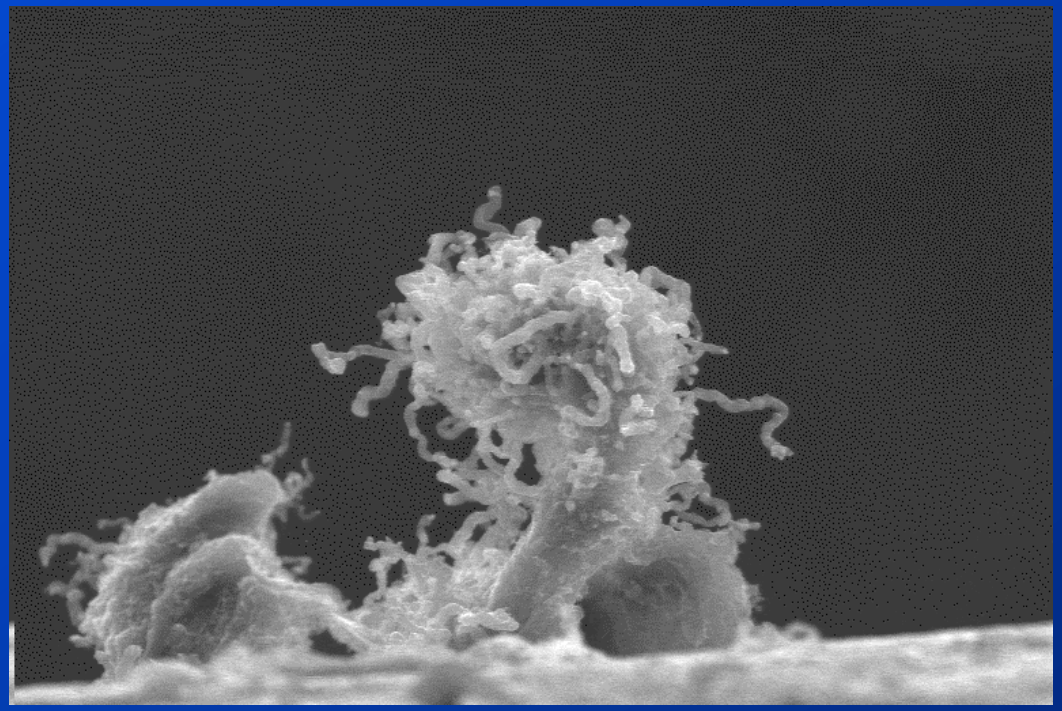
Crecimiento de nanotubos de carbono y su aplicación a biosensores



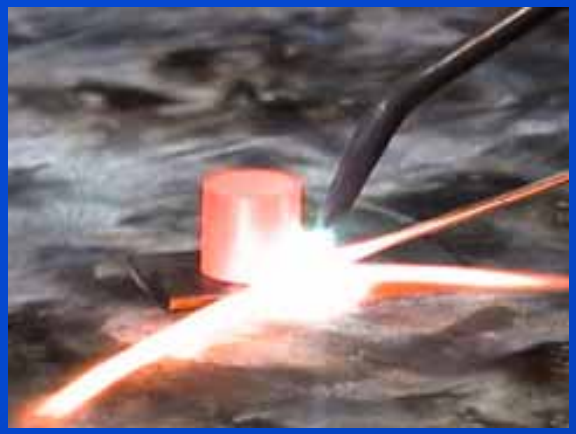
Ernest Mendoza
Institut Català de Nanotecnologia
Ernest.Mendoza.icn@uab.es

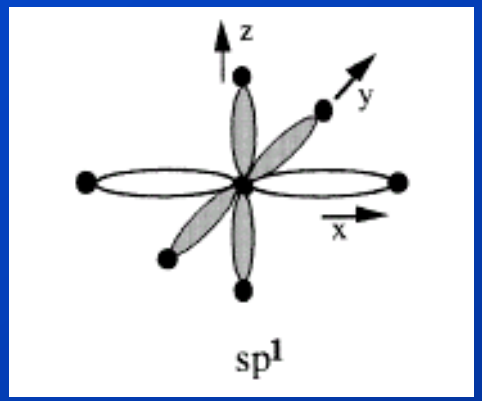
Contenido

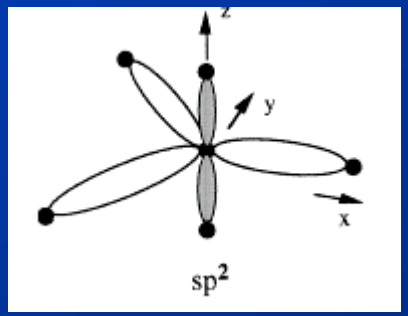
- Que es un nanotubo de carbono?
- Crecimiento de nanotubos de carbono
- Polímeros con CNTs: materiales estructurales
- Fabricación de dispositivos basados en CNTs
- Sensores de gases basados en CNTs
- Biosensores basados en CNTs

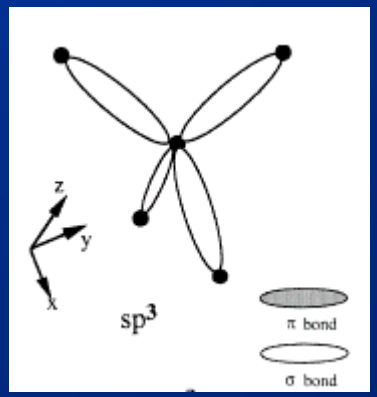
Que es un nanotubo de carbono?

Formas alotrópicas del carbono

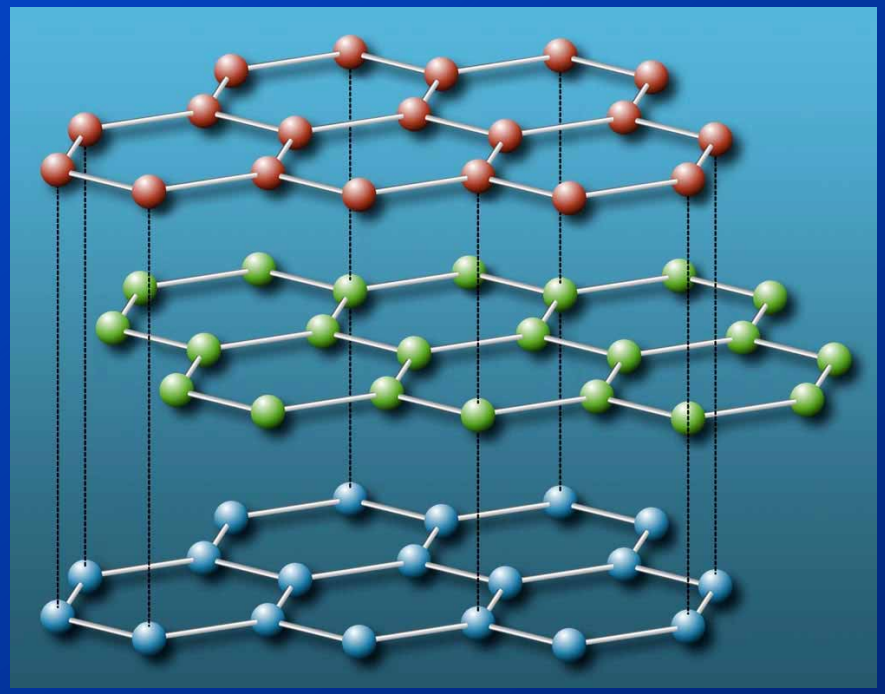






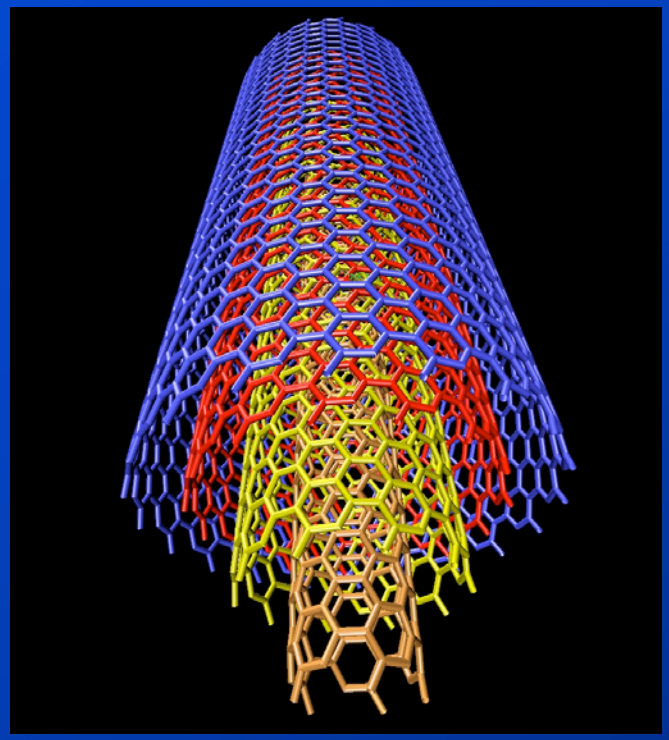


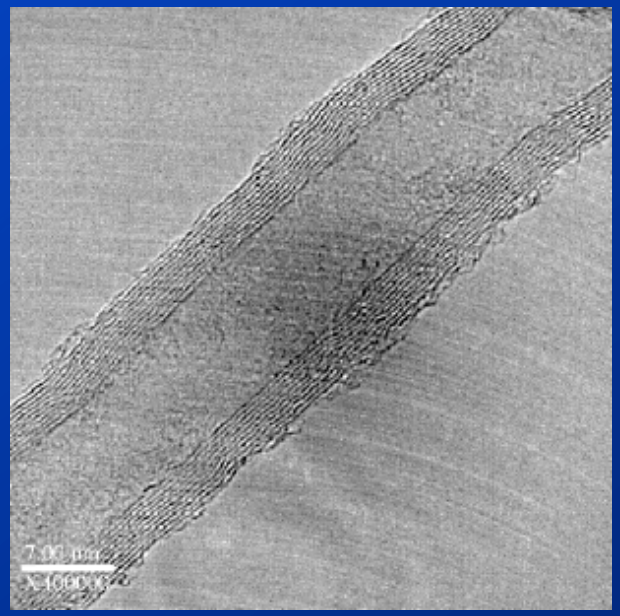
Grafito



Que es un CNT?

~ 1.2 nm



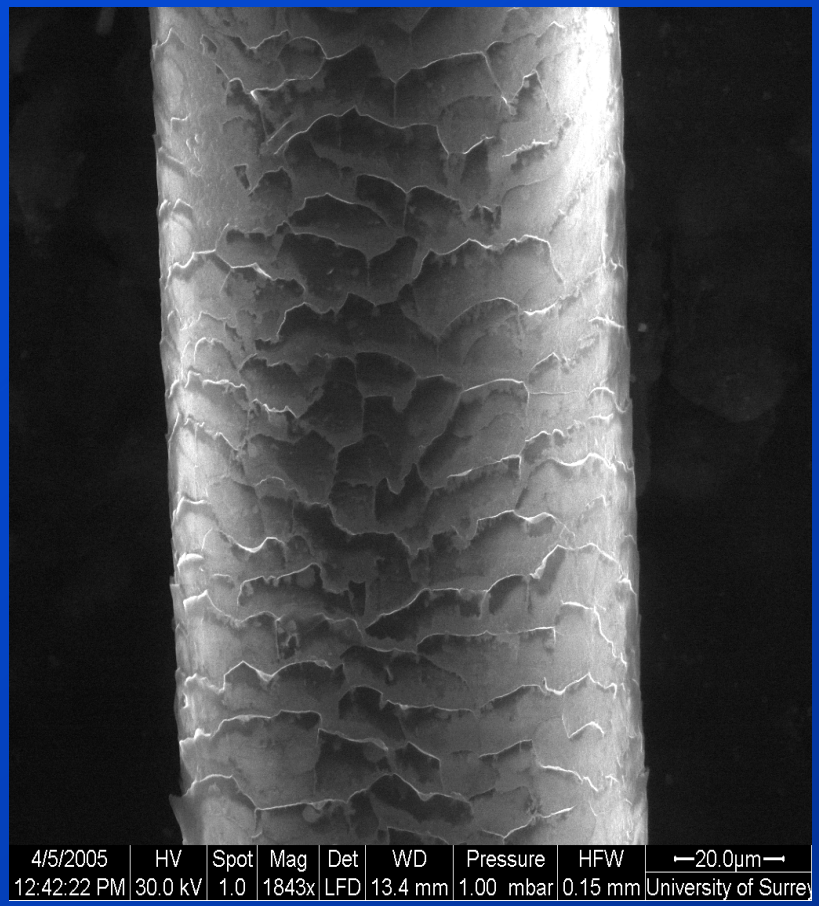


< ~ 50 nm

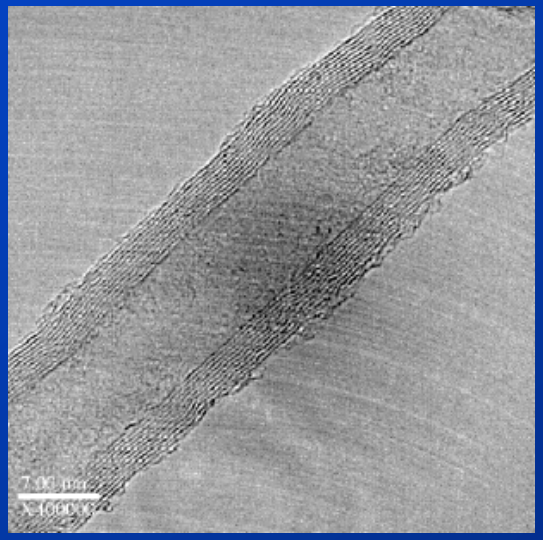
Nanotubo Monocapa (SWCNT)

Nanotubo Multicapa

Que es un CNT?



1 pelo humano ~ 100 µm
100 µm = 100 000 nm



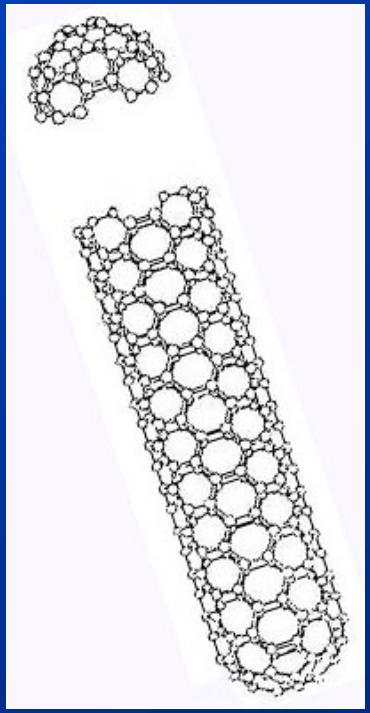
2000 veces mas pequeño

85000 veces mas pequeño

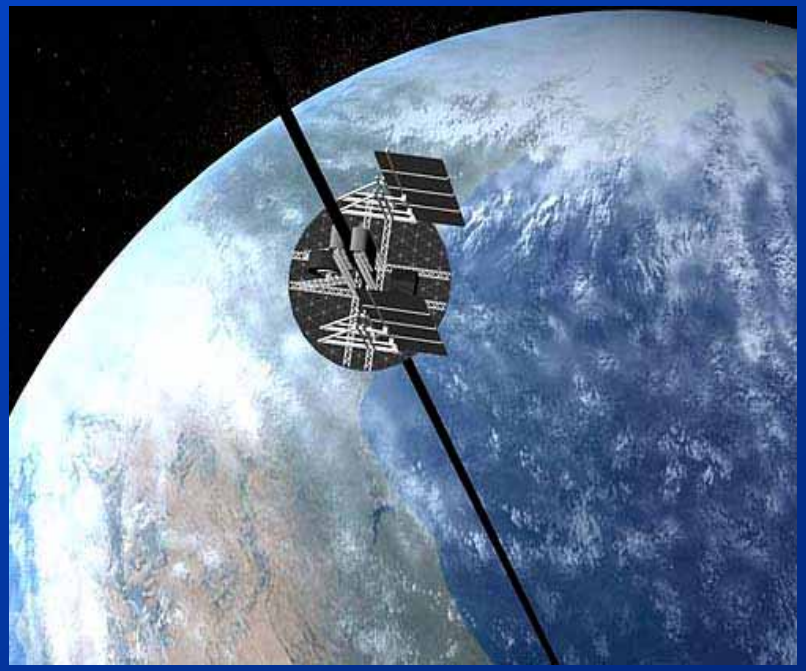
Que es un CNT?

Propiedades

- **Electricas:** Metales/Semiconductores
- **Densidad:** 1.33 – 1.40 g/cm^3 (Aluminio: 2.7g/cm^3)
- **Propiedades mecanicas:** 45·10^{9}Pa (Acero 2·10^{9}Pa)
- **Transporte de corriente:** 10^{9}A/cm^2 (Cobre: 10^{6}A/cm^2)
- **Transporte de calor:** 6000 W/mK (Diamante: 3320 W/mK)
- **Precio:** ~ 1000 €/g



“Ascensor espacial …”



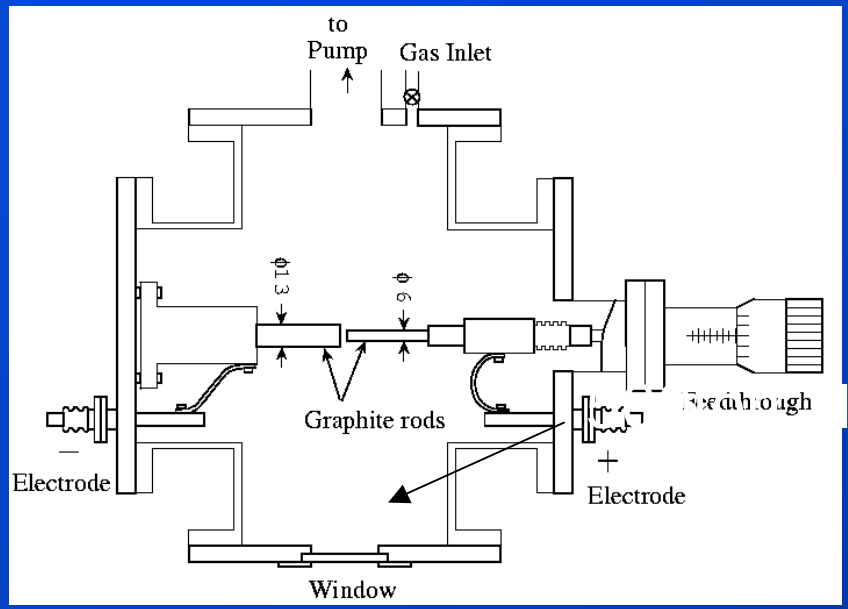
The biggest technical obstacle is finding a material strong but light enough to make the cable; this is where the carbon nanotubes come in. These are microscopically thin tubes of carbon that are as strong as diamonds but flexible enough to turn into fibre. In theory, a nanotube ribbon about one metre wide and as thin as paper could support a space elevator. No scientist has yet succeeded in making such a fibre, ……..

Guardian, David Adam, science correspondent
Saturday September 13, 2003

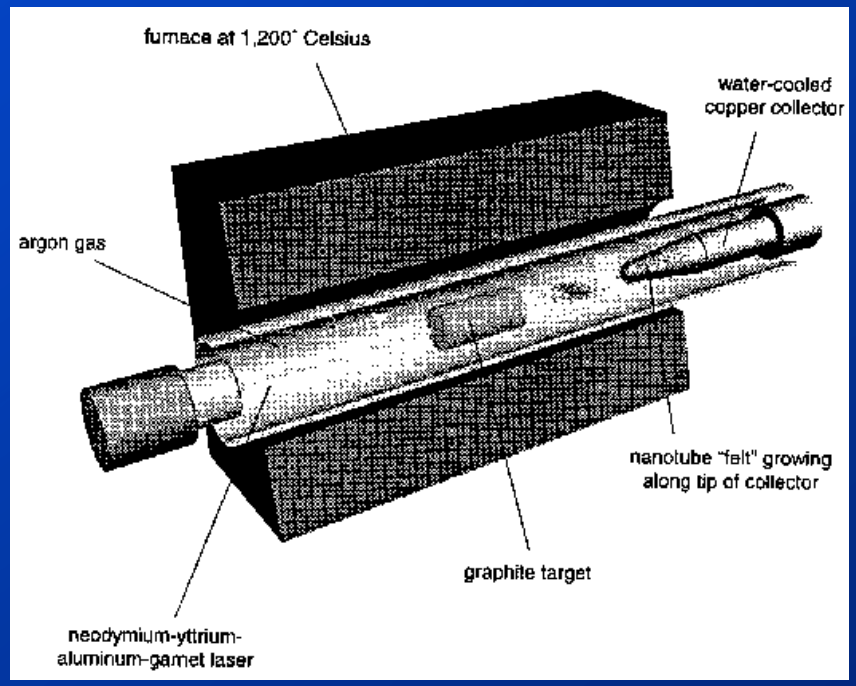
Crecimiento de CNTs

Crecimiento de CNTs

Descarga de arco



Ablación láser



S. Iijima, *Nature* **354** 56 (1991)

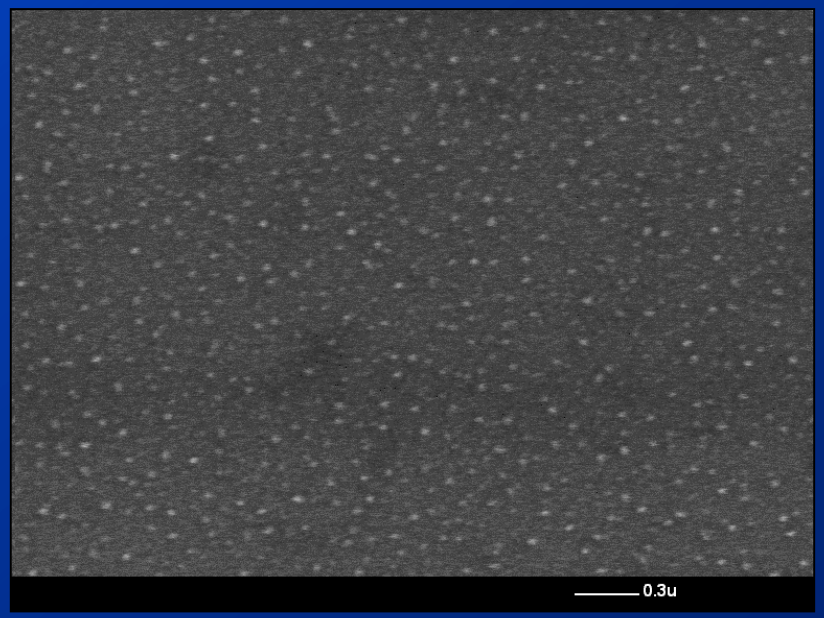
A. Thess *et al. Science* 273 483 (1996)

Su síntesis requiere alta energía
Se producen muchas impurezas

Crecimiento de CNTs

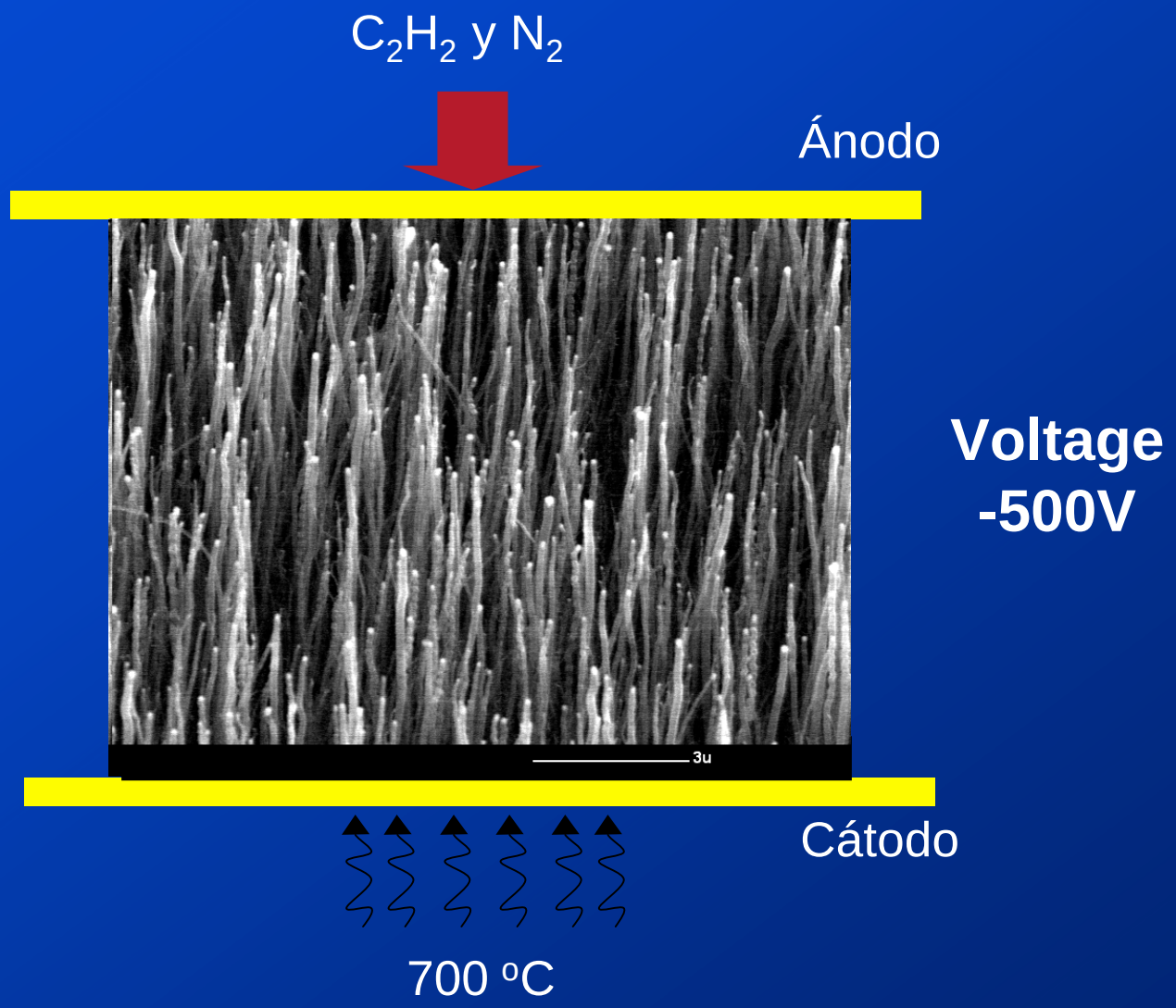
Deposito de vapores químicos (CVD)

Fuente de carbono gaseosa (CH_4)
Utilizacion de catalizadores sobre sustrato

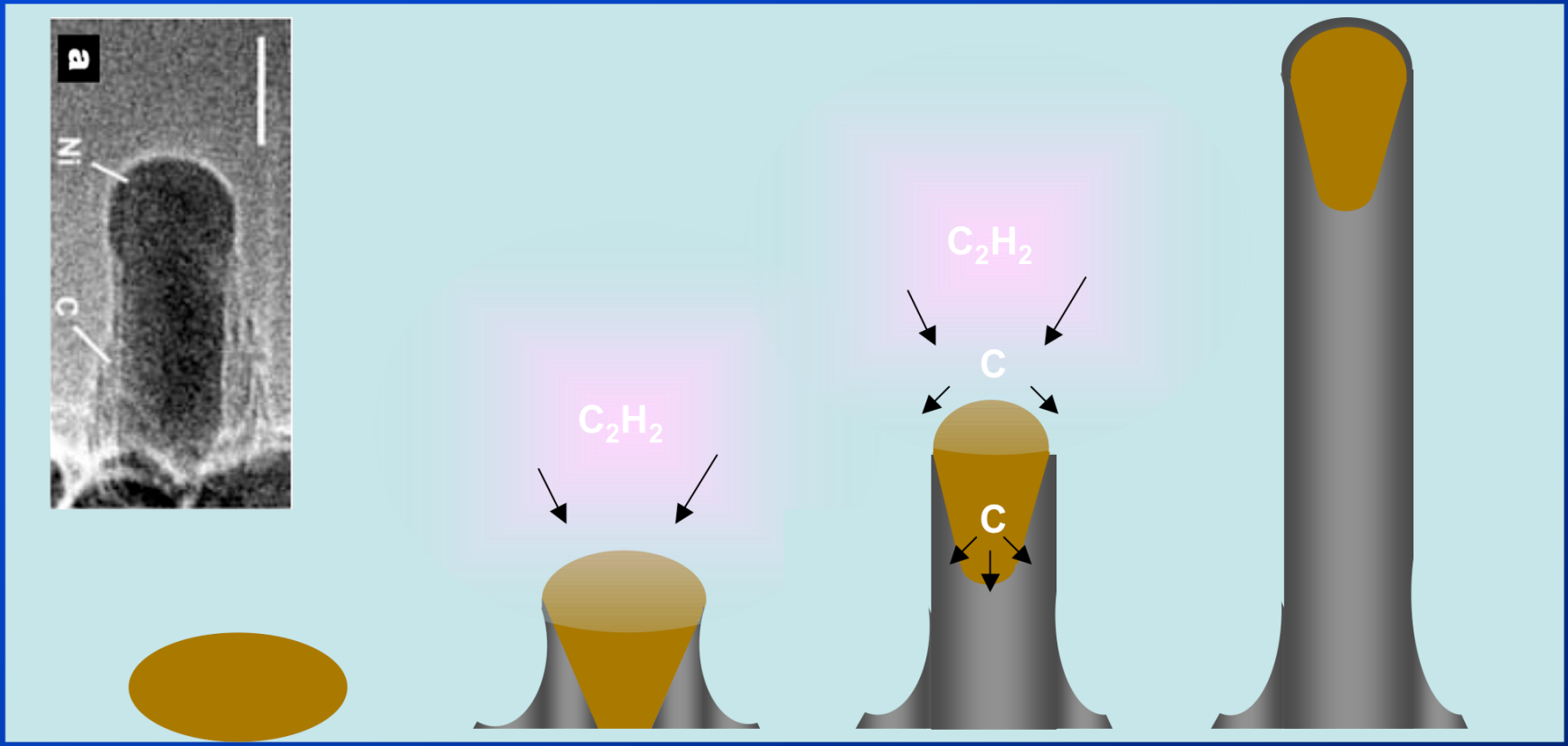


Menor energía requerida

Síntesis de CNTs

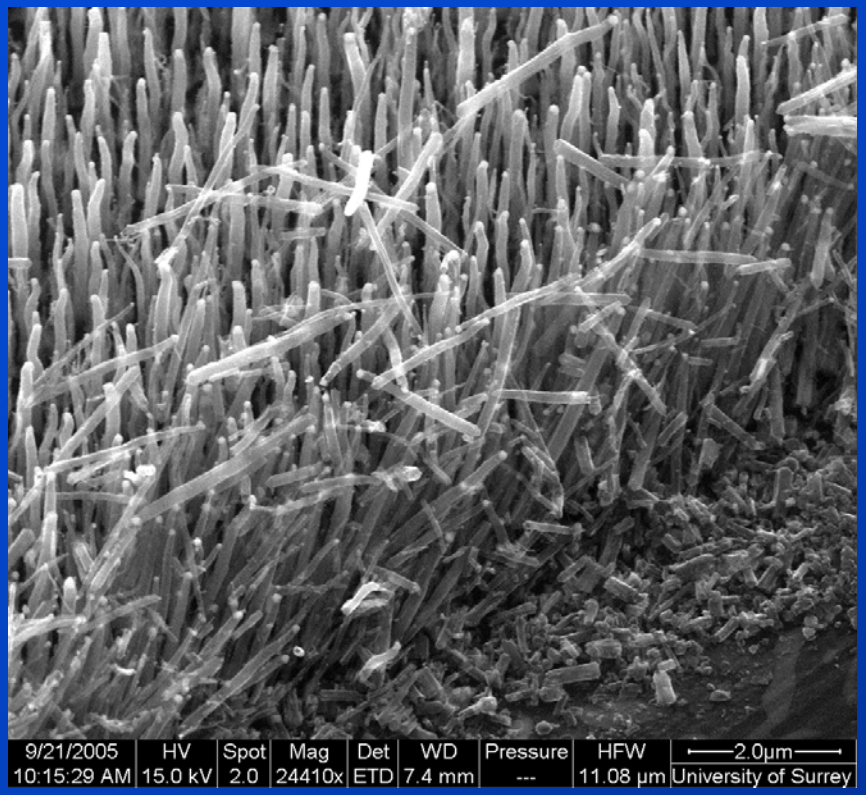


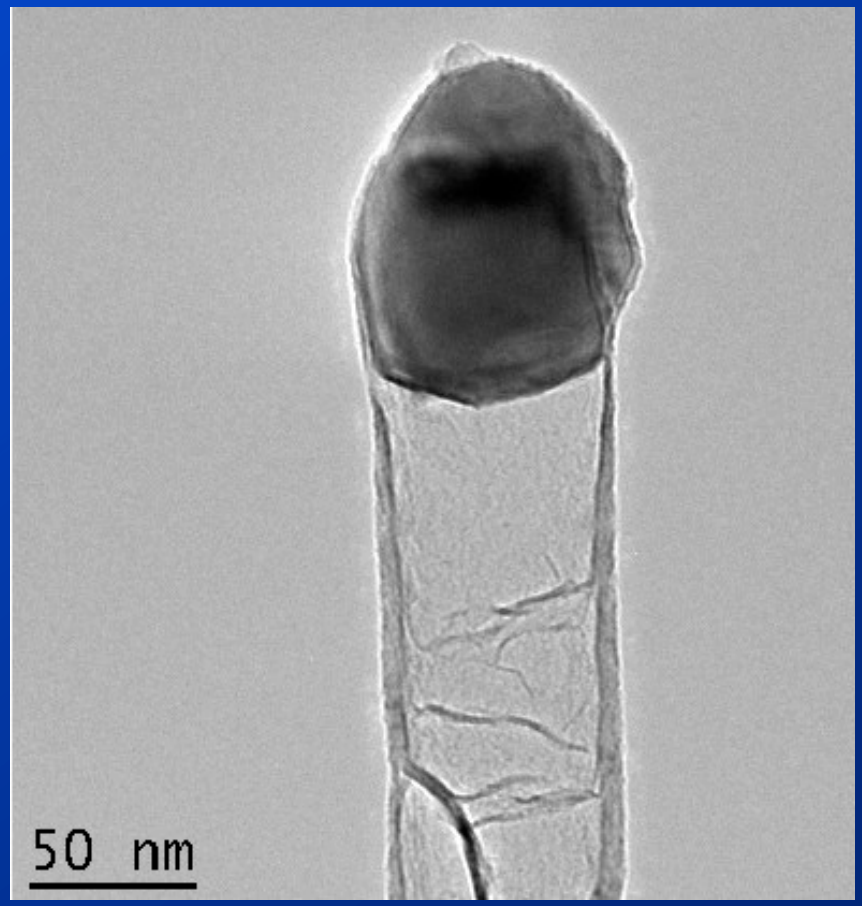
Crecimiento por CVD



R.T.K. Baker, Carbon, **27** 315 (1989)
Helveg *et al.* Nature **427**, 426 (2004)

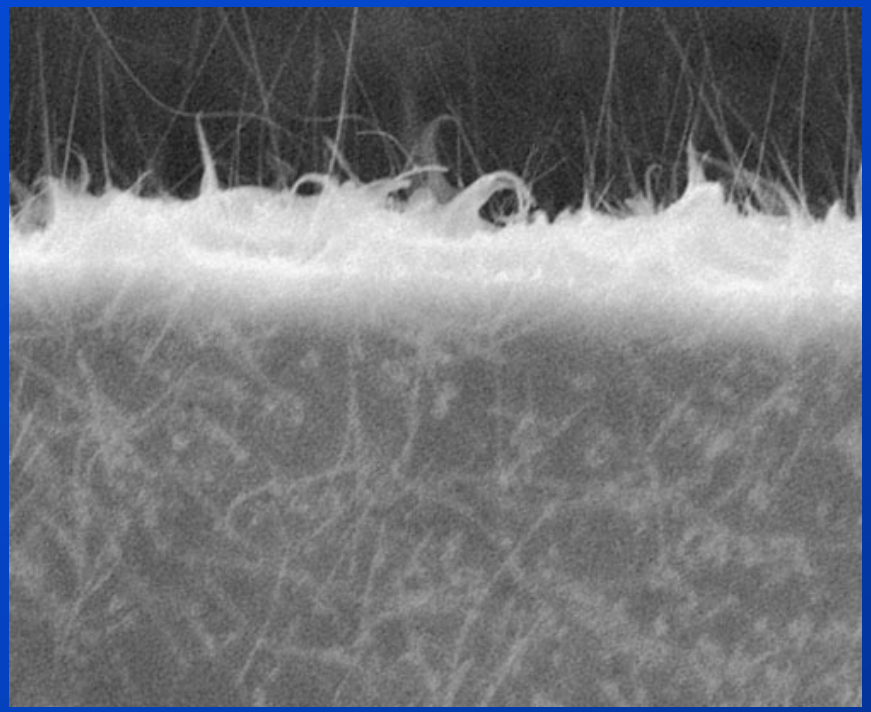
La partícula catalizadora

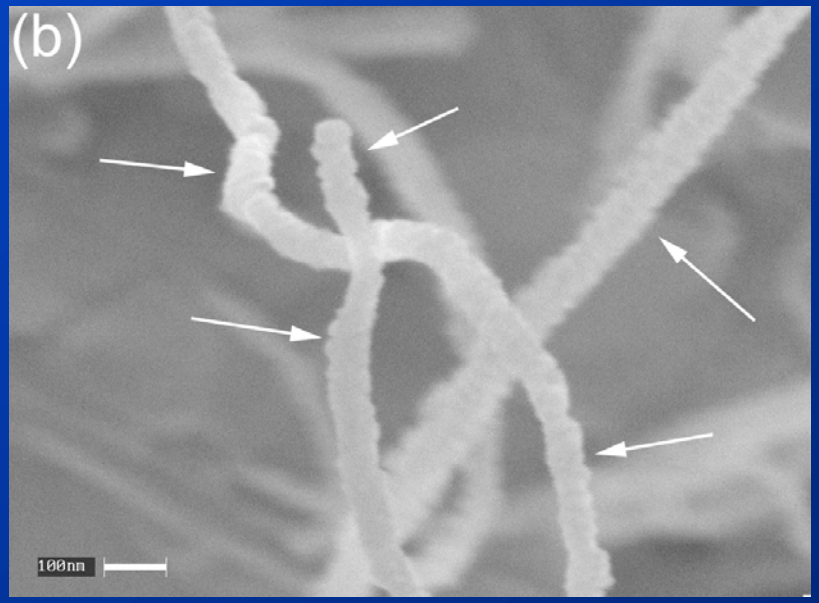




Polímeros con CNTs

Compuestos CNT-Polímero





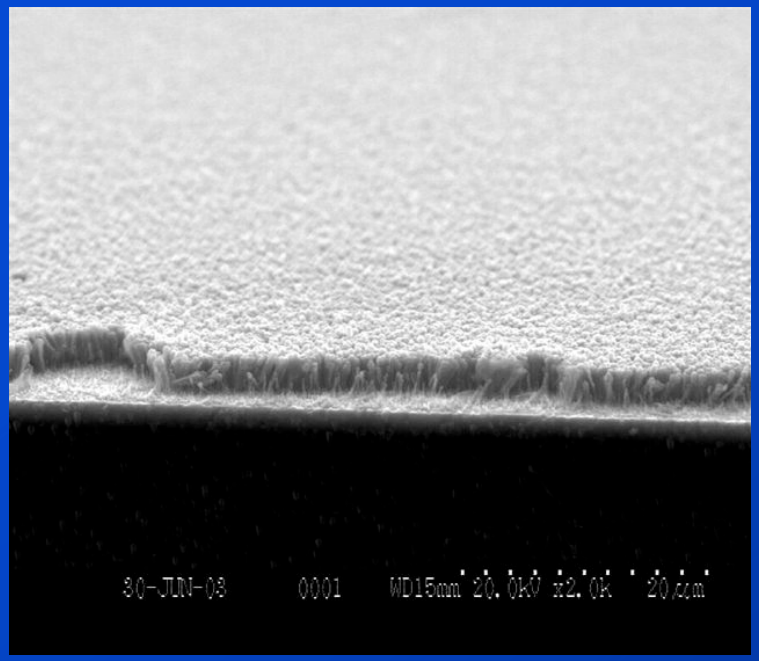
Aplicaciones CNT-Polímero

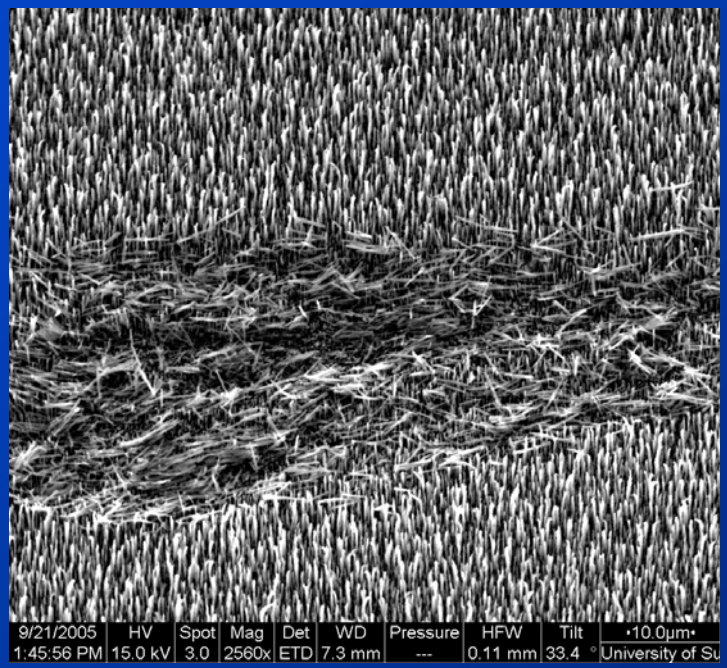
La inclusion de CNT en compuestos de fibras de carbono refuerza la estructura.

Aplicaciones: bicicletas, palos de golf y hockey…

De momento aplicaciones limitadas por el alto coste pero se prevé un buen mercado para los polimeros reforzados con CNTs

El material “perfecto” para sensores



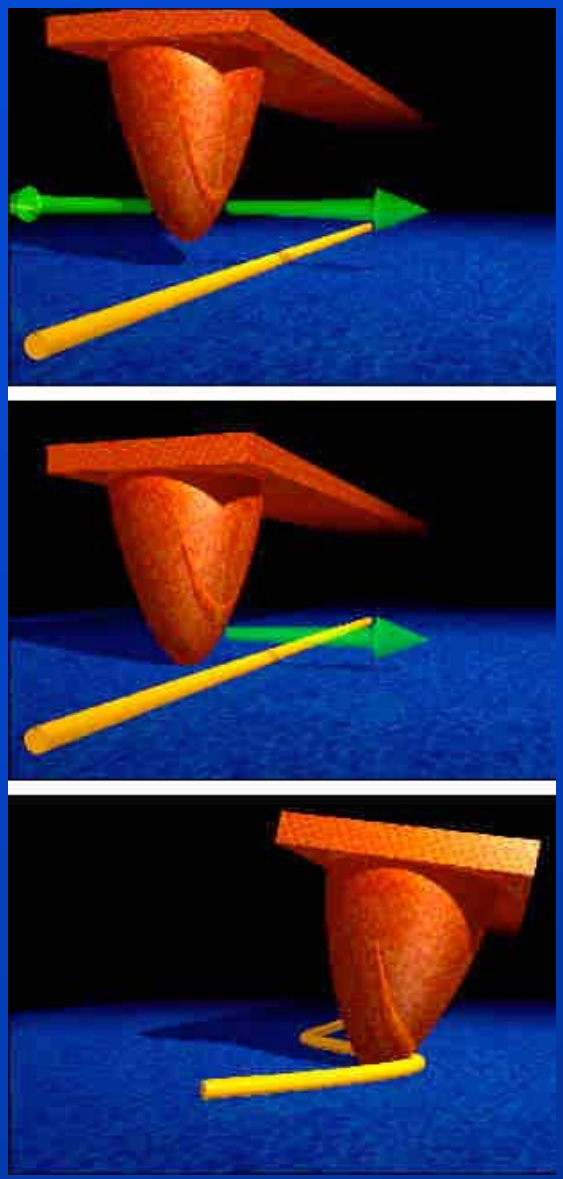


- Gran superficie especifica
- Buenas propiedades mecánicas
- Estabilidad química
- La R varia cuando las moléculas se adsorben en la superficie !!!

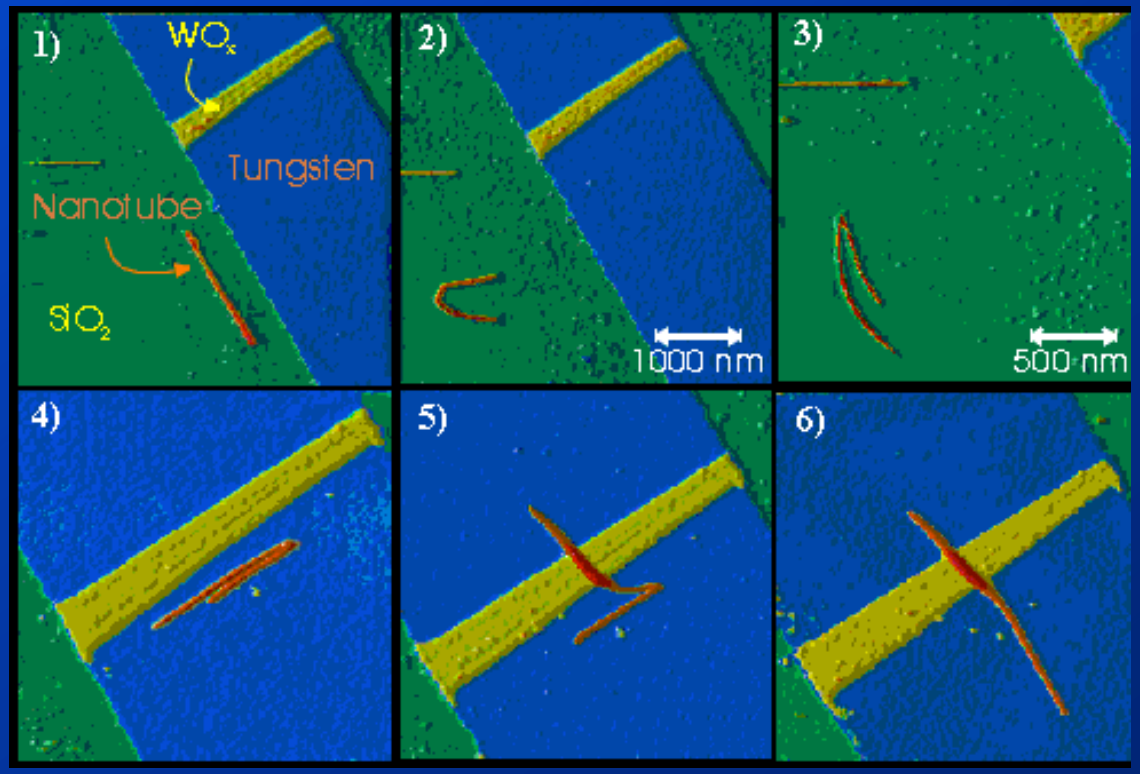
Fabricación de dispositivos basados en CNTs

Tamaño: ~ 1-20 nm diámetro
longitud 200 – 1000 nm

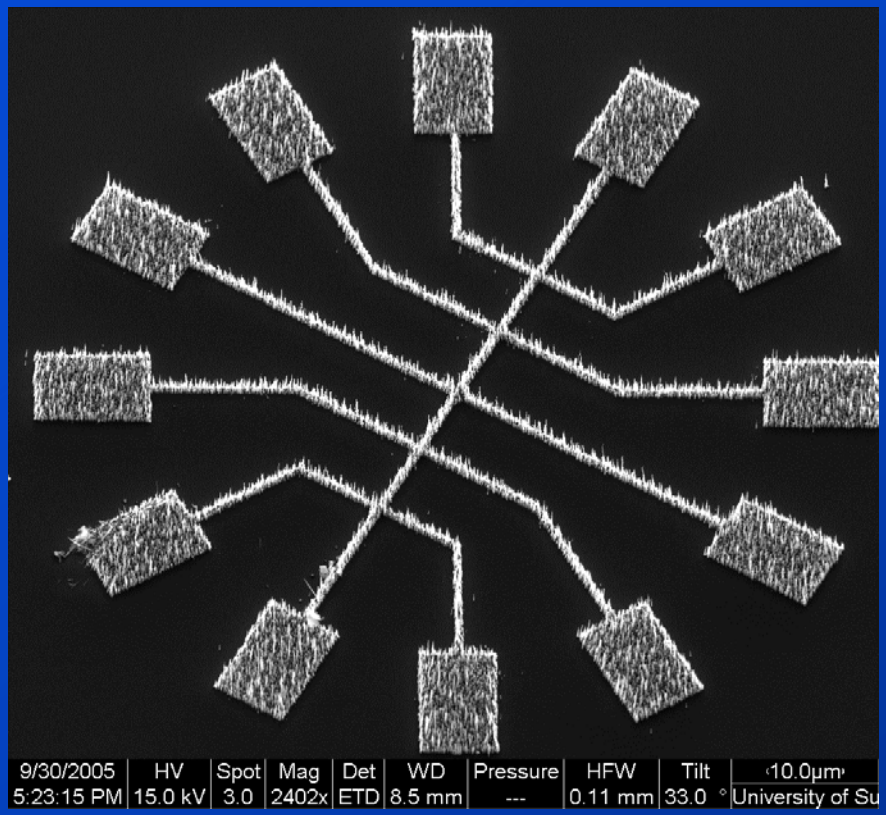
Tecnología vs Investigación

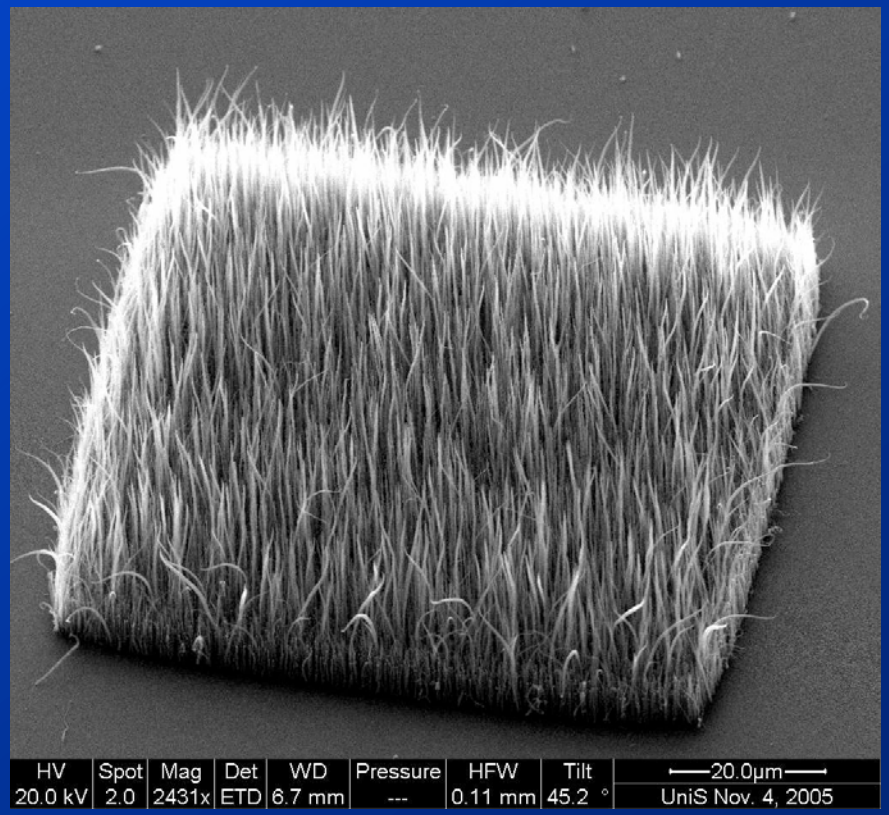


Técnicas Escalables !!!



Fabricación de dispositivos

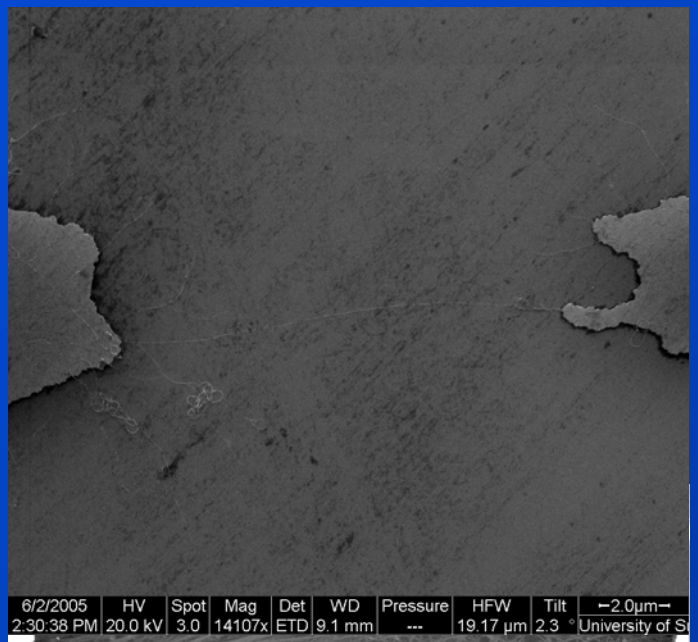


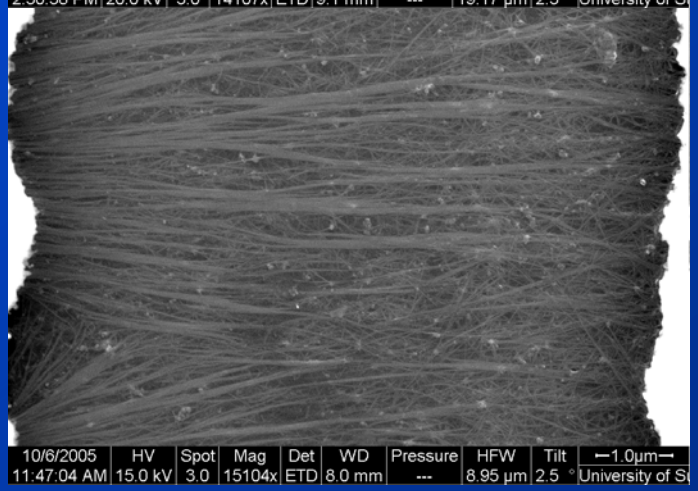


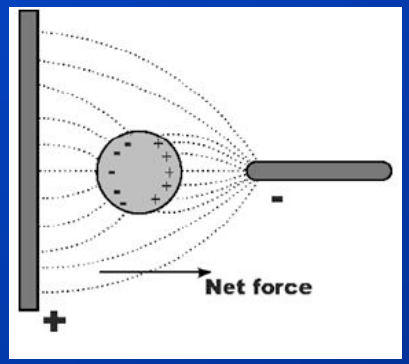
CNTs crecen solamente donde hay catalizador

Fabricación de dispositivos

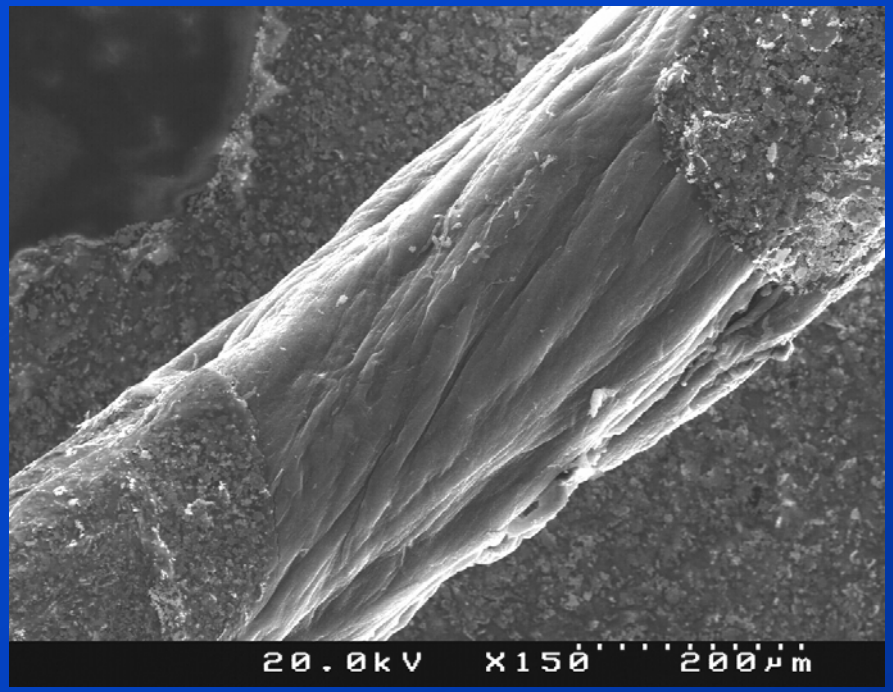
Dielectrofóresis para atraer los CNTs des de una solución

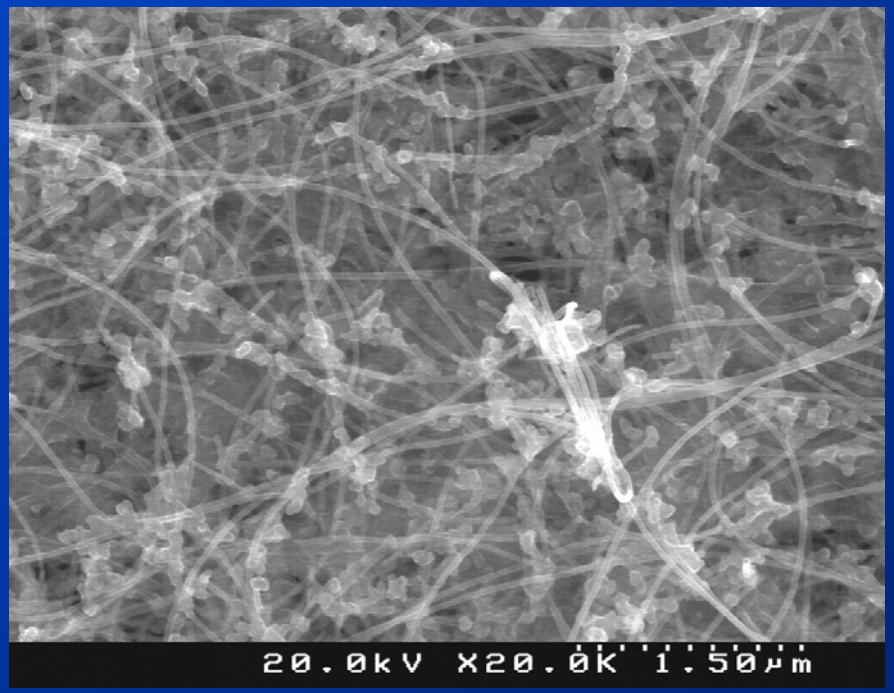






Fabricación de dispositivos



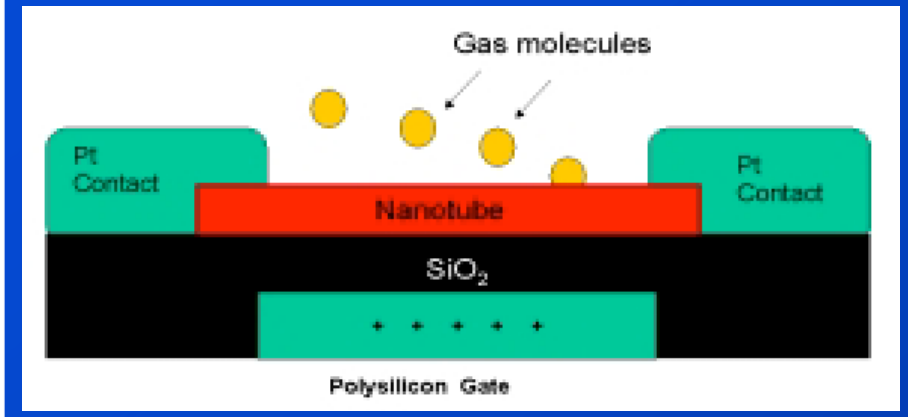


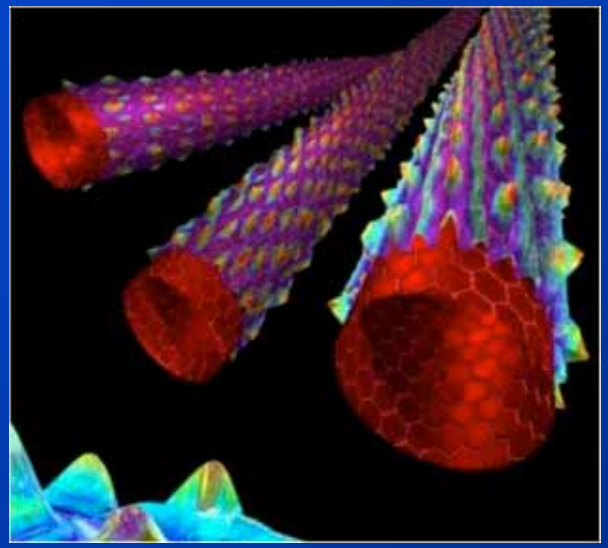
Fibras macroscópicas de CNTs

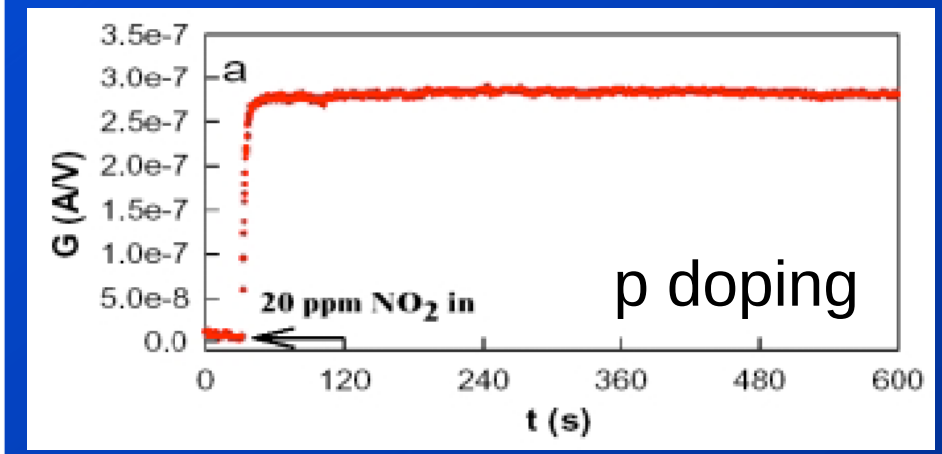
Aplicaciones medioambientales

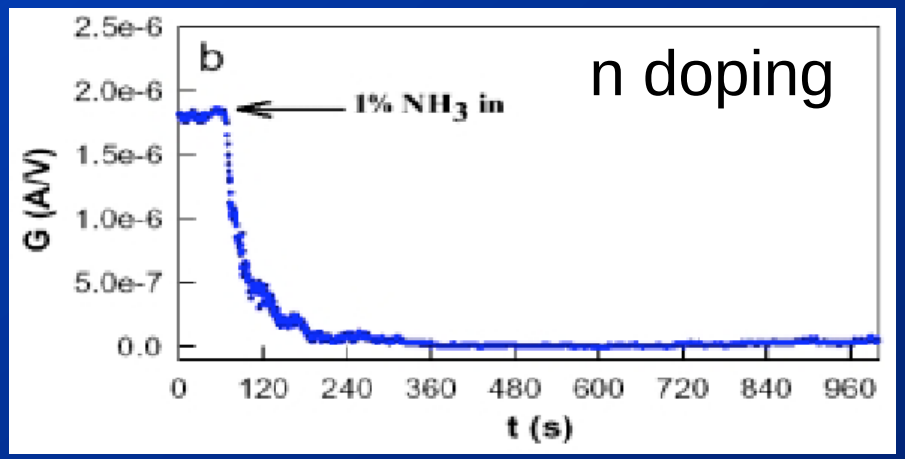
Sensores de gases basados en CNTs

Sensores de gases









Sensores convencionales operan a alta temperatura (~ 400 C)

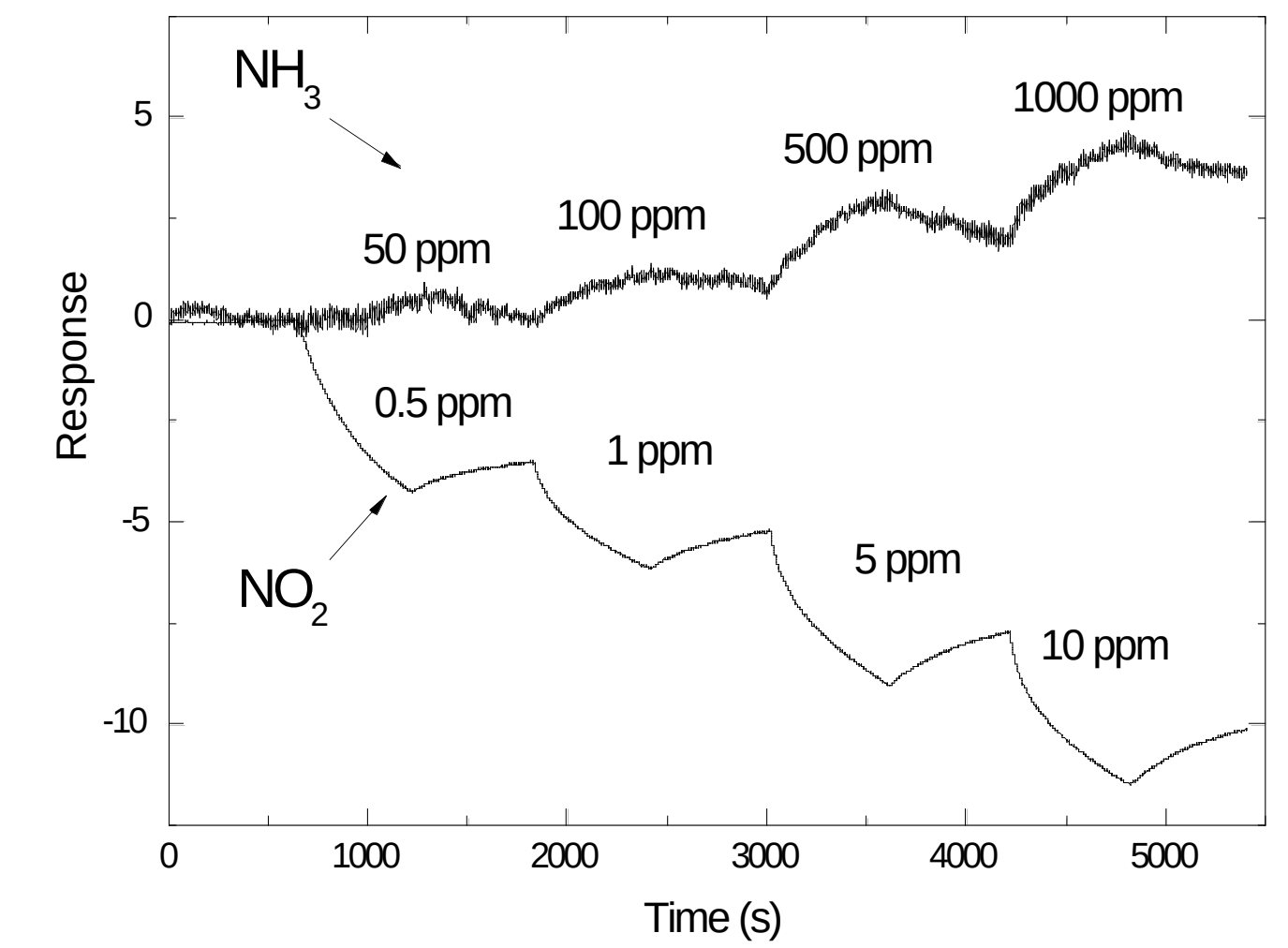
J. Kong et al, Science 287, 622 (2000)

Sistema experimental

Aire sintético

NO_2: 0.5 – 5 ppm
NH_3: 50 – 1000 ppm
H_2: 100 - 2000 ppm

Resultados



- no completamente reversible a alta temperatura

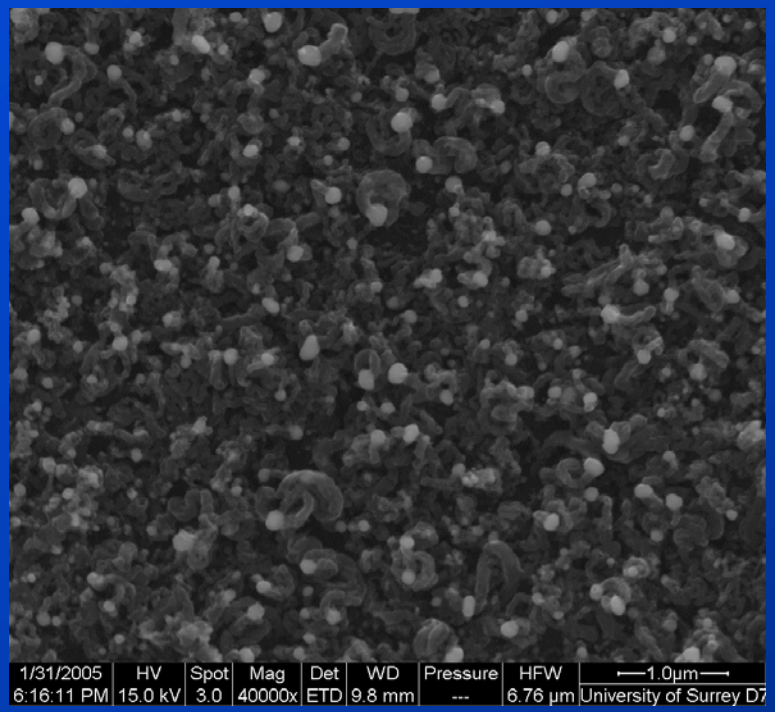
Hasta ahora...

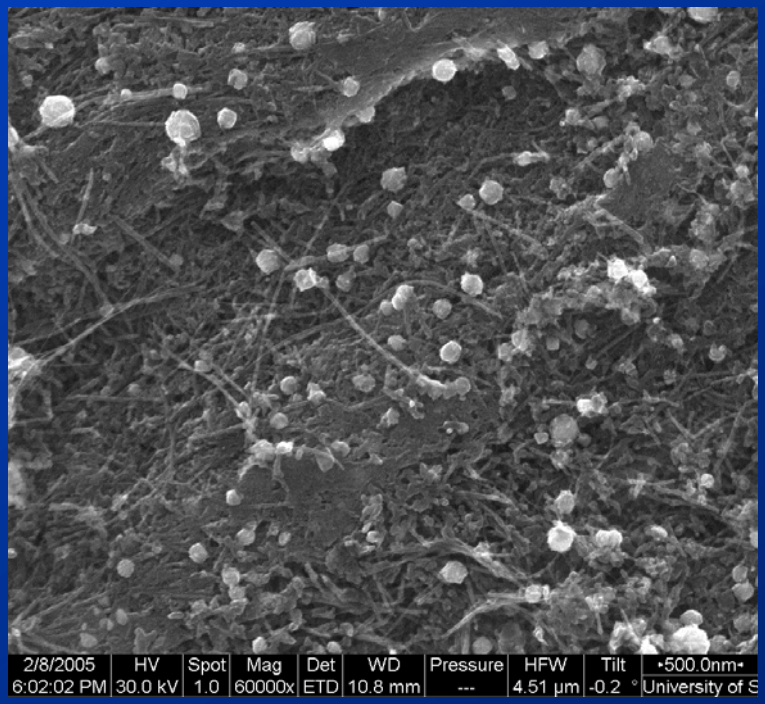
- Los CNTs se pueden utilizar como sensores

Podemos conseguir SELECTIVIDAD ??

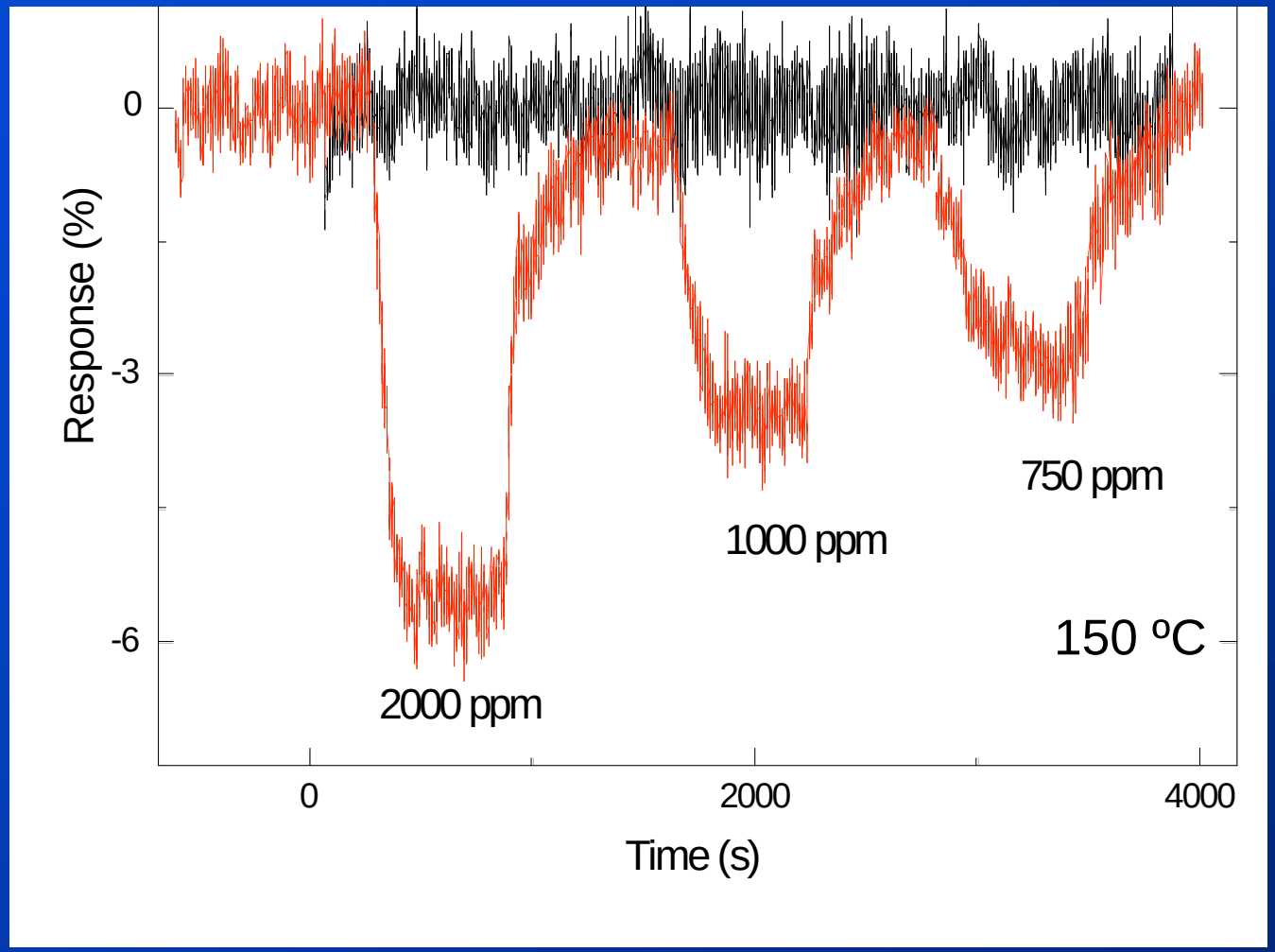
Electrodeposito de Pd

Pd cataliza la descomposición de H_2





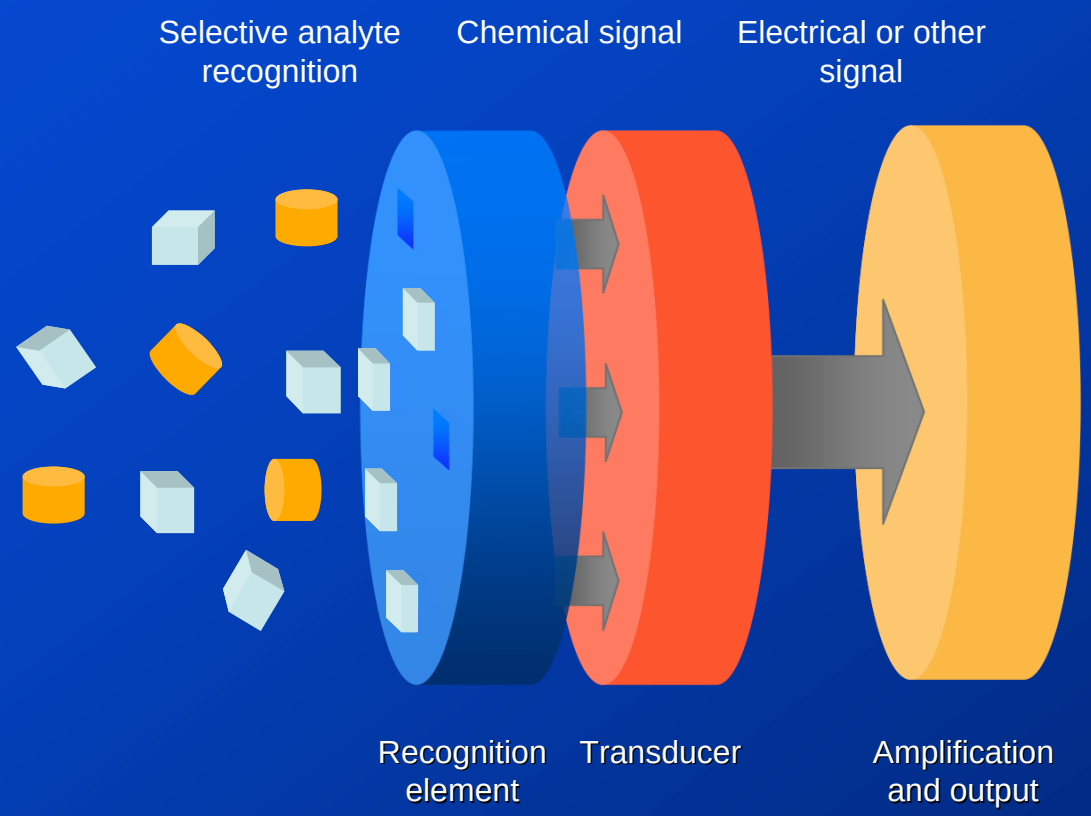
Sensores de hidrogeno



Los CNTs se pueden modificar para detectar sustancias predeterminadas !

Biosensores basados en CNTs

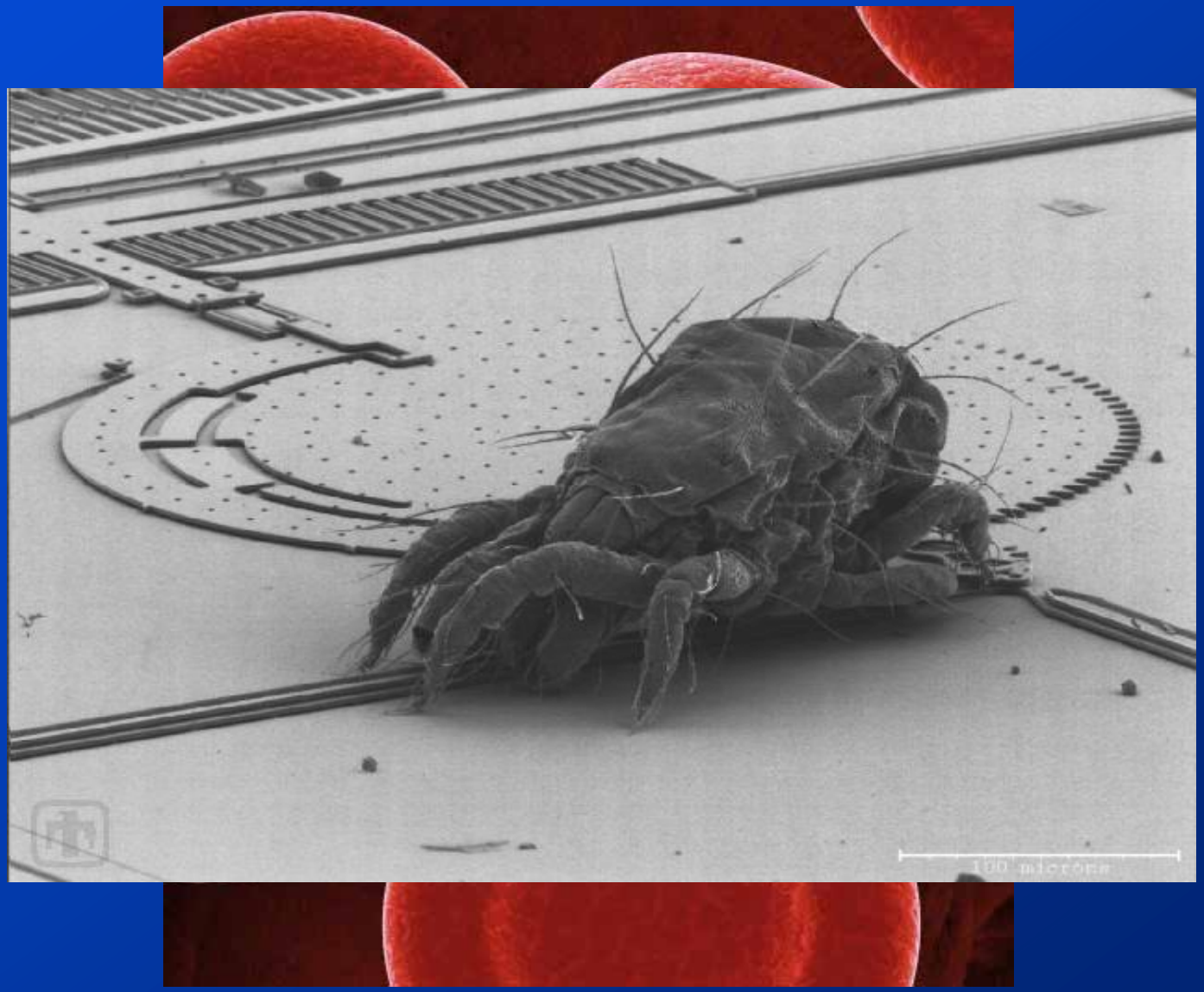
Que es un biosensor?



Nanotecnologia: lecciones de la naturaleza

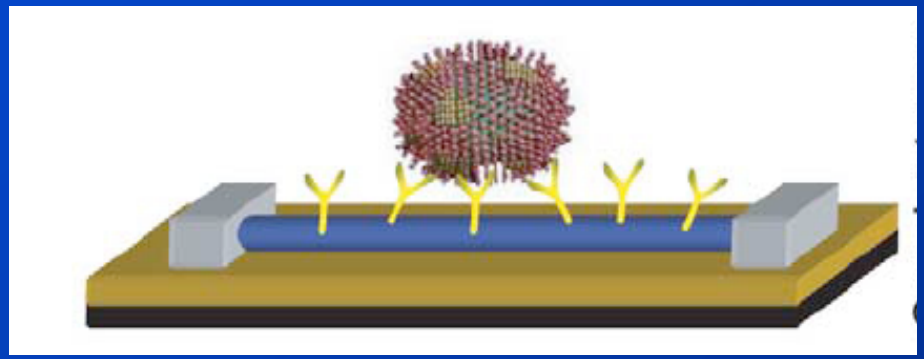
Professor Rogers, Vanderbilt University

Nanotecnologia: donde realmente estamos?



Biosensores

Los organismos utilizan enzimas, anticuerpos,… para interactuar con el entorno.

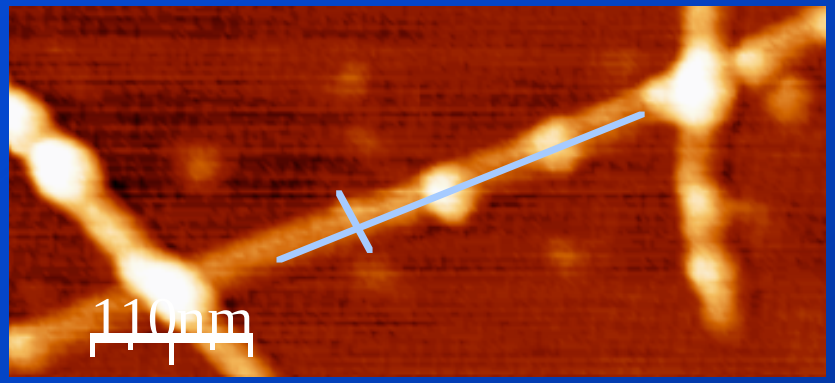


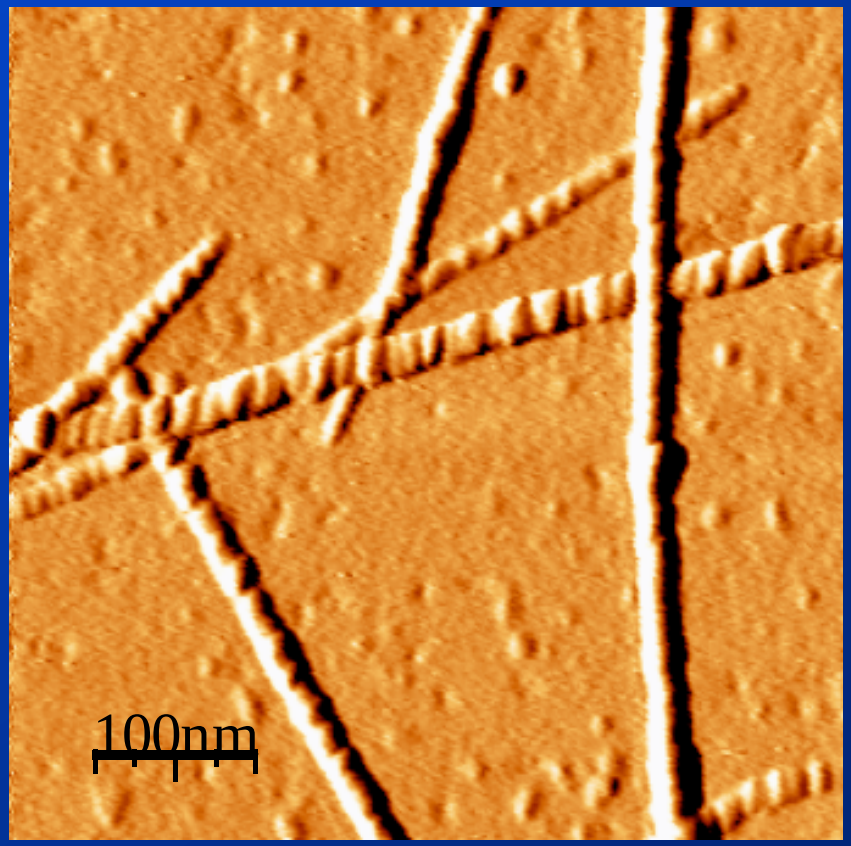
Funcionalización de la superficie con biomoléculas

Tamaño nanotubos similar a las biomoléculas. Elevada sinergia

Miniaturización gracias a la nanotecnologia

Funcionalización de CNT con ácidos nucleicos

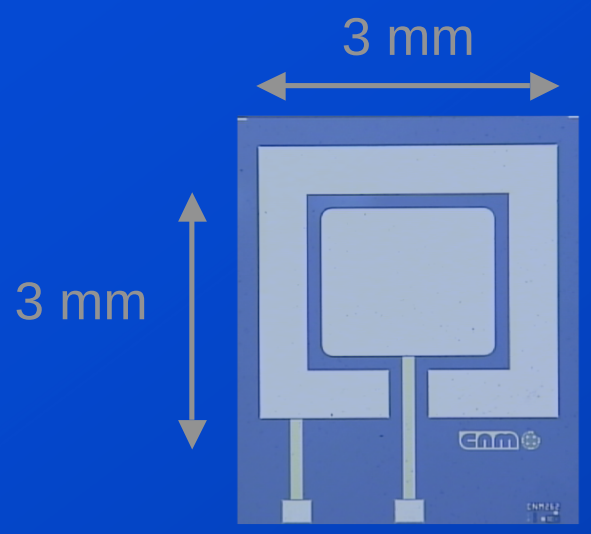




Caso práctico:

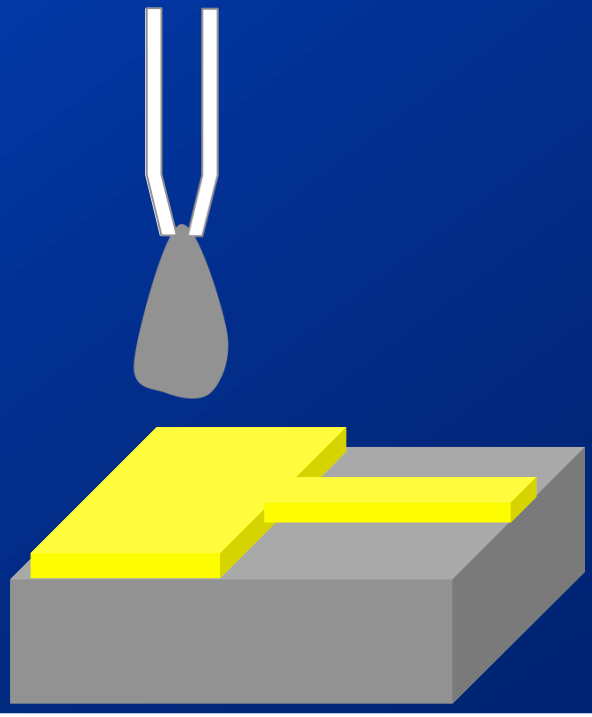
Immunosensor

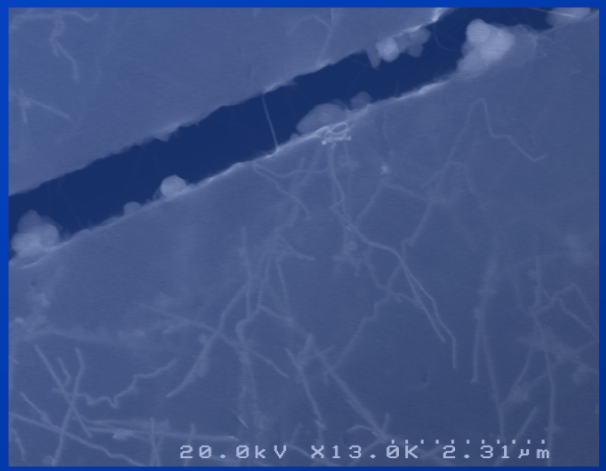
Fabricación dispositivos



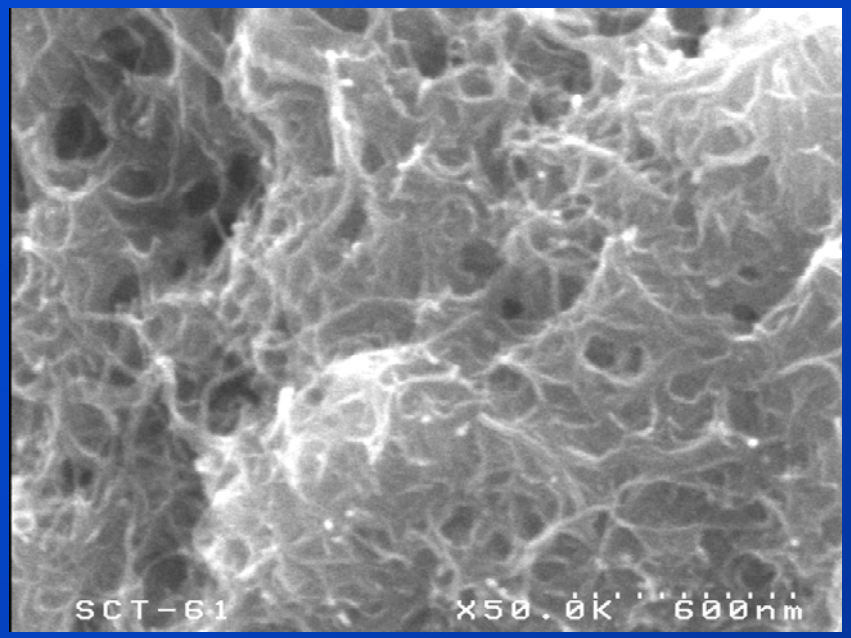
Fabricación dispositivos

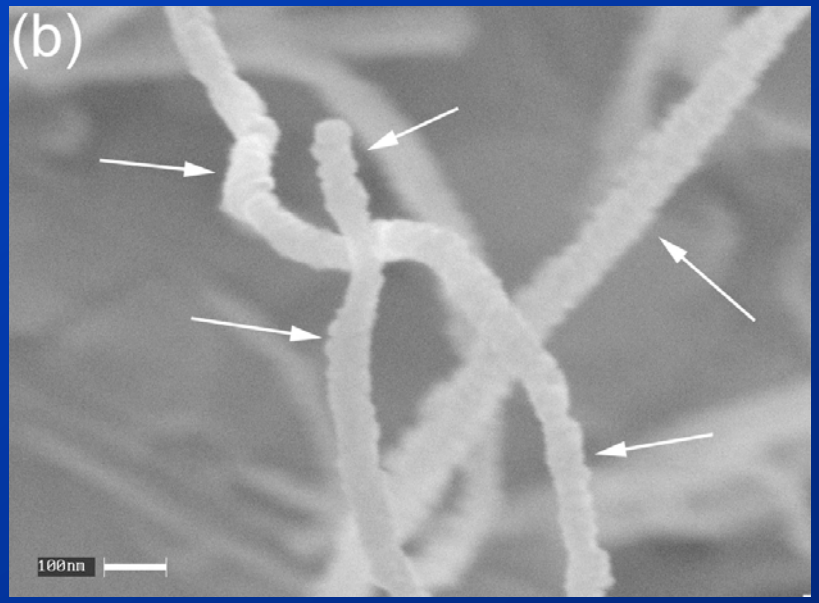
Drop casting



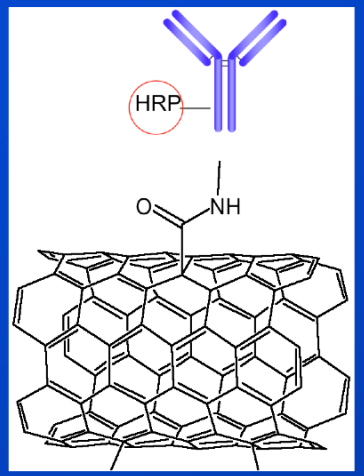


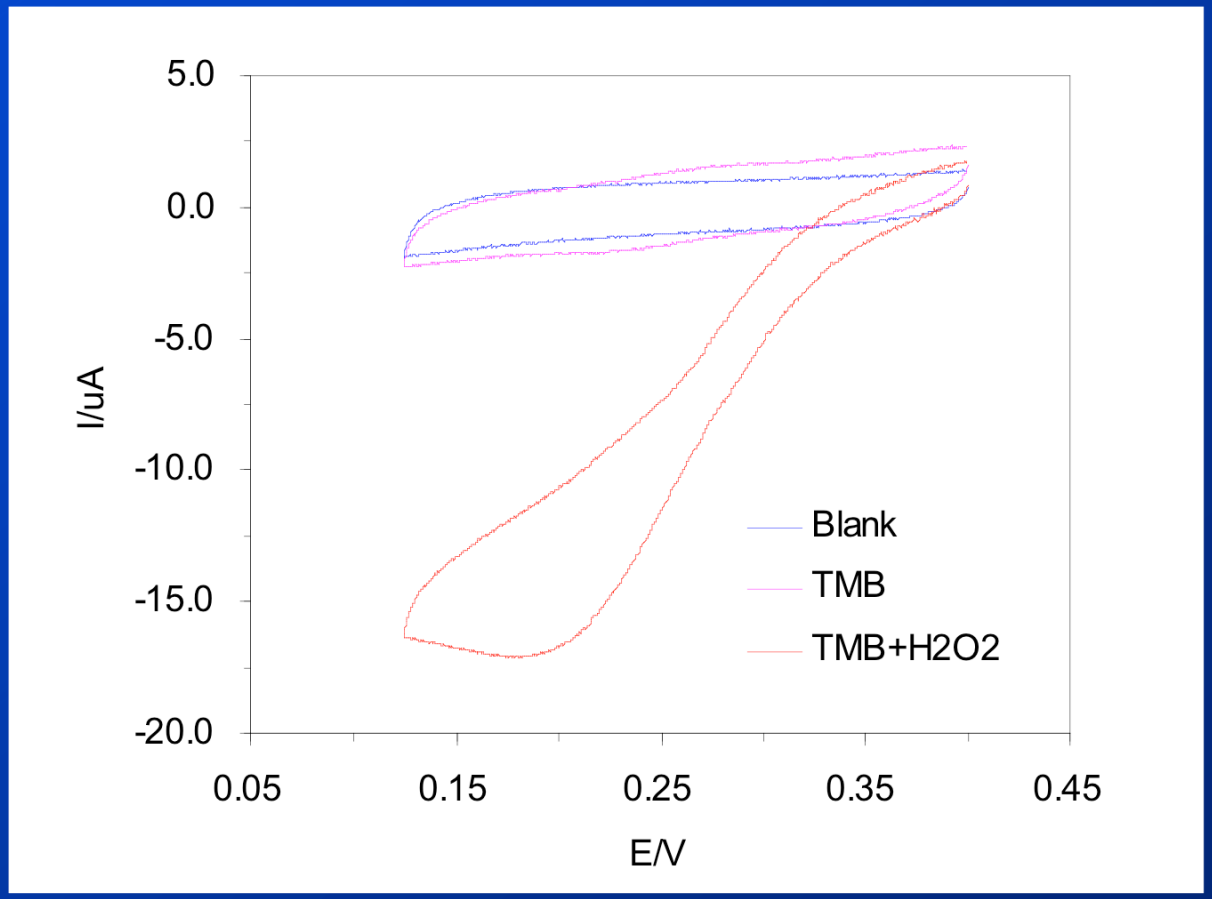
Compuestos polímericos



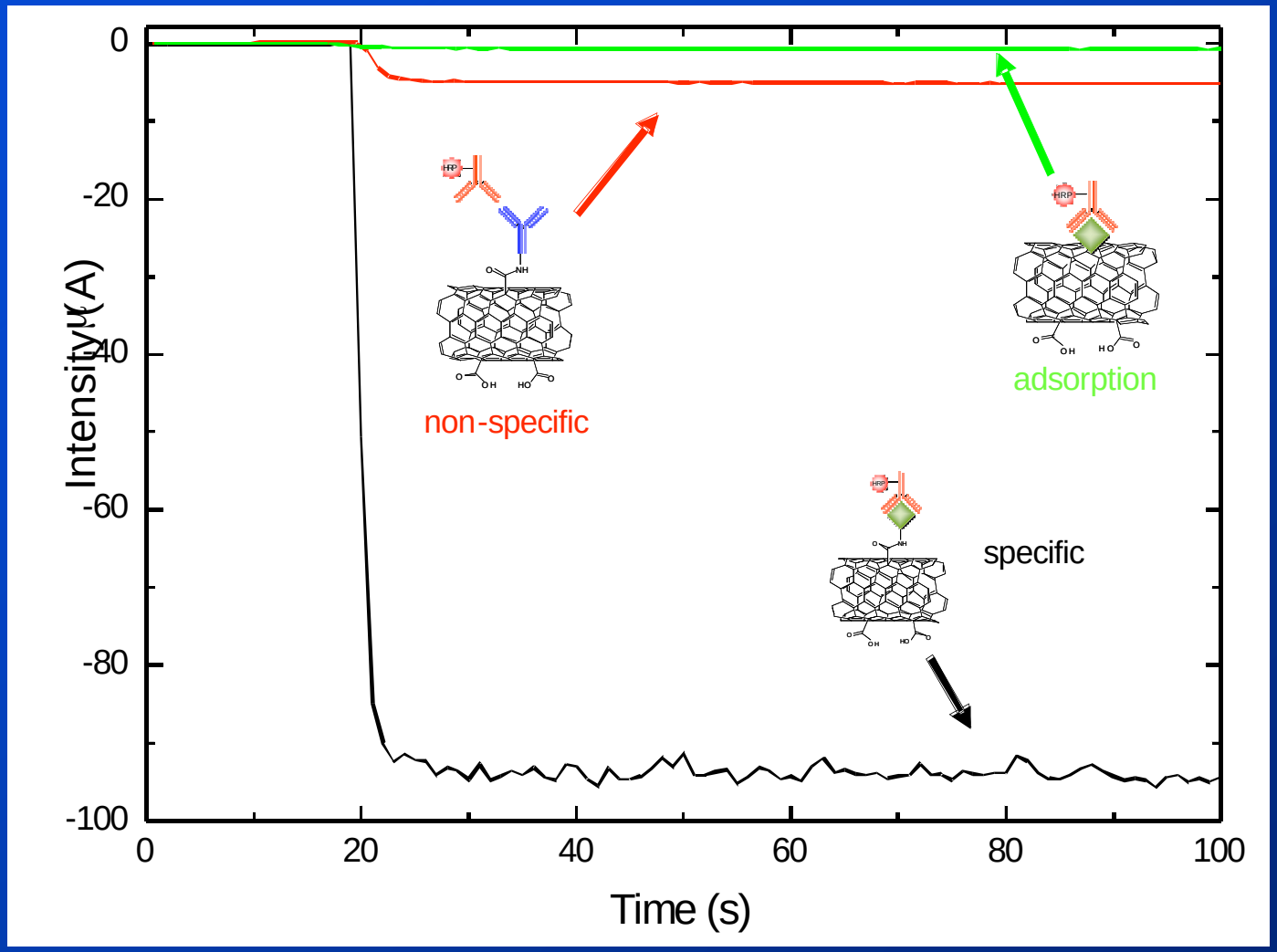


Sensor electroquímico





Resultados



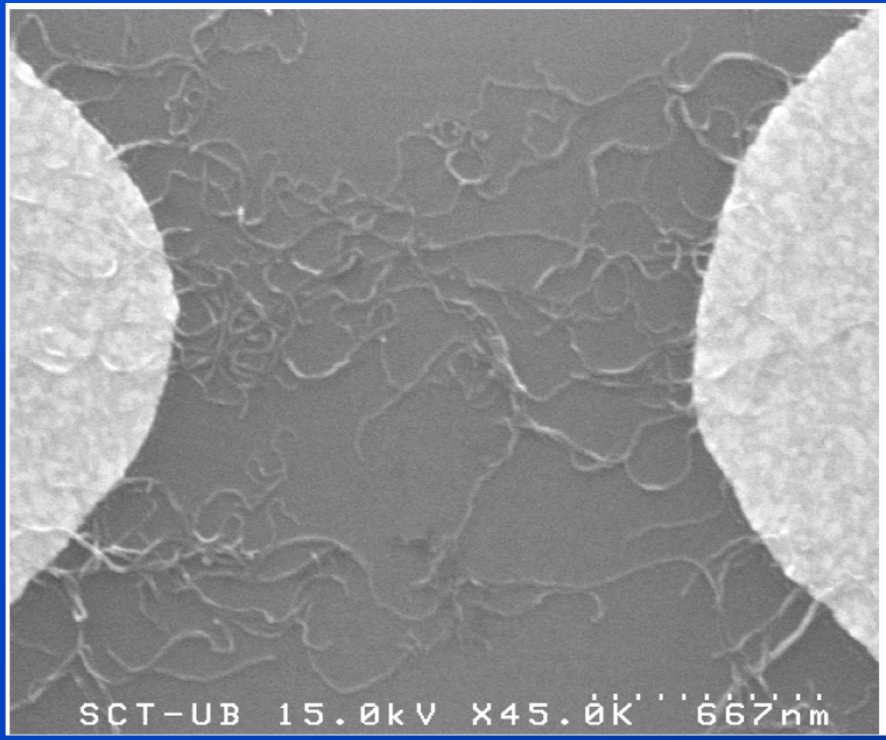
% signal specificity = ~ 90 %

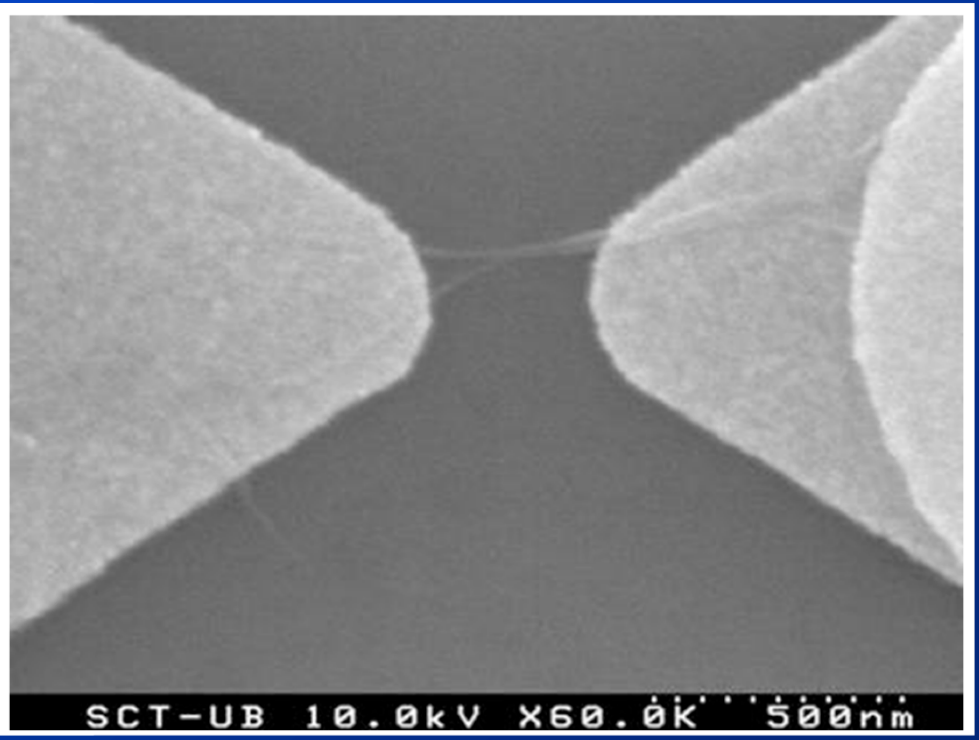
% signal enhancement = ~ 97 %

Covalent binding results in better signal

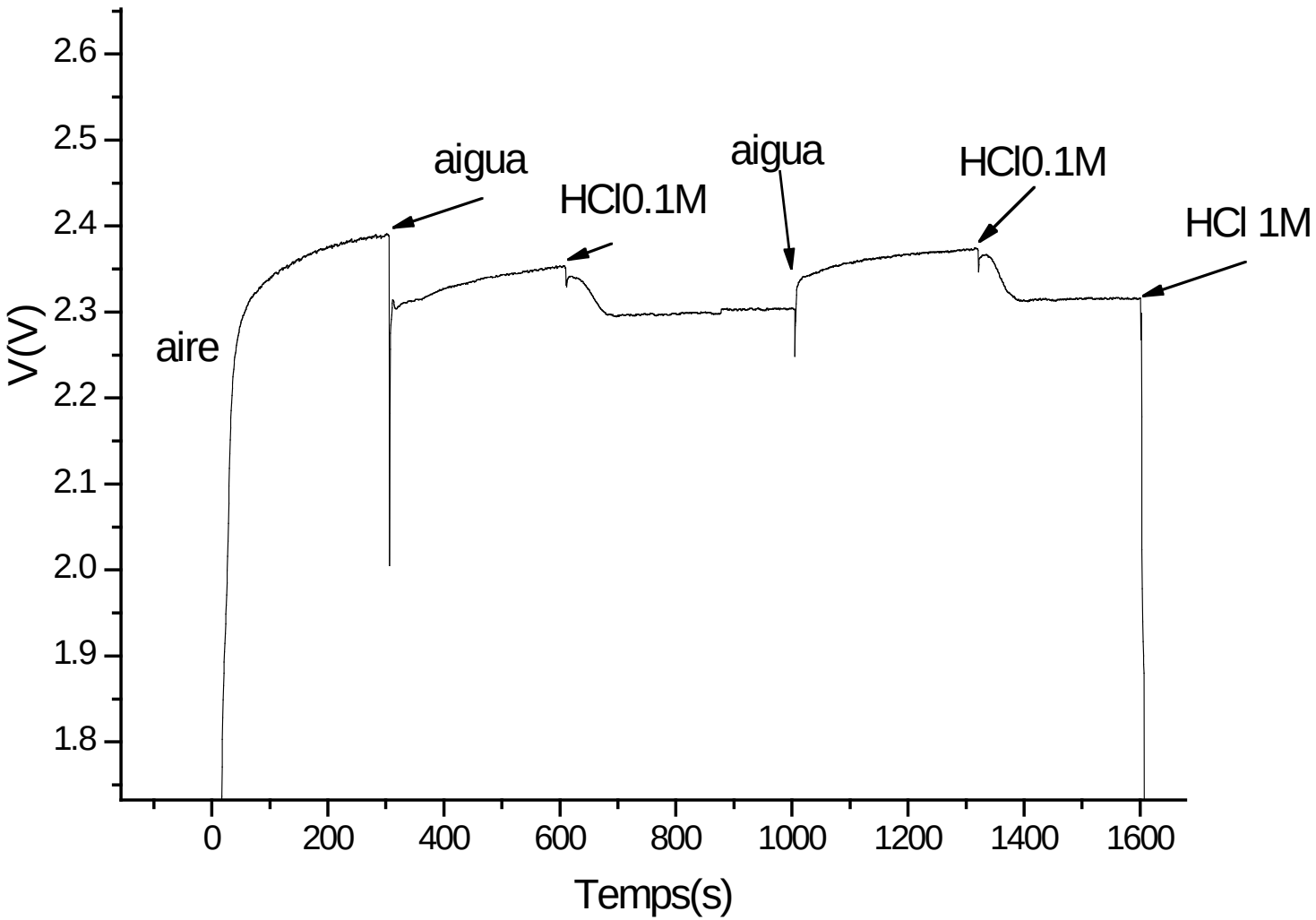
Hacia nanosensores integrados

Conexión de los nanotubos



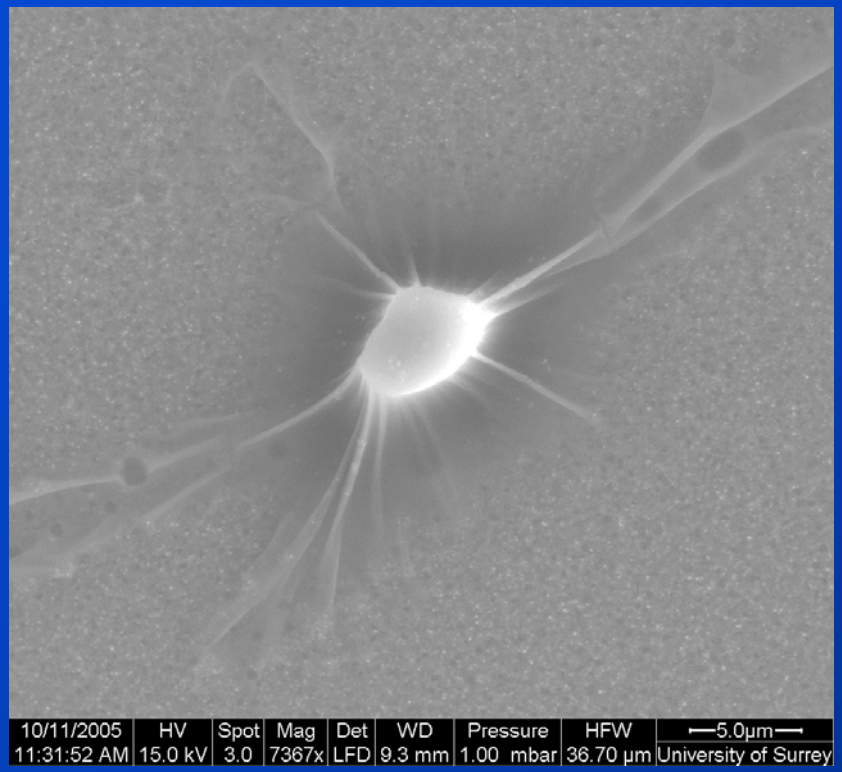


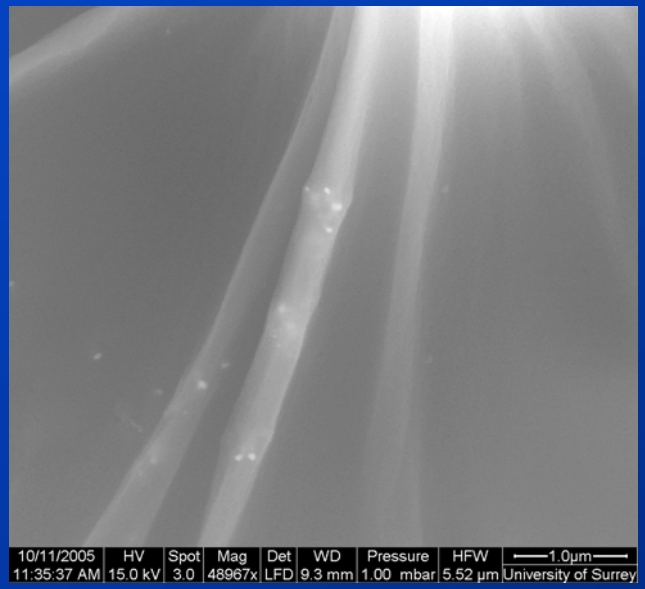
Primeros resultados

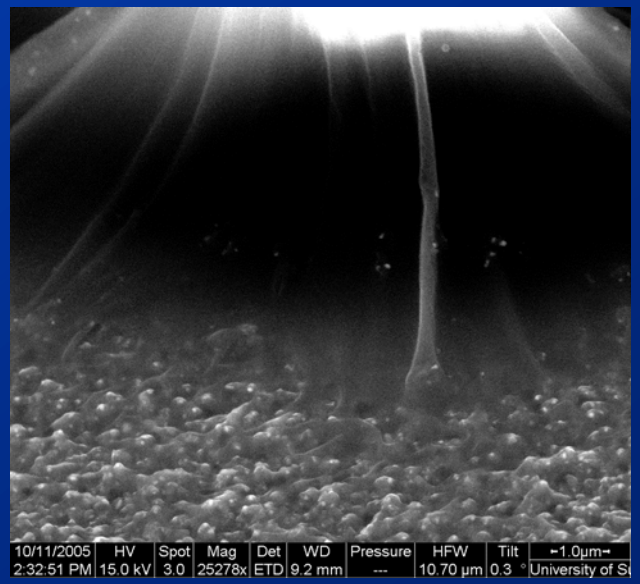


Toxicidad de nanomateriales

Are CNT biocompatible??







Resumen

- Se ha estudiado crecimiento y fabricación de dispositivos basados en CNTs.
- La funcionalización de la superficie de los CNTs permite la detección de moléculas predeterminadas.
- Los sensores basados en nanotubos de carbono tienen sensibilidad suficiente para su aplicación clínica.

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Más información

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