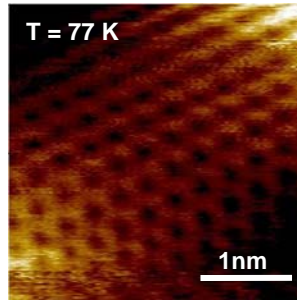
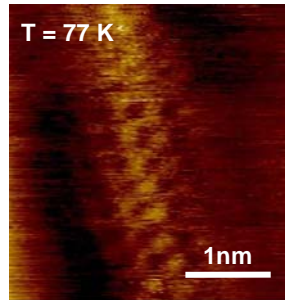


Transport + EFM study

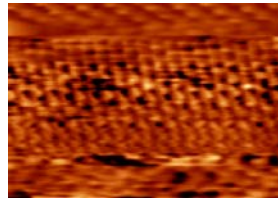


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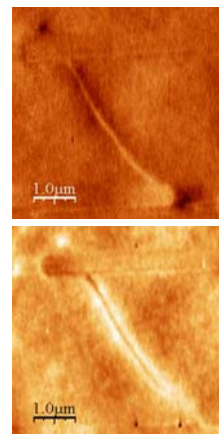
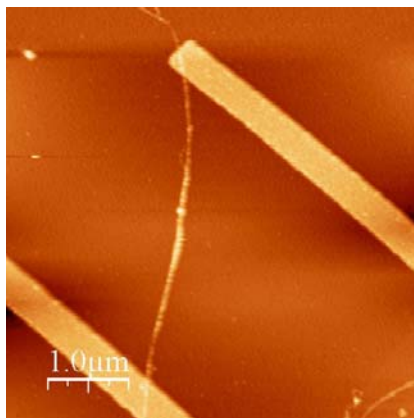
Future plans: STM on CNTs with different diameters



+ defects...



Future plans: EFM + transport; scanning gate microscopy



Thank you!

