Aligned Carbon Nanofibre-Polymer Composite Membranes

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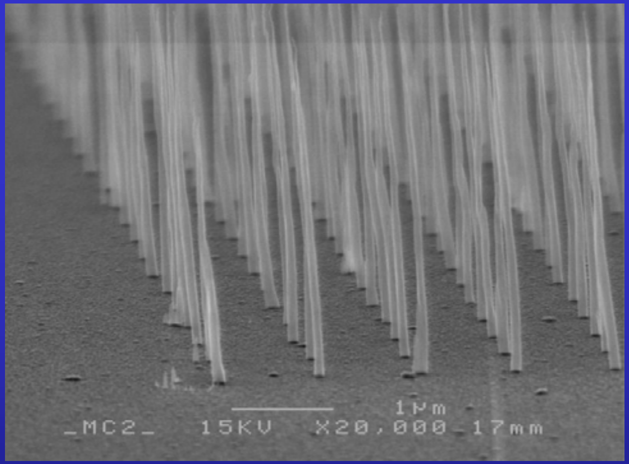
CNT Growth and Manipulation



Eleanor Campbell
Dept. of Physics, Göteborg University

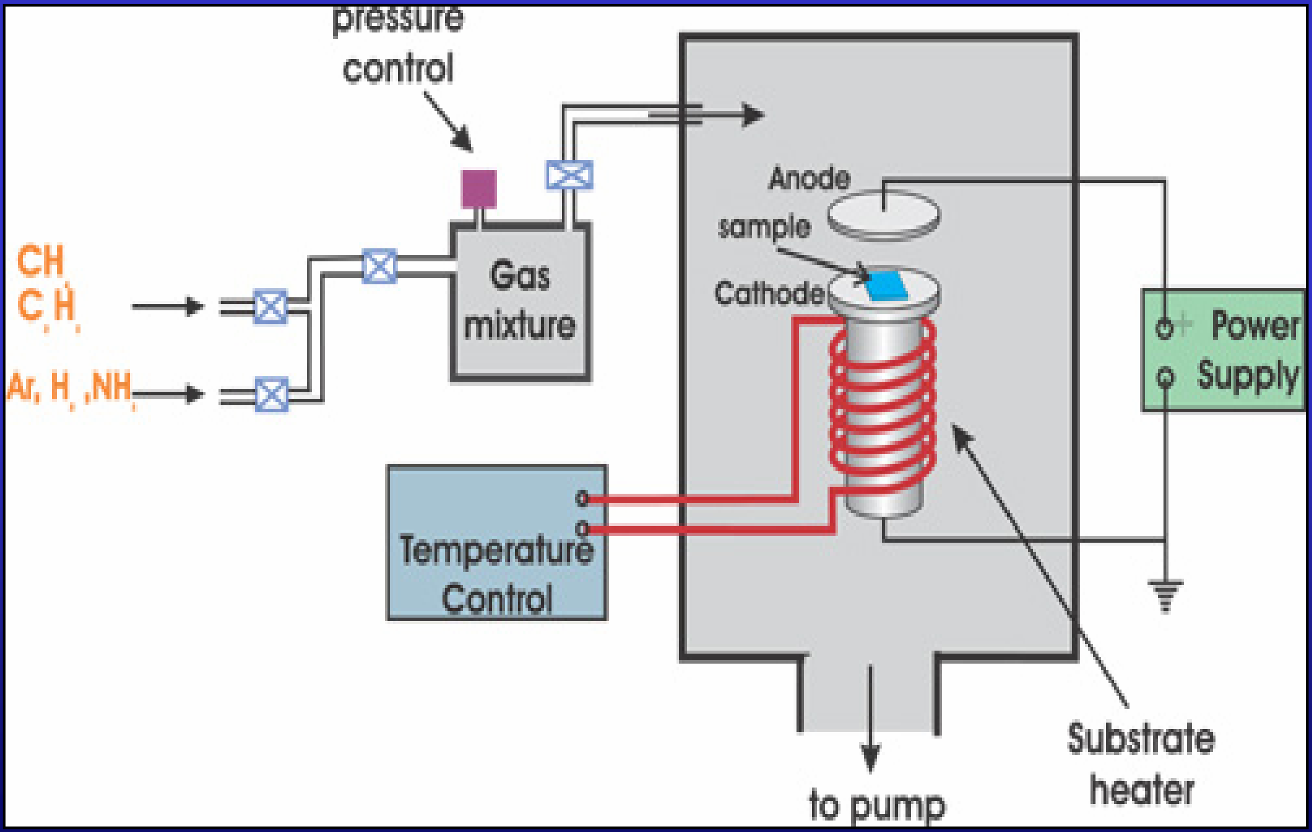
- **Plasma CVD Growth – Polymer/Nanofibre Composite**
- **Low ambient temperature growth**
- **Dielectrophoretic separation of metallic and semiconducting SWNT & its use in device fabrication (if time)**

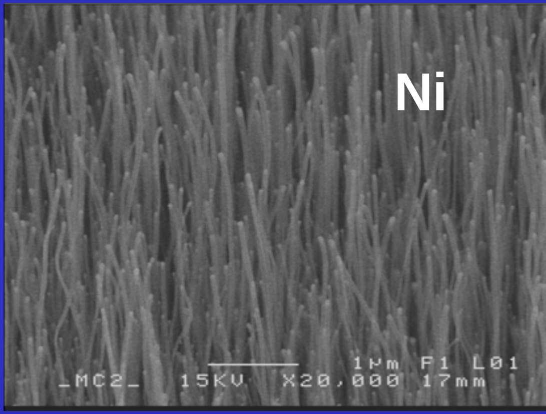
Plasma CVD Growth of Nanotubes /fibres

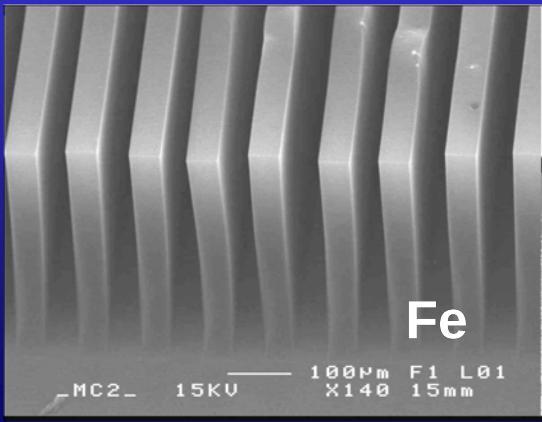
T = 700 °C

Ni catalyst $C_2H_2:NH_3 = 1:5$, 4 Torr tip-grown fibres

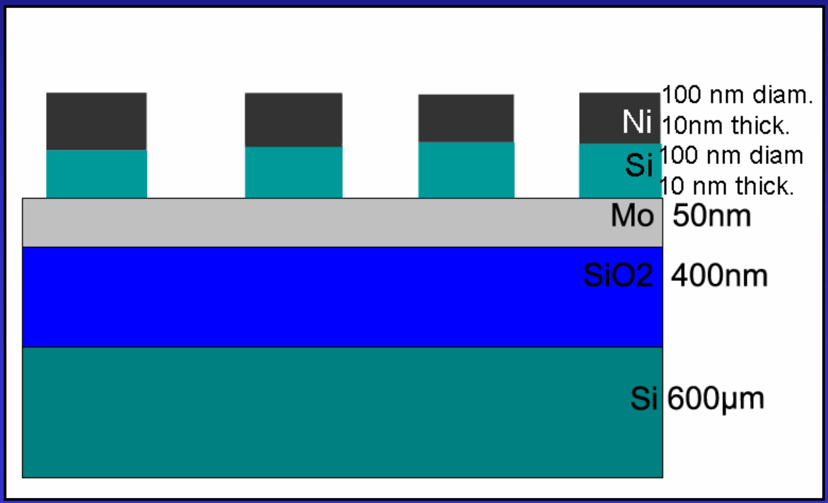
Fe catalyst $C_2H_2:H_2 = 1:3$ 7 Torr base-grown MWNT

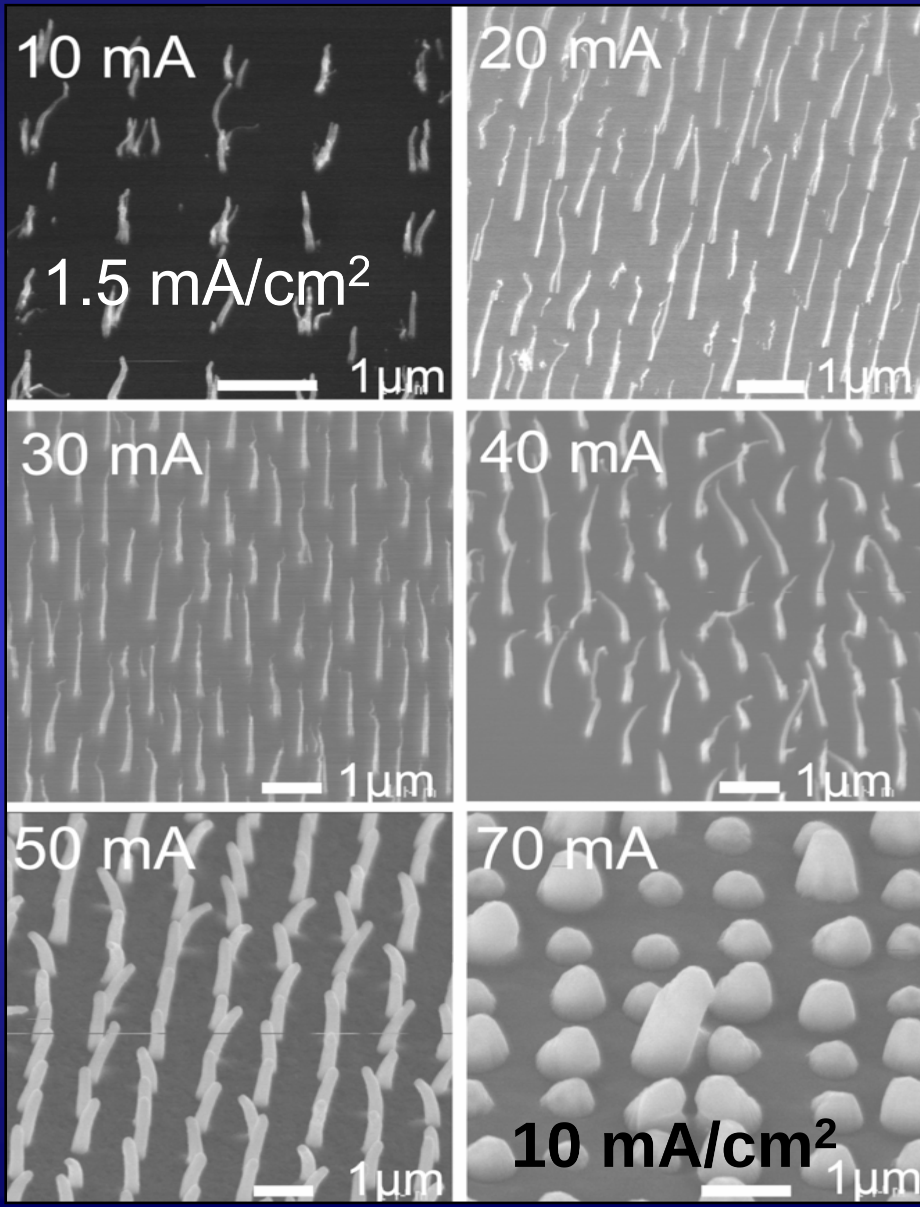






Growth Quality depends critically on Plasma Current Density



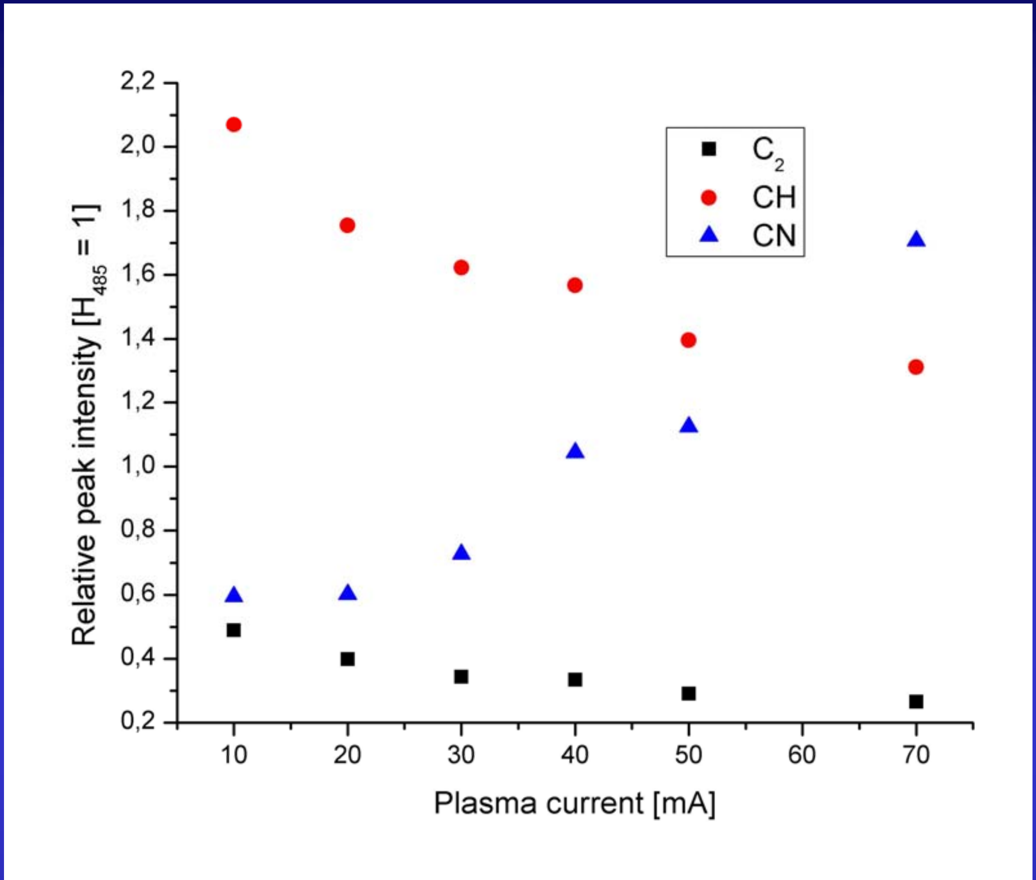


Array growth on Mo substrate

$C_2H_2:NH_3 = 1:5$

Kabir et al., Nanotech. **16** (2005) 458

Kabir et al., Nanotech. **17** (2006) 790

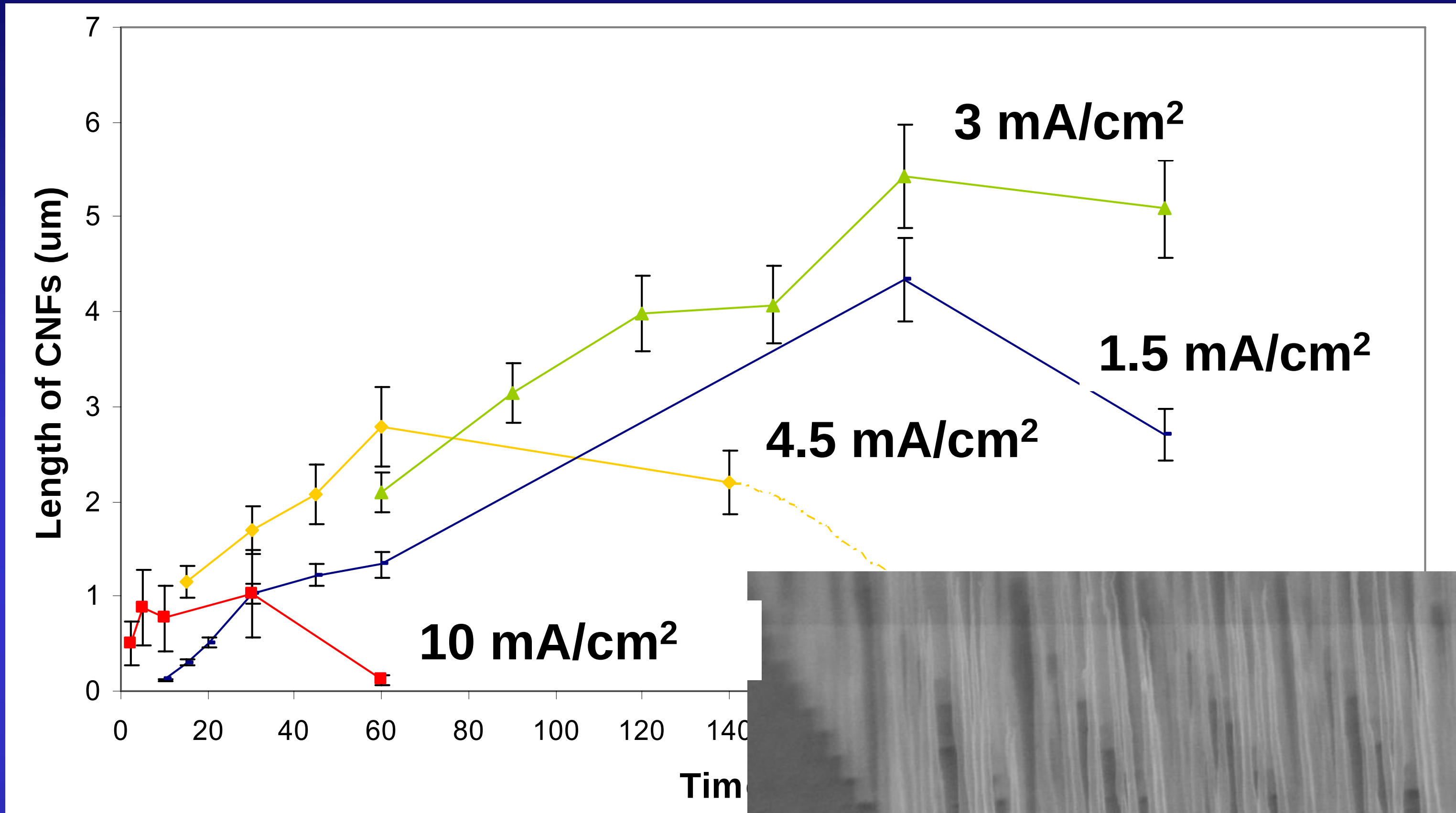


Optical spectroscopy shows the relative decrease in molecular/atomic precursors and also a clear increase in CN intensity beyond 30 mA (4.5 mA/cm^2)

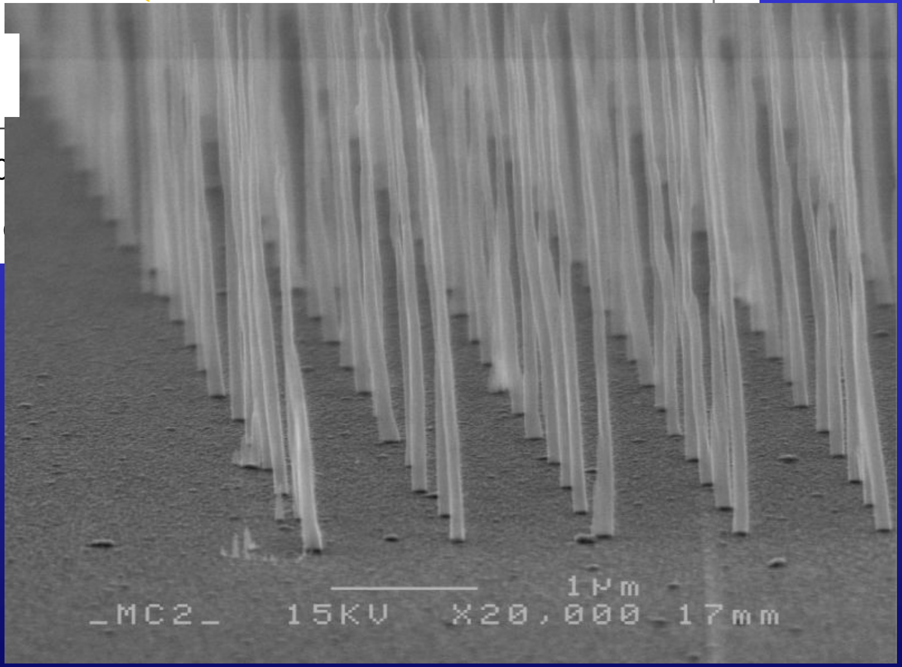
- Onset of non-catalytic deposition and increased sputtering

M. Jönsson

B. Gindre

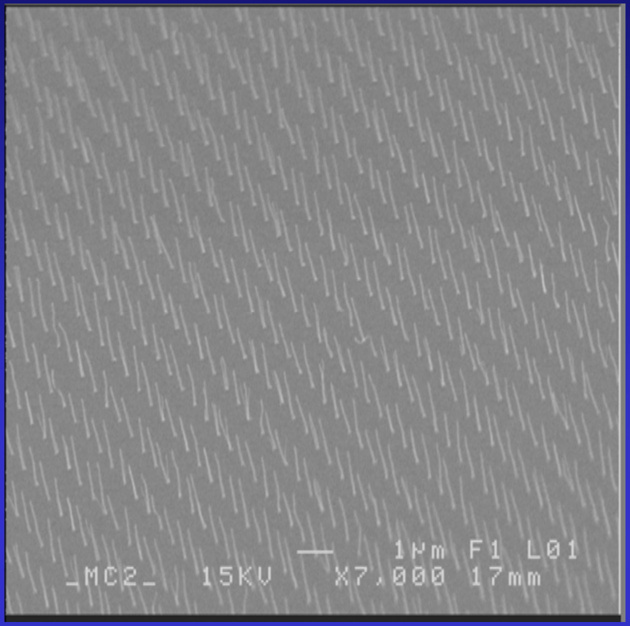


Can these vertically aligned CNF be used to make an anistropically conducting polymer membrane?

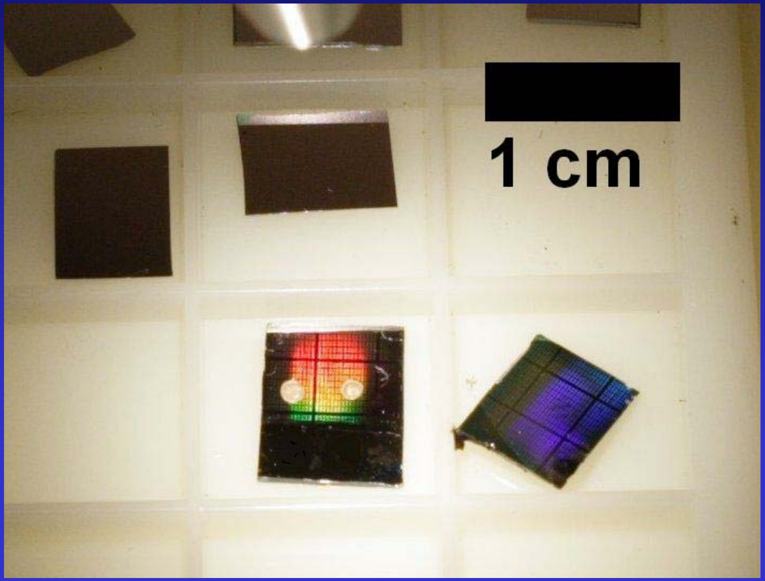


Diameter ca. 50 nm

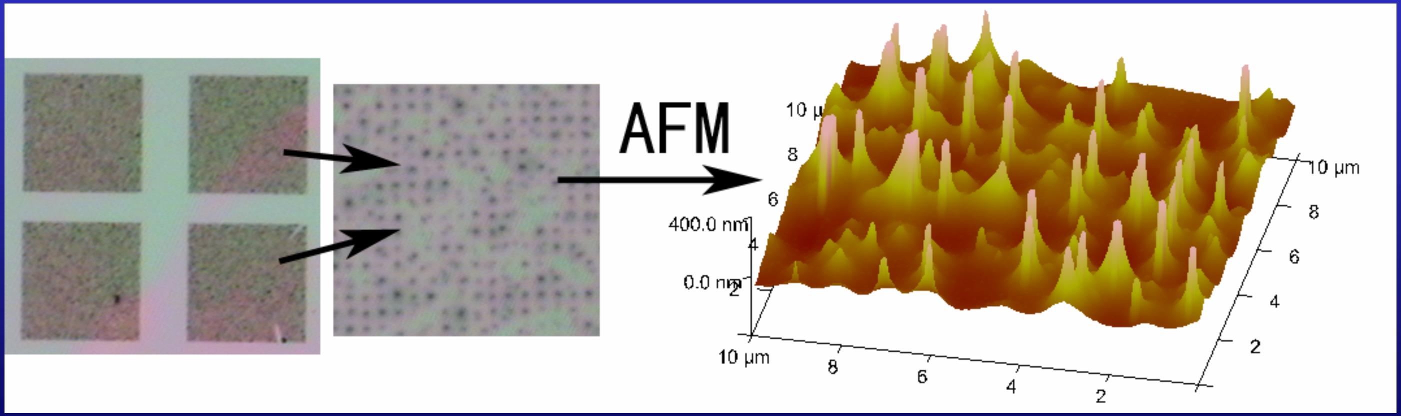
Polymer – CNT Composite Materials



Array of individual nanotubes grown on a Mo substrate



Arrays after spin-coating showing photonic-crystal effects



Morjan, Gromov, Gindre

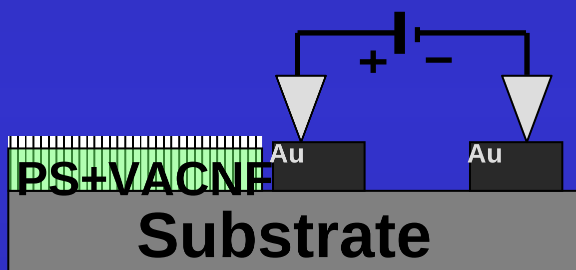
Electrical Characterisation

Two probe measurements (-5;+5)V

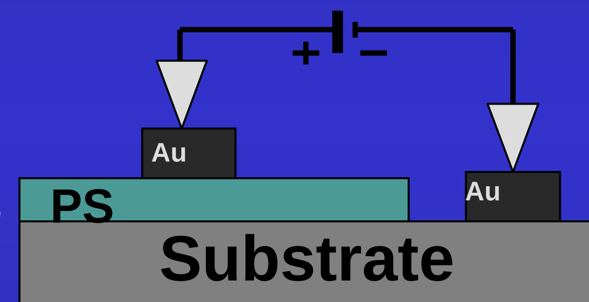
Deposition of gold electrodes by metal evaporation with a mask

(0.5mm in diameter and 2mm apart)

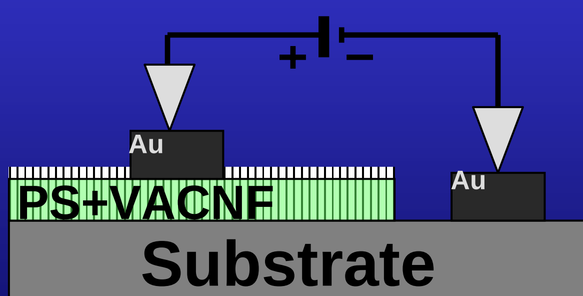
Mo &Mo layer



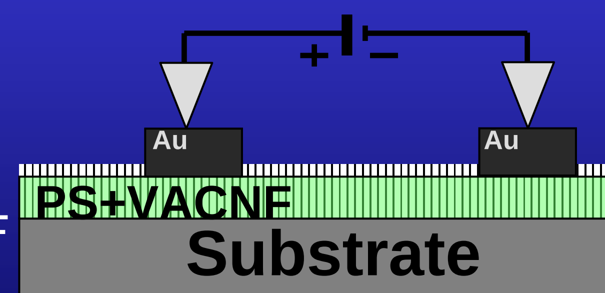
PS &Mo layer



PS+VACNF & Mo layer



PS+VACNF & PS+VACNF layer



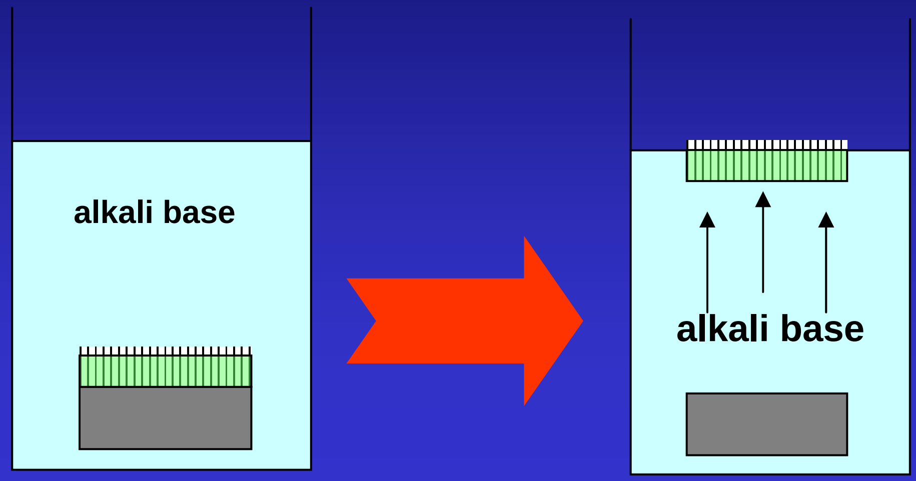
Measured resistance through film without fibre
i.e. Polystyrene alone (3 μm thick): 10^4 Ω

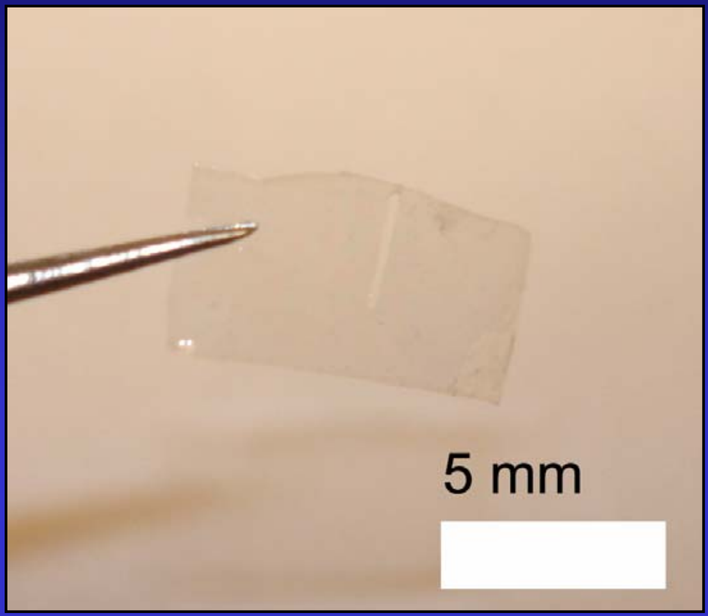
With CNF: 50 Ω

There are approximately 45000 nanofibres contacted for each measurement

-The average resistance per fibre is ca. 200-300 kΩ (compares with ca. 100 kΩ for individual fibres with 0.5 mA current carrying capacity)

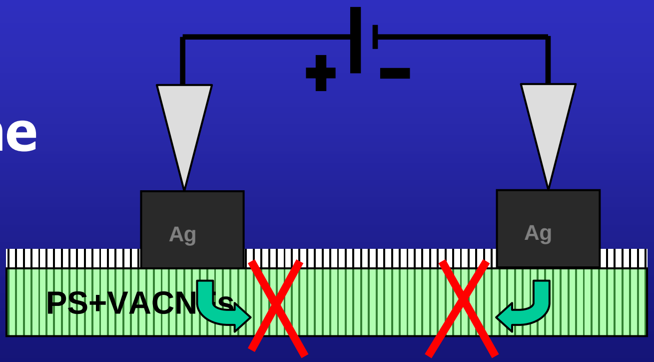
Removing the polymer from the substrate



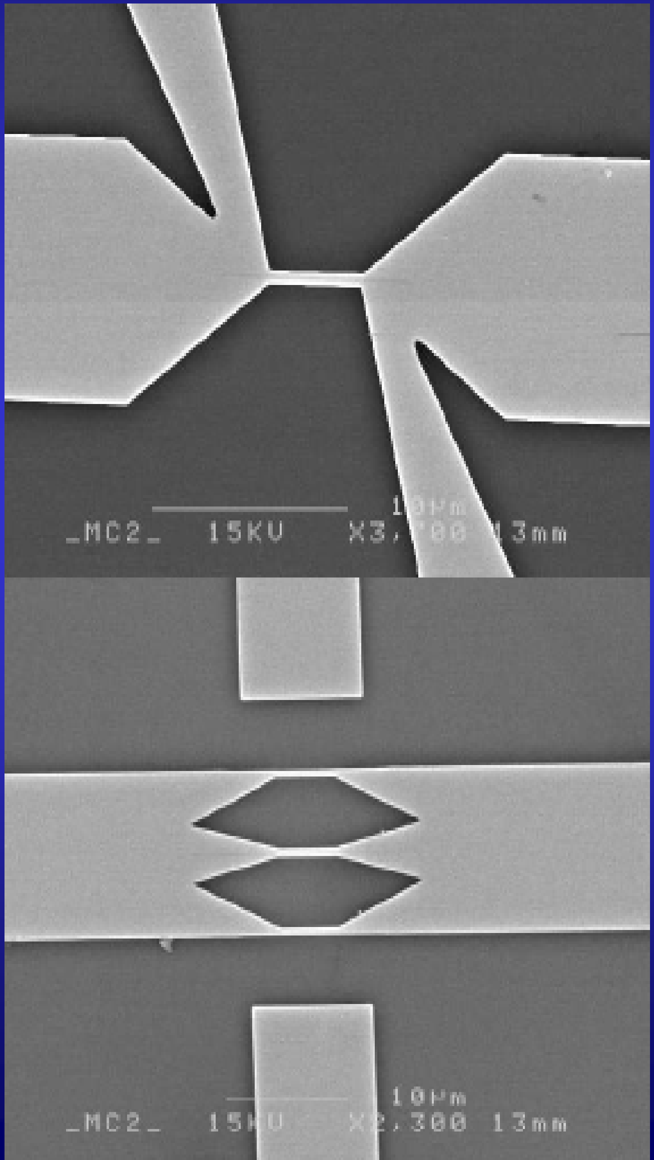


Leave for a couple of days

Few GΩ along the membrane (2mm distance)



How to reduce the chip temperature to make good quality CNT at temperatures lower than 450 °C (CMOS compatibility)?

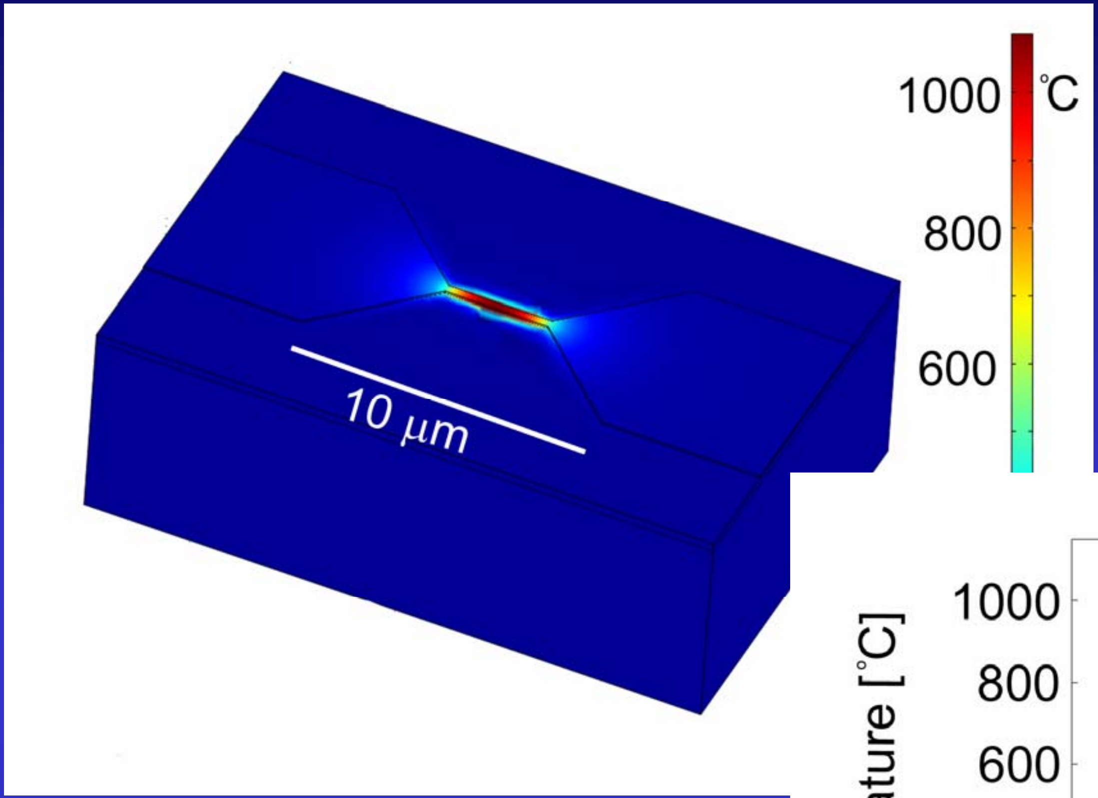


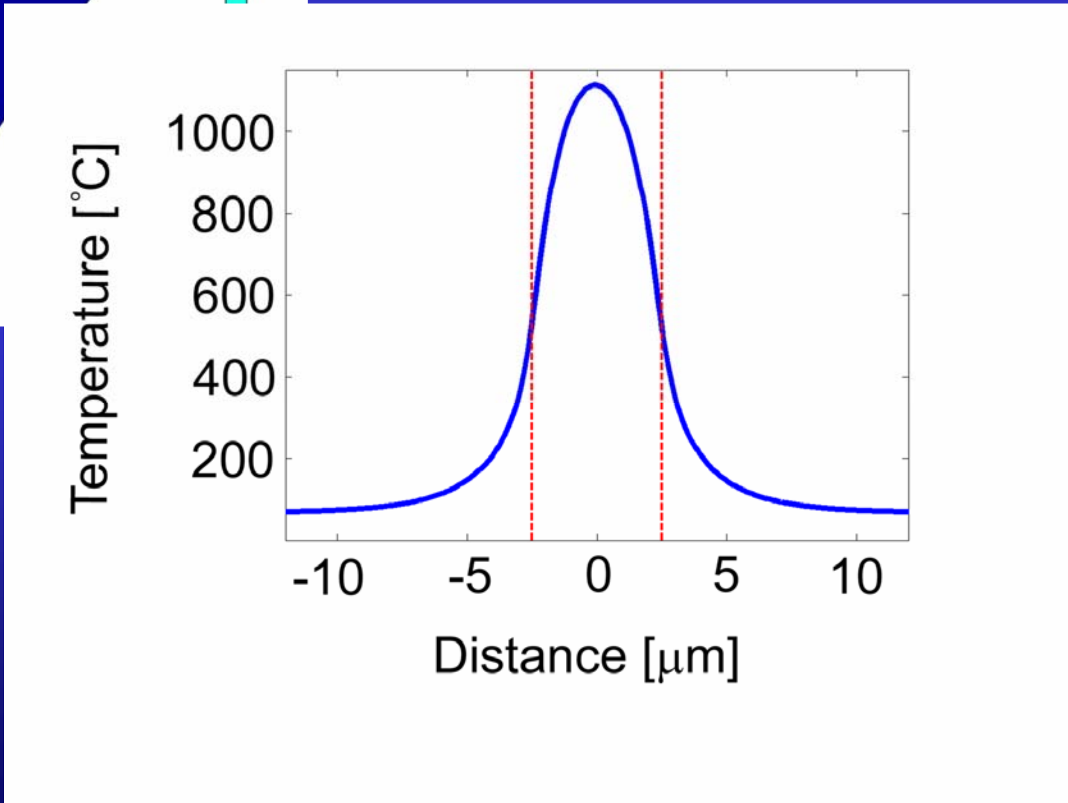
Use very local resistive heating only where you want the nanotube(s) to grow.

Mo Electrodes with narrow resistive bridge. Catalyst deposited on bridge (5nm Al_2O_3, 1 nm Fe)

14 mA, 2V for heating

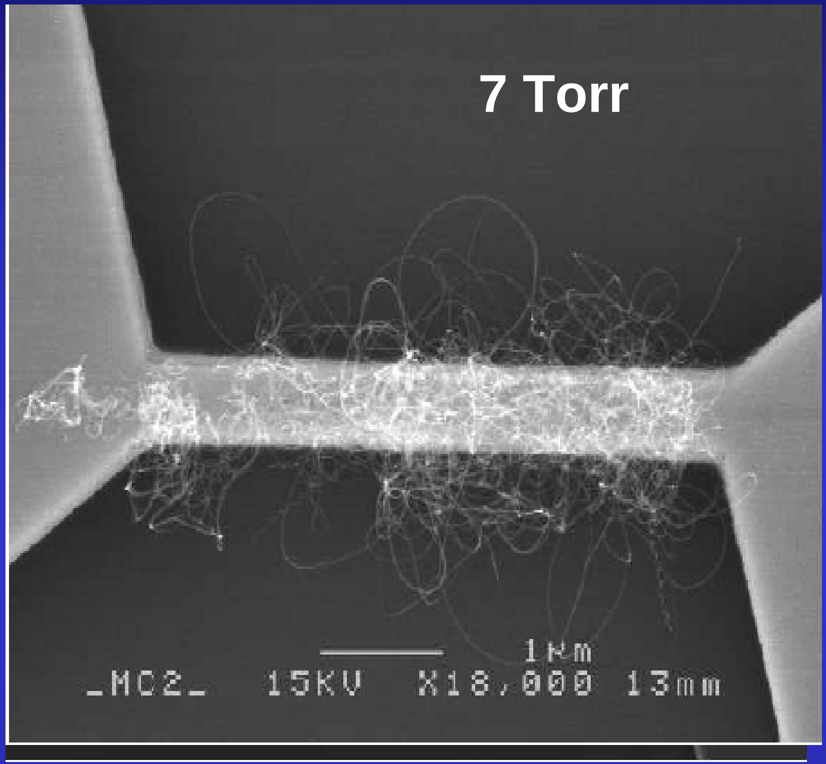
Dittmer et al., Appl. Phys. A in press



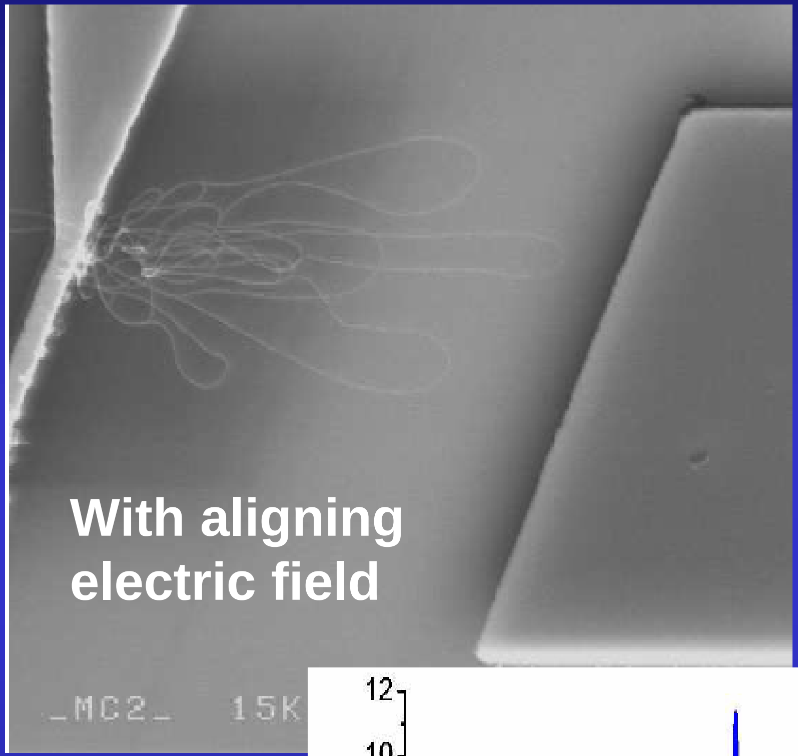


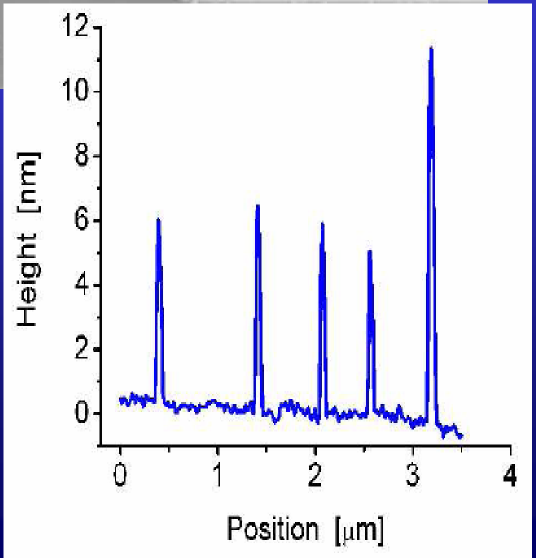
Temperature simulation corresponding to conditions in the experiment

Room Temperature Growth: MWNT



No electric field applied during growth

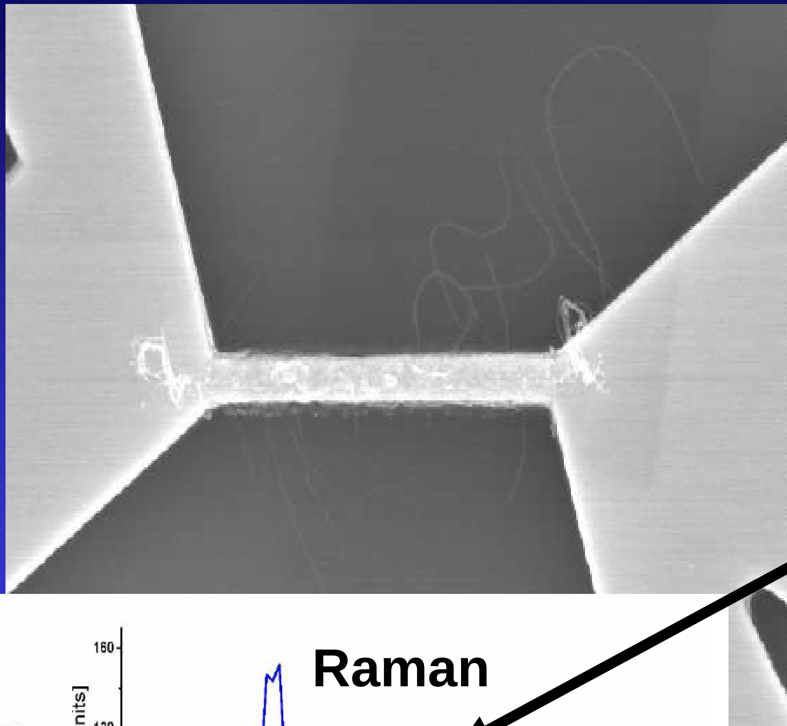


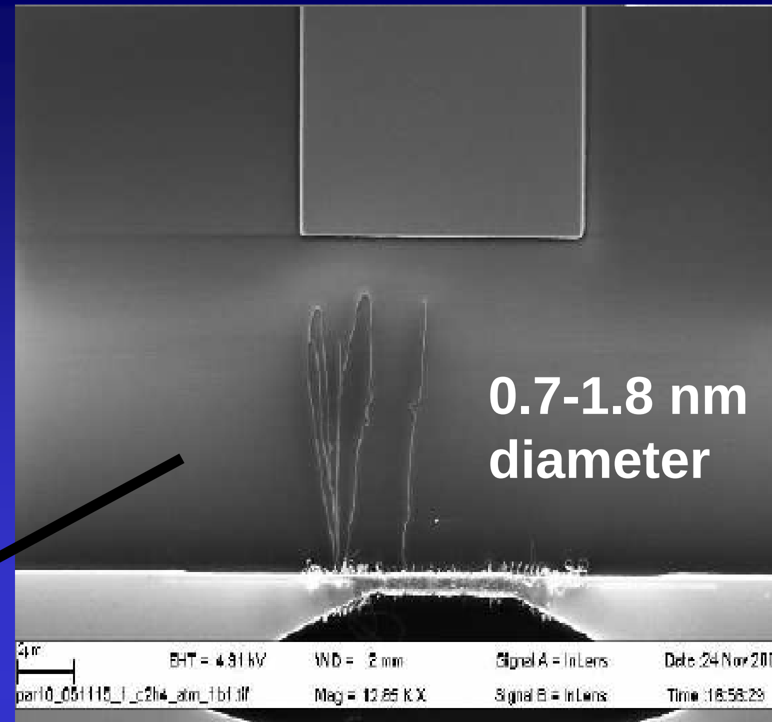


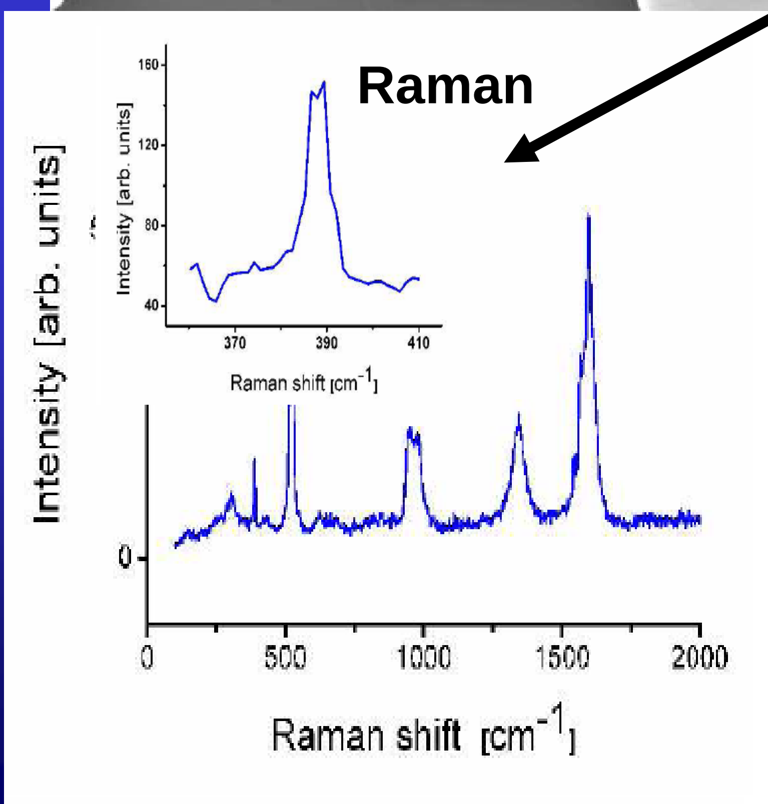
MWNT (Fe catalyst, acetylene precursor)

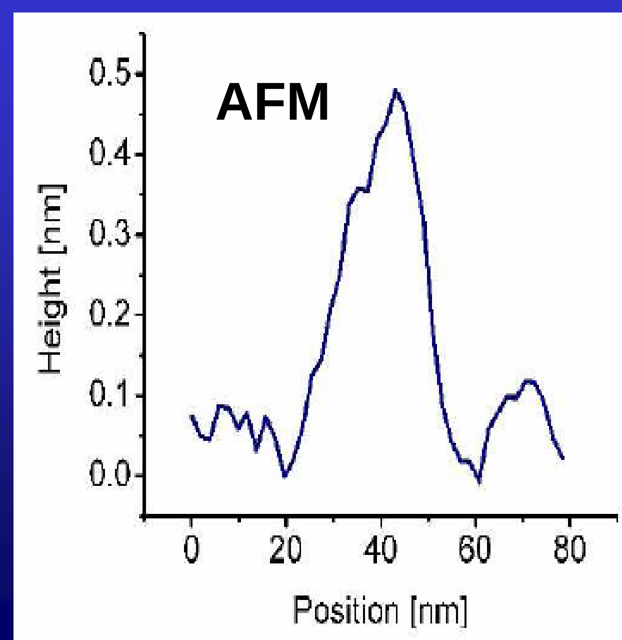
C_2H_2:H_2:Ar = 10 sccm: 300 sccm: 500 sccm

Dittmer et al., Appl. Phys. A, in press





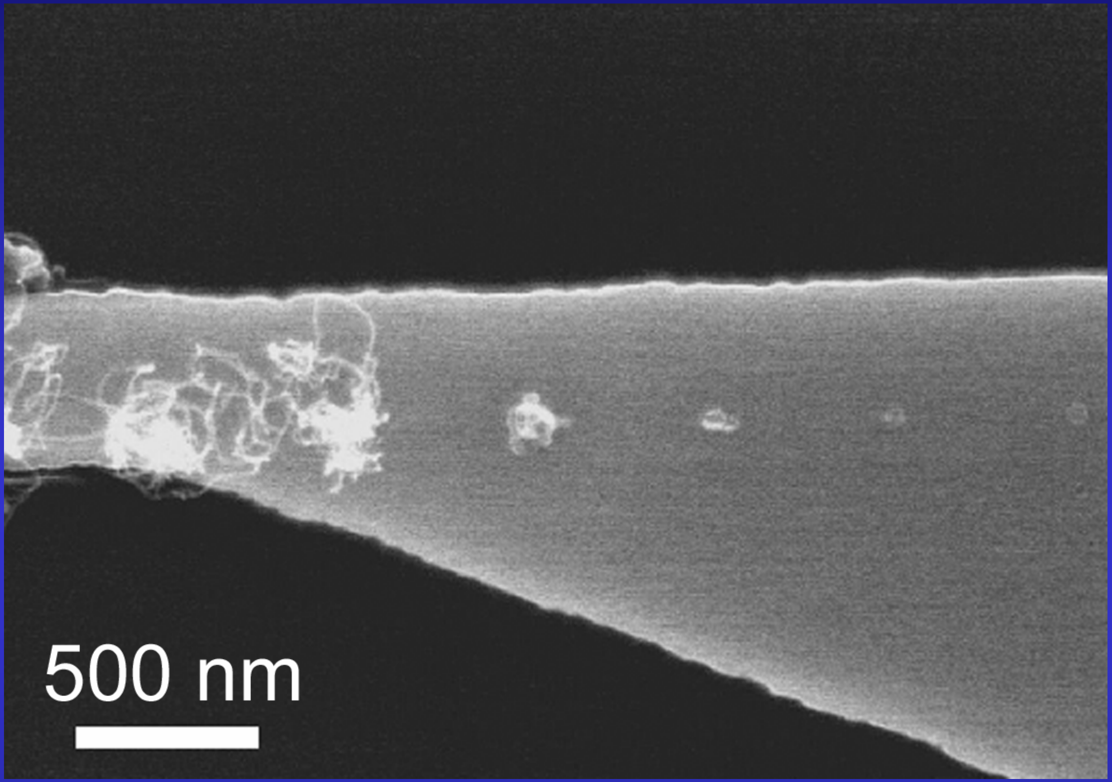




Replace acetylene with ethylene

SWNT

Chip at 60 ^{o}C



Growth stops when temperature falls below ca. 500 ºC

Thanks to:

Array Growth and Membranes:

Oleg Nerushev
Raluca Morjan
Martin Jönsson
Baptiste Gindre
Andrei Gromov
Shafiq Kabir

Nanorelay:

SangWook Lee
Anders Eriksson
Jari Kinaret et al (theory)

Dielectrophoretic Separation:

Andrei Gromov

Low Temperature Growth:

Staffan Dittmer
Oleg Nerushev

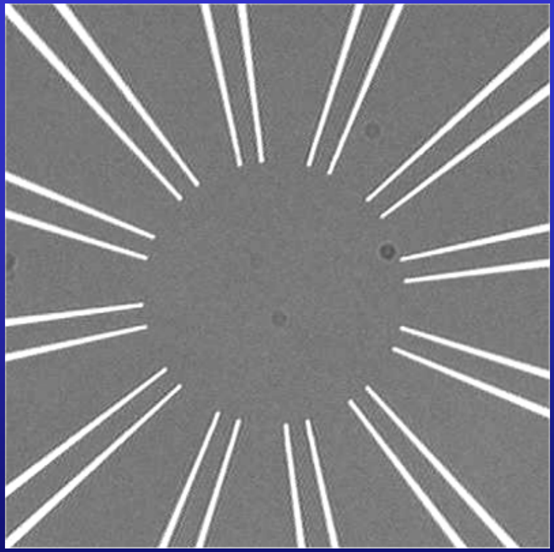
AC Dielectrophoresis for separating metallic and semiconducting nanotubes

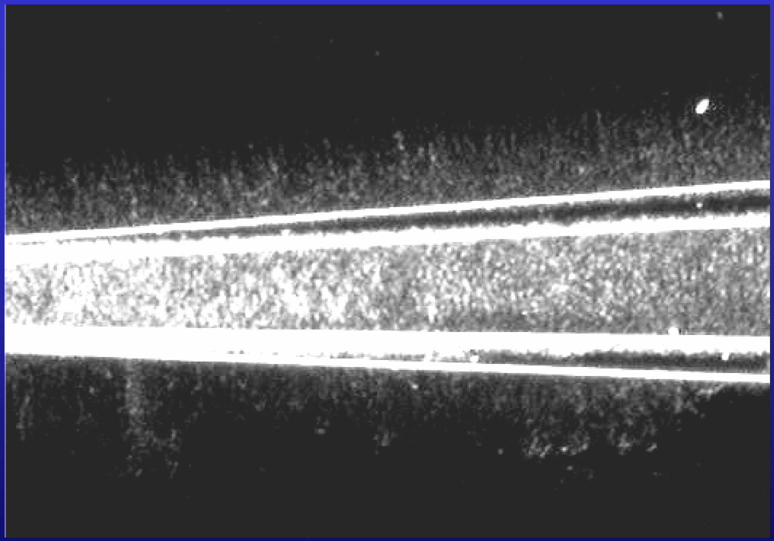
$$\vec{F} \propto \varepsilon_1 \operatorname{Re}\left(\frac{\varepsilon_2^* - \varepsilon_1^*}{\varepsilon_2^* + 2\varepsilon_1^*}\right)\nabla\left|\vec{E}\right|^2$$

2: nanotube
1: solvent

For semiconducting SWNT F is negative, for metallic SWNT the force is positive, attracting the CNT to the electrodes. (Krupke et al)

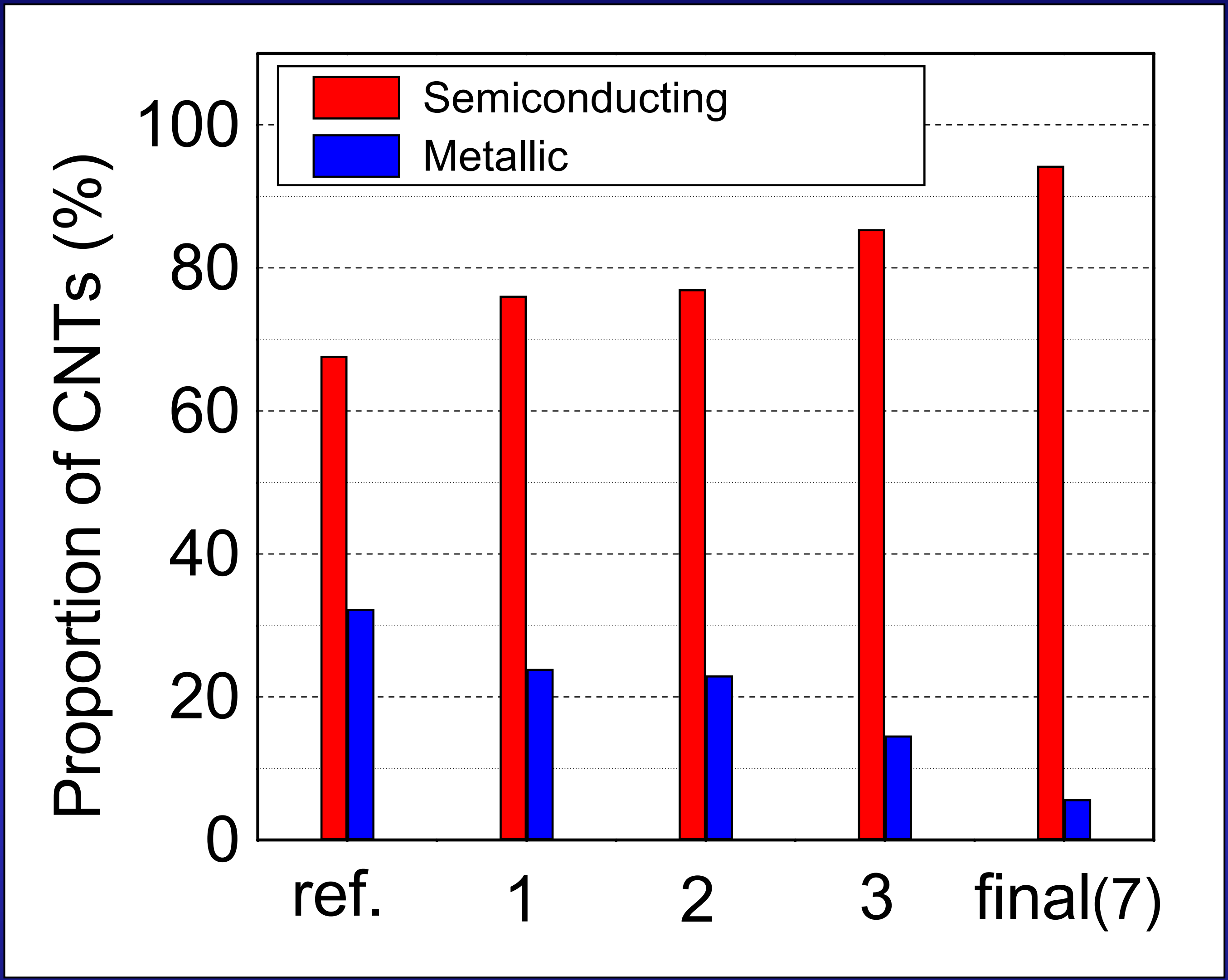
In this way metallic nanotubes can be preferentially attracted to electrodes leaving proportionately more semiconducting SWNT in dispersion.





D.S. Lee, et al., Appl. Phys. A 80 (2005), 5

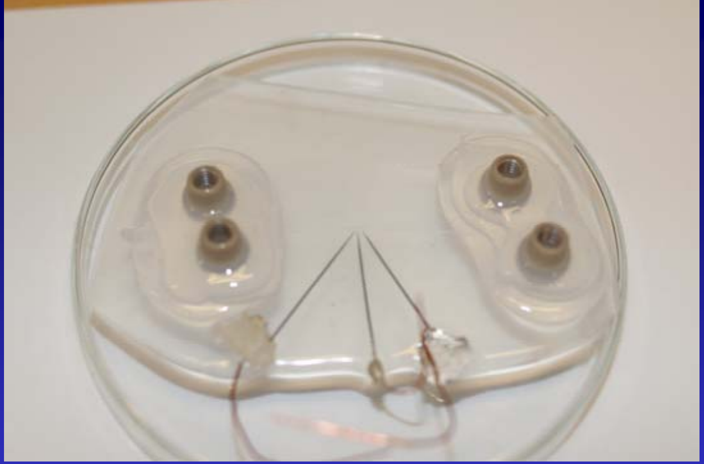
Nanotubes left in dispersion after deposition cycles



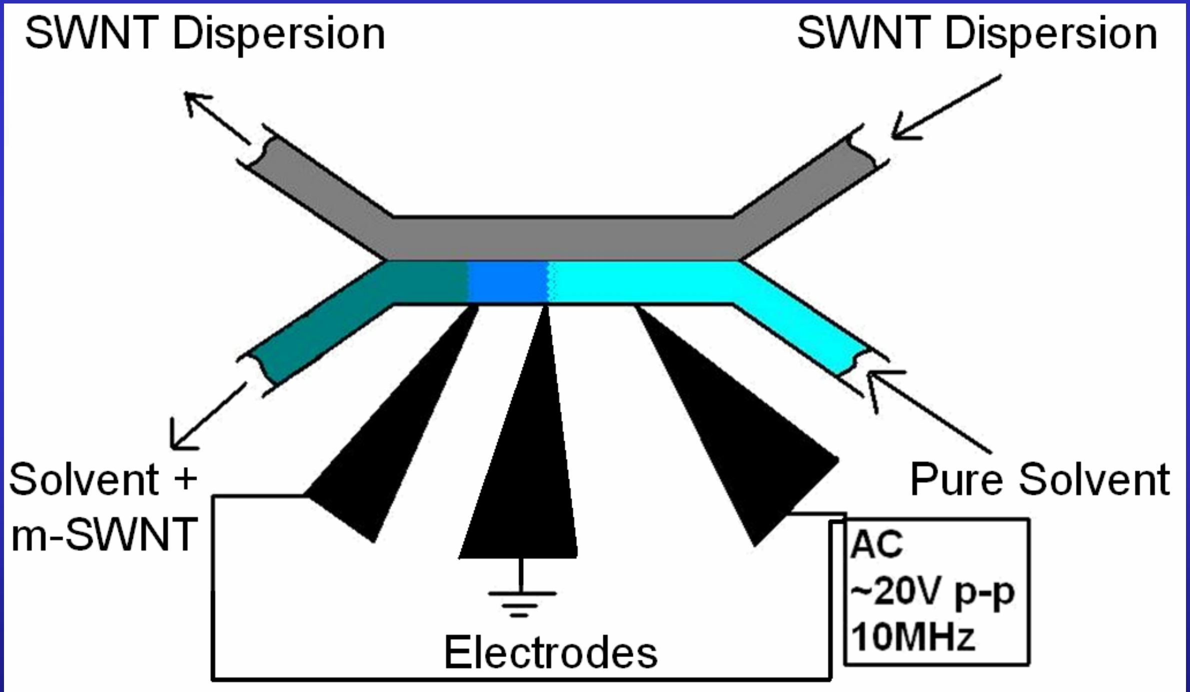
Raman analysis

Number of Deposition Cycles

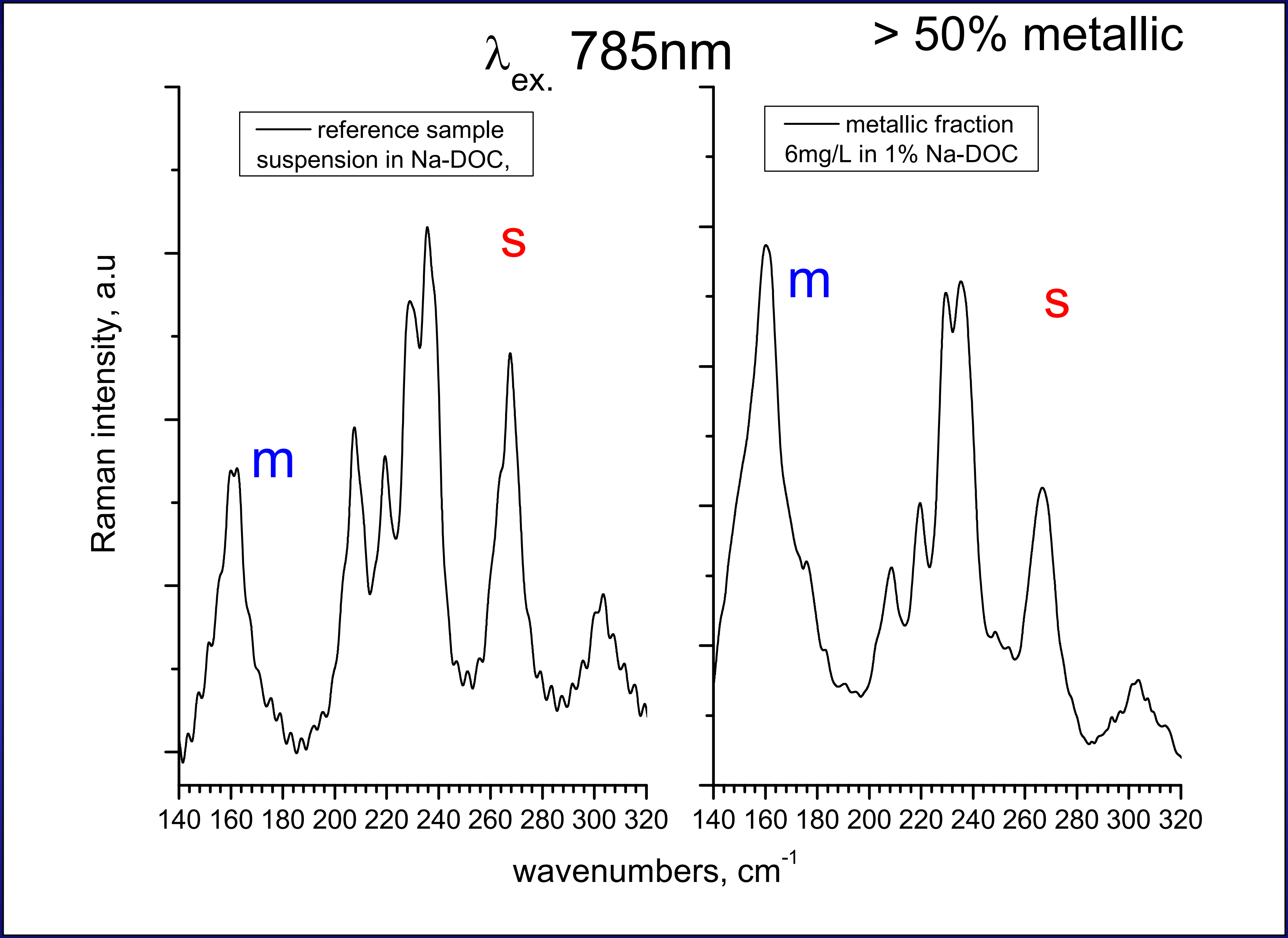
D.S. Lee, et al., Appl. Phys. A 80 (2005), 5



Laminar flow – no mixing of liquids

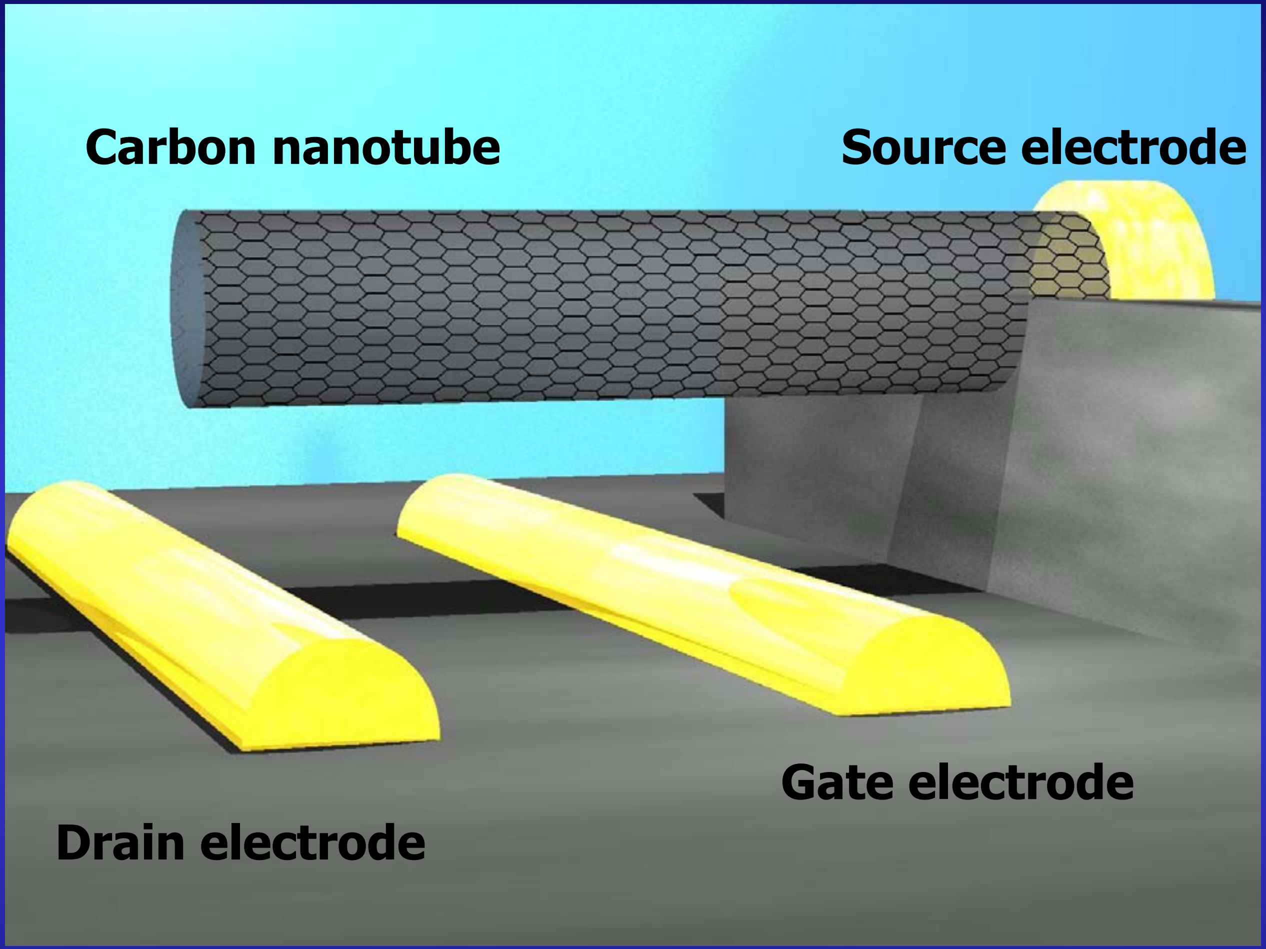


Although the interaction time is very short we get a significant increase in metallic content of lower channel on a single pass



Still problem with bundle formation

Carbon Nanotube Nanorelay

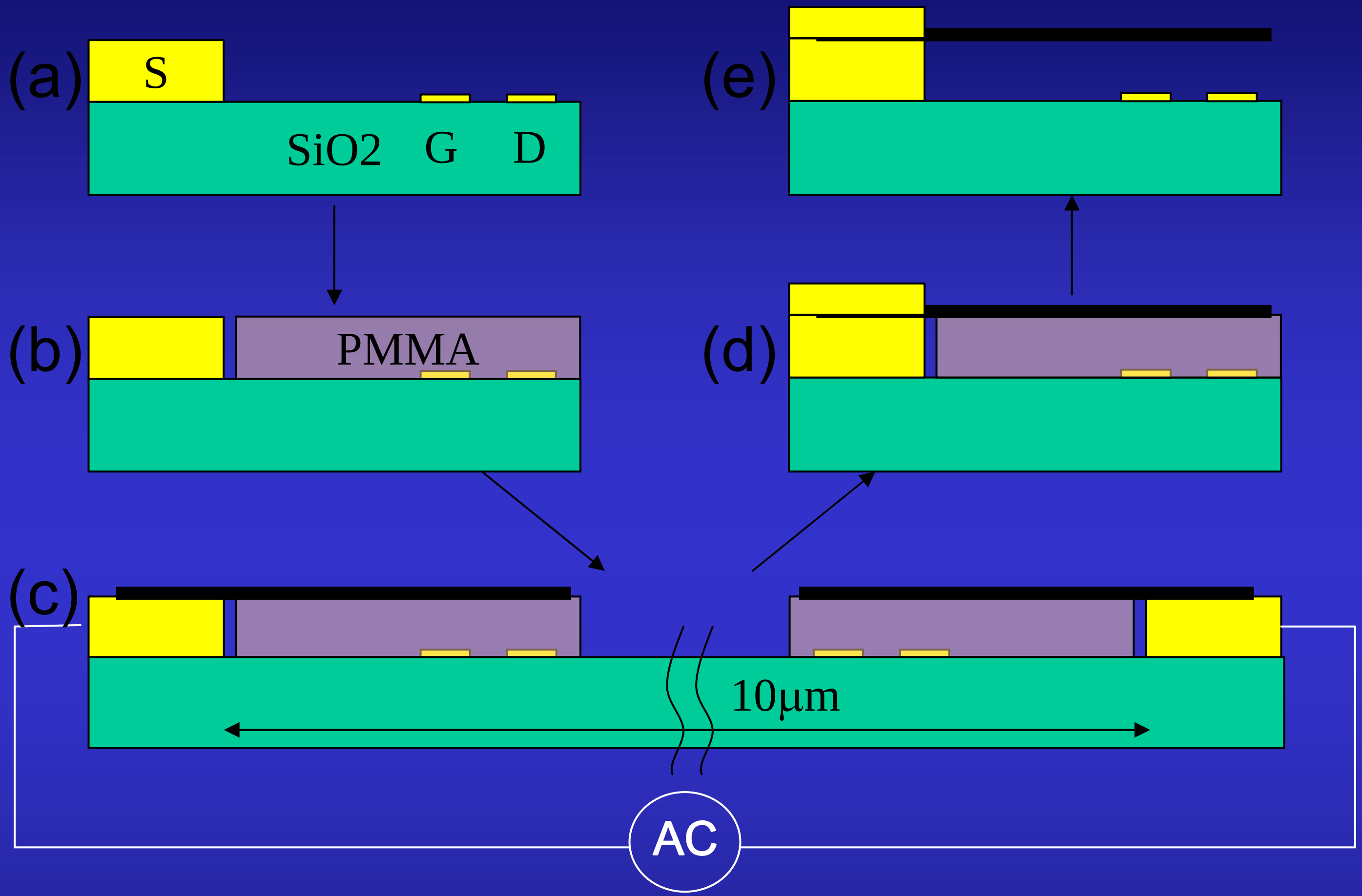


high Q oscillator, logical switch, bistable memory element,
Mechanical resonance frequency in GHz range, switching speed could be faster.

J. Kinaret et al. (S. Viefers) , Appl. Phys. Lett. 82, 1287 (2003)

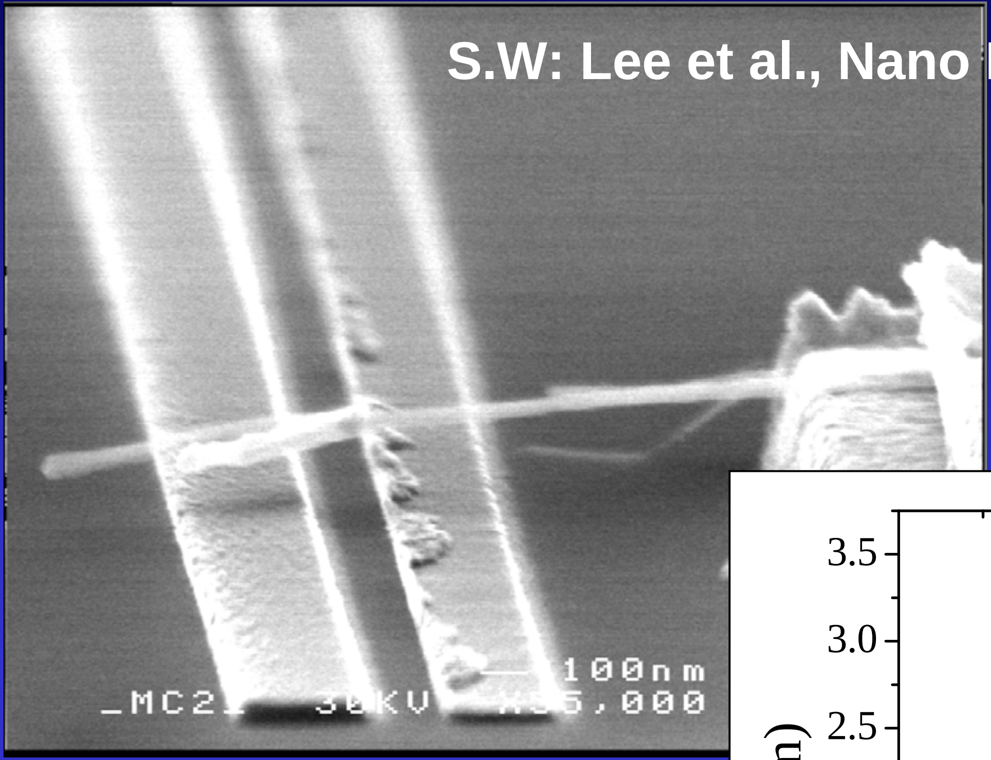
L.M. Jonsson et al., J. Appl. Phys. 96, 629 (2004)

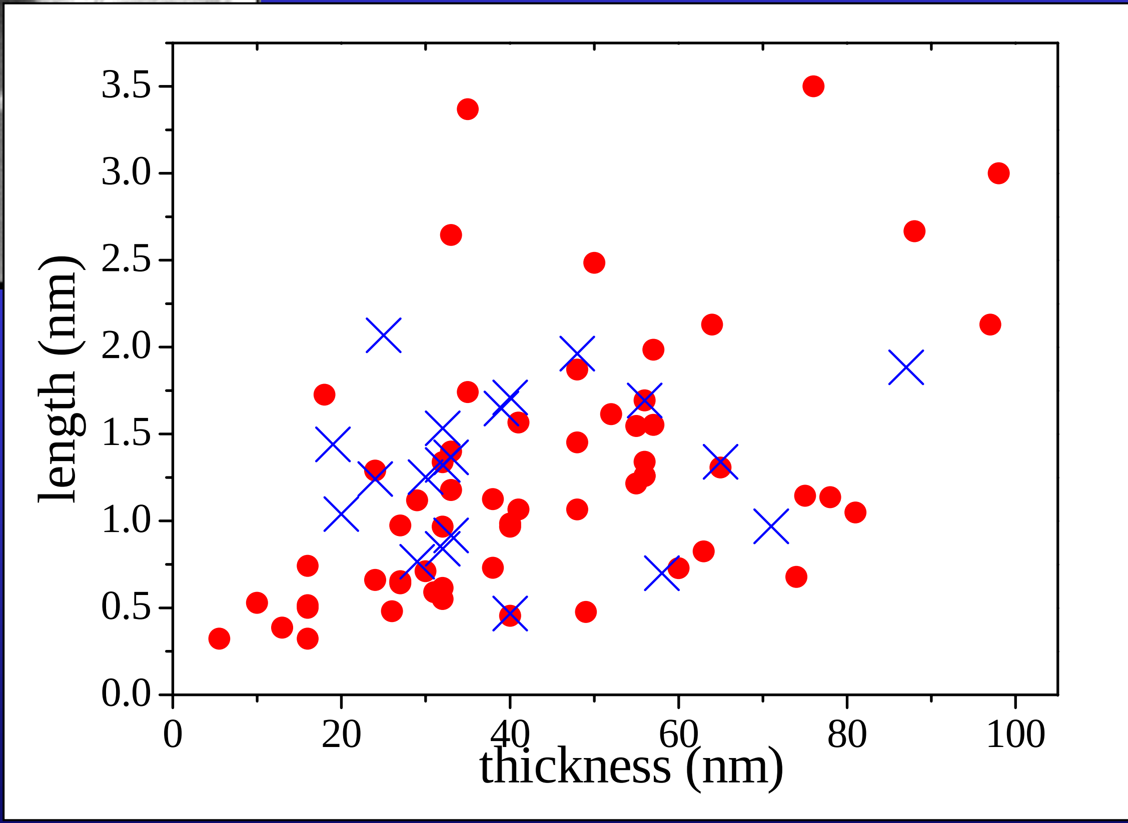
Nanorelay Fabrication



Acid free method to make suspended structure:
S. W. Lee et. al Appl. Phys. A 78, 283 (2004)

S.W: Lee et al., Nano Lett. 4 (2004) 2027





Introduction of critical point drying led to 75% suspension

Axelsson et al., New J. Phys **7** (2005) 245

$I_{source\text{-}drain}$ vs Gate Voltage, V_{SD} = 0.5 V