

Materiali ibridi: l'incontro tra cellule e materiali nanostrutturati



Huck



Cos'è un materiale ibrido?

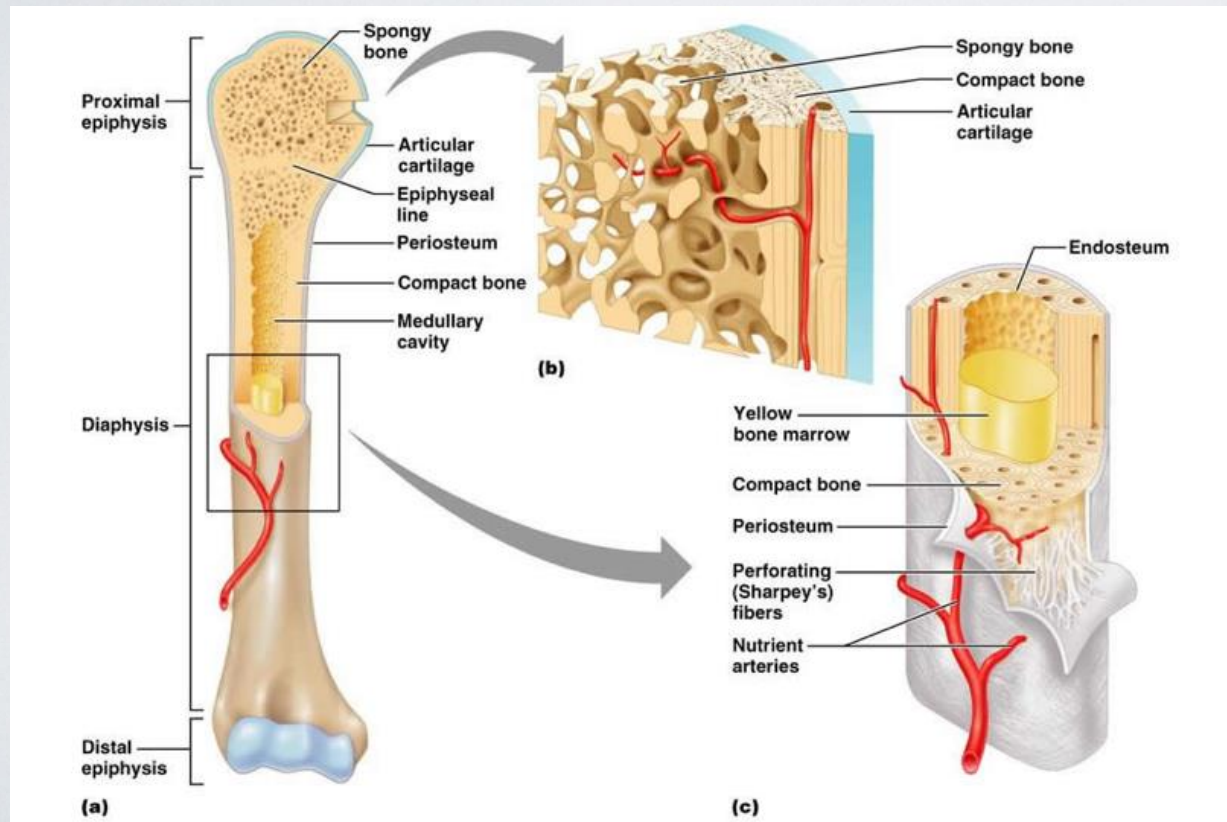
I materiali ibridi organico/inorganico sono caratterizzati dall'intima interazione (su scala nanometrica o molecolare) di una fase organica e di una fase inorganica. Le proprietà finali dipendono fortemente dalle interazioni che si instaurano tra le due fasi.

Il materiale ibrido presenta **proprietà nuove** che non esistono nei componenti singoli. In questo l'ibrido si distingue da un materiale composito.

Materiali ibridi in natura

La parte inorganica fornisce la resistenza meccanica e la struttura globale dell'organo/tessuto mentre la parte organica fa da ligando tra parte inorganica e parte cellulare del tessuto.

Un esempio tipico sono le ossa.



Parte organica:
collagene, osseina,
glicoproteine

Parte minerale:
Idrossiapatite, carbonato di
calcio, etc..

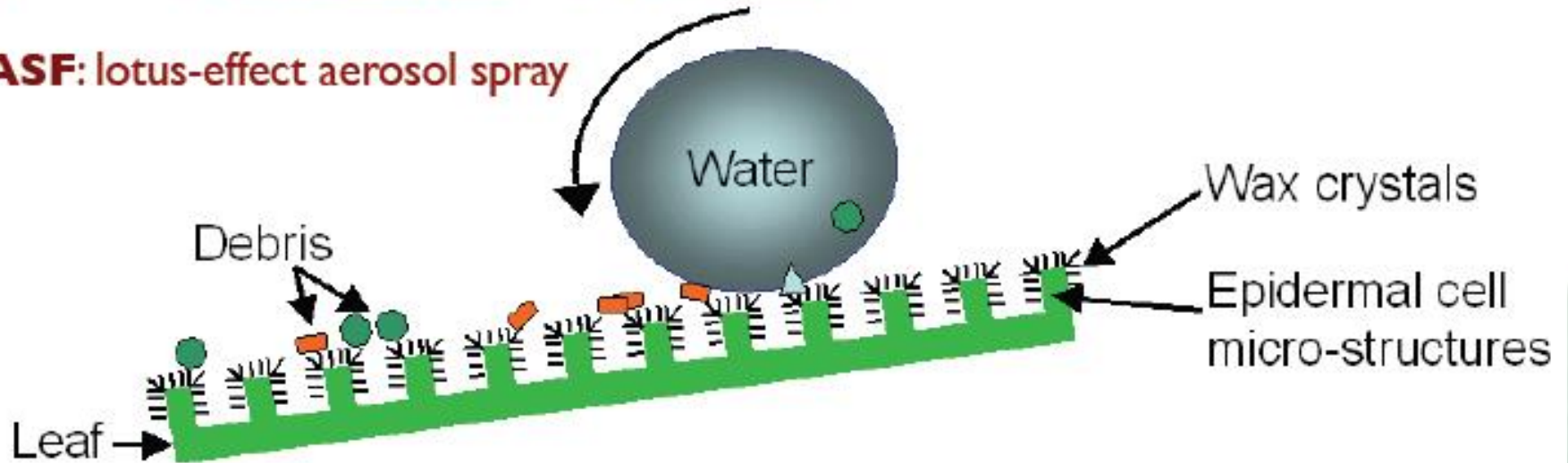
Parte cellulare (attiva!):
Osteoblasti, osteoclasti che
rinnovano costantemente la
parte minerale (utilizzando
collagene), piu' osteociti e
midollo osseo.

Esempi di Nanocompositi



Nature teaches...
nanotechnology learns!

BASF: lotus-effect aerosol spray



Esempi di Nanocompositi

beetle



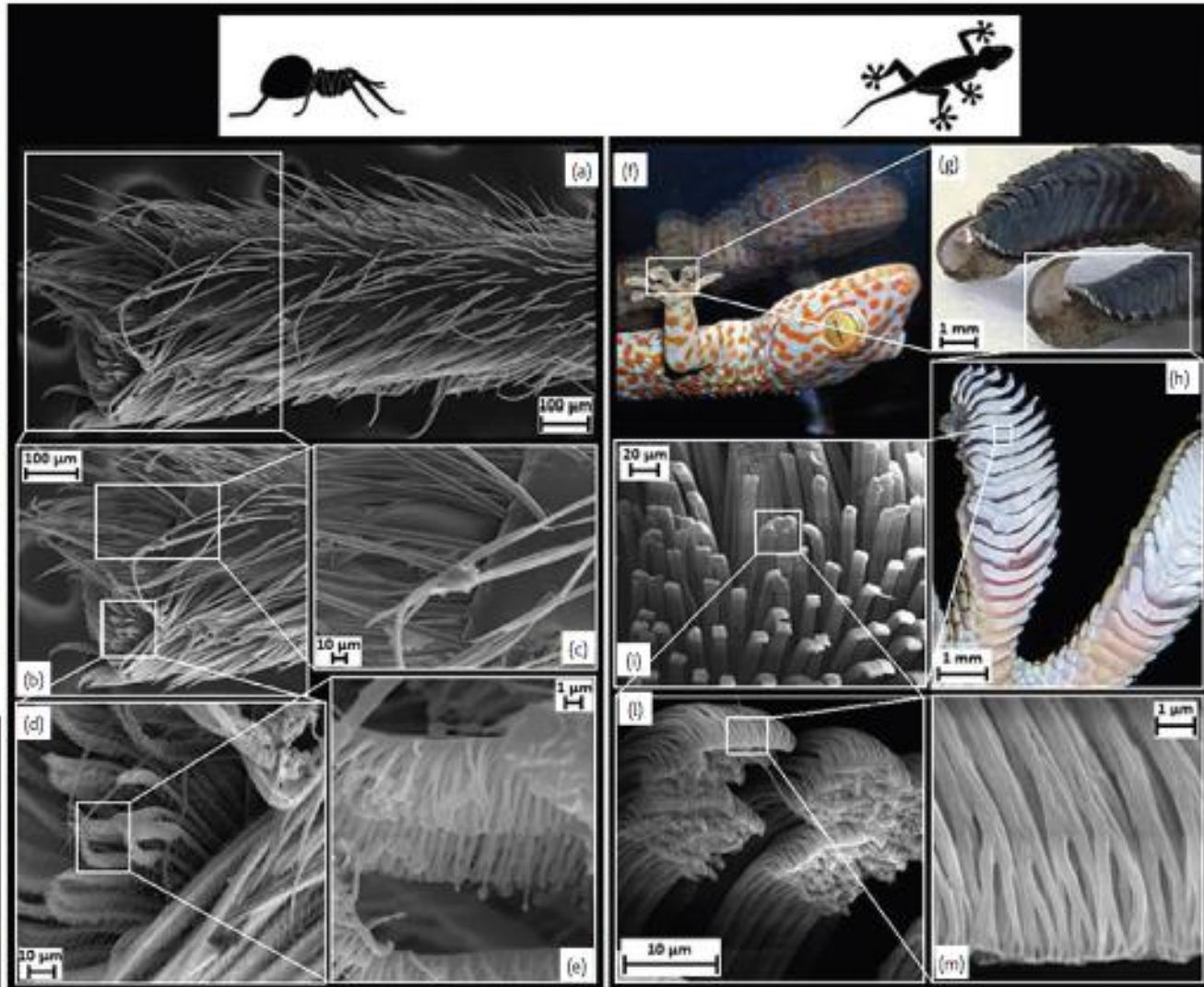
fly



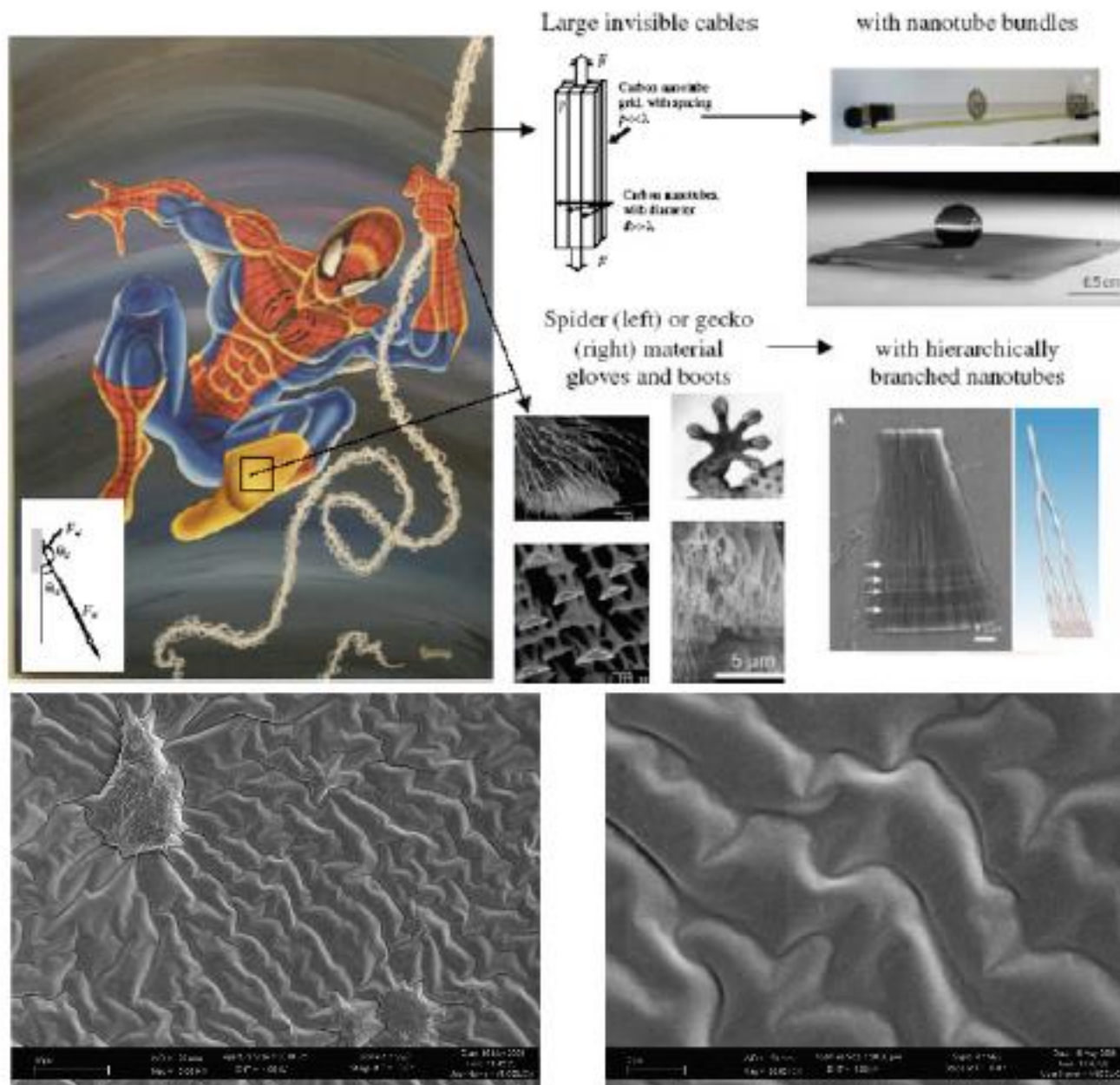
spider



gecko



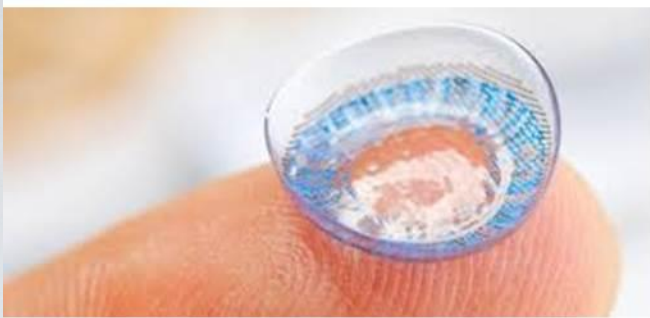
Esempi di Nanocompositi



Esempi di Nanocompositi



Tissue engineering: protesi “meccaniche”



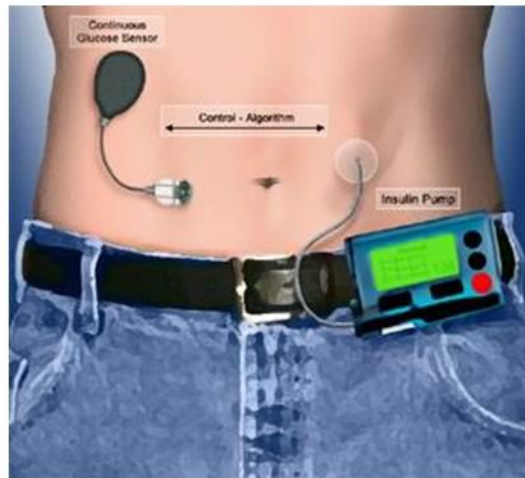
Lente a contatto



Pacemaker



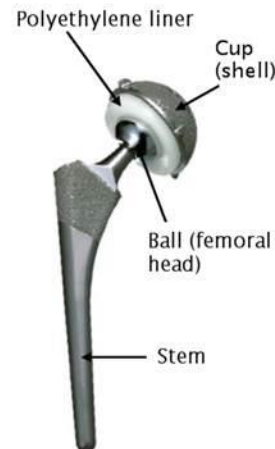
Hemopump
(artificial heart)



Insulin infusion devices
(artificial pancreas)

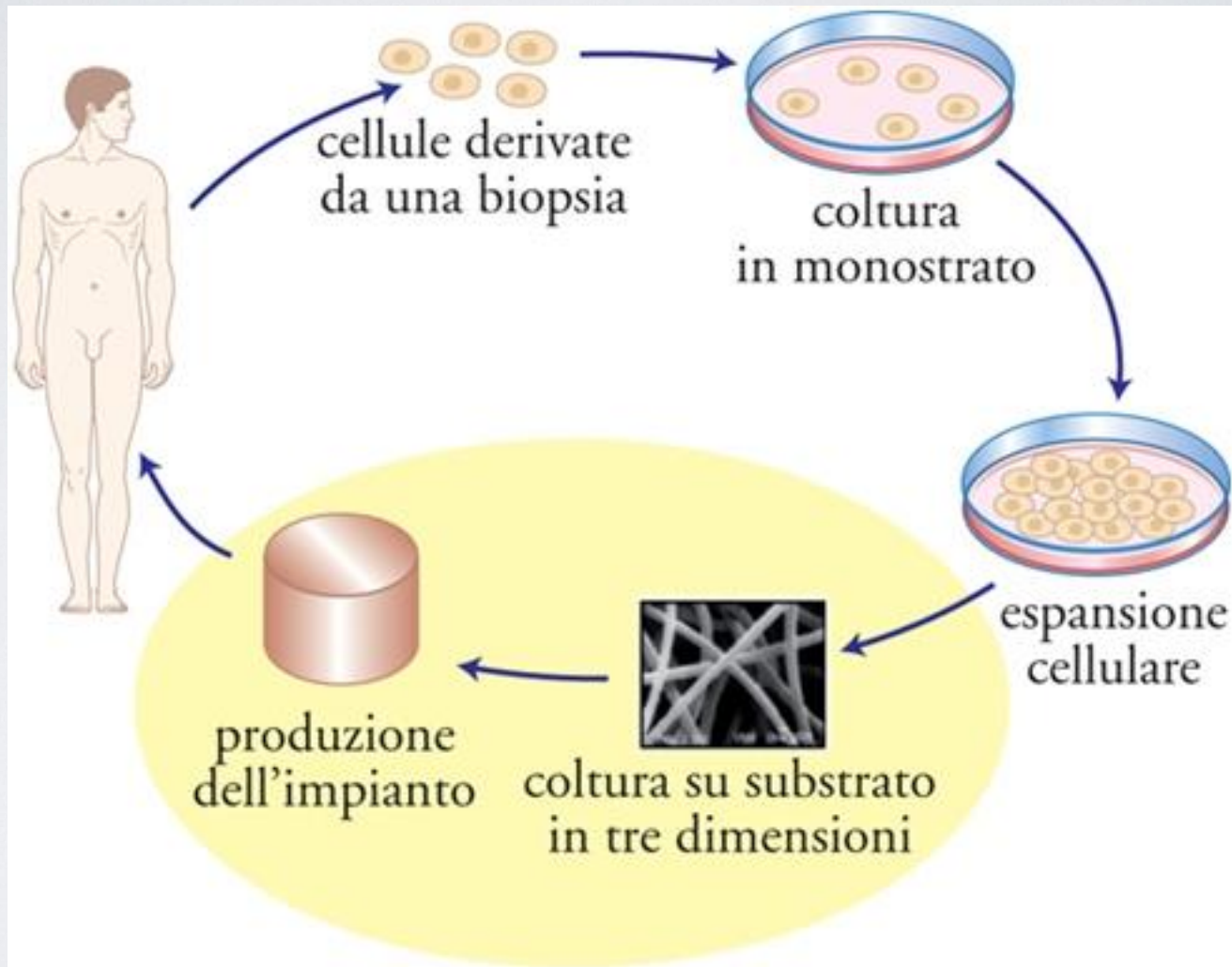


Artificial joint
(hip)

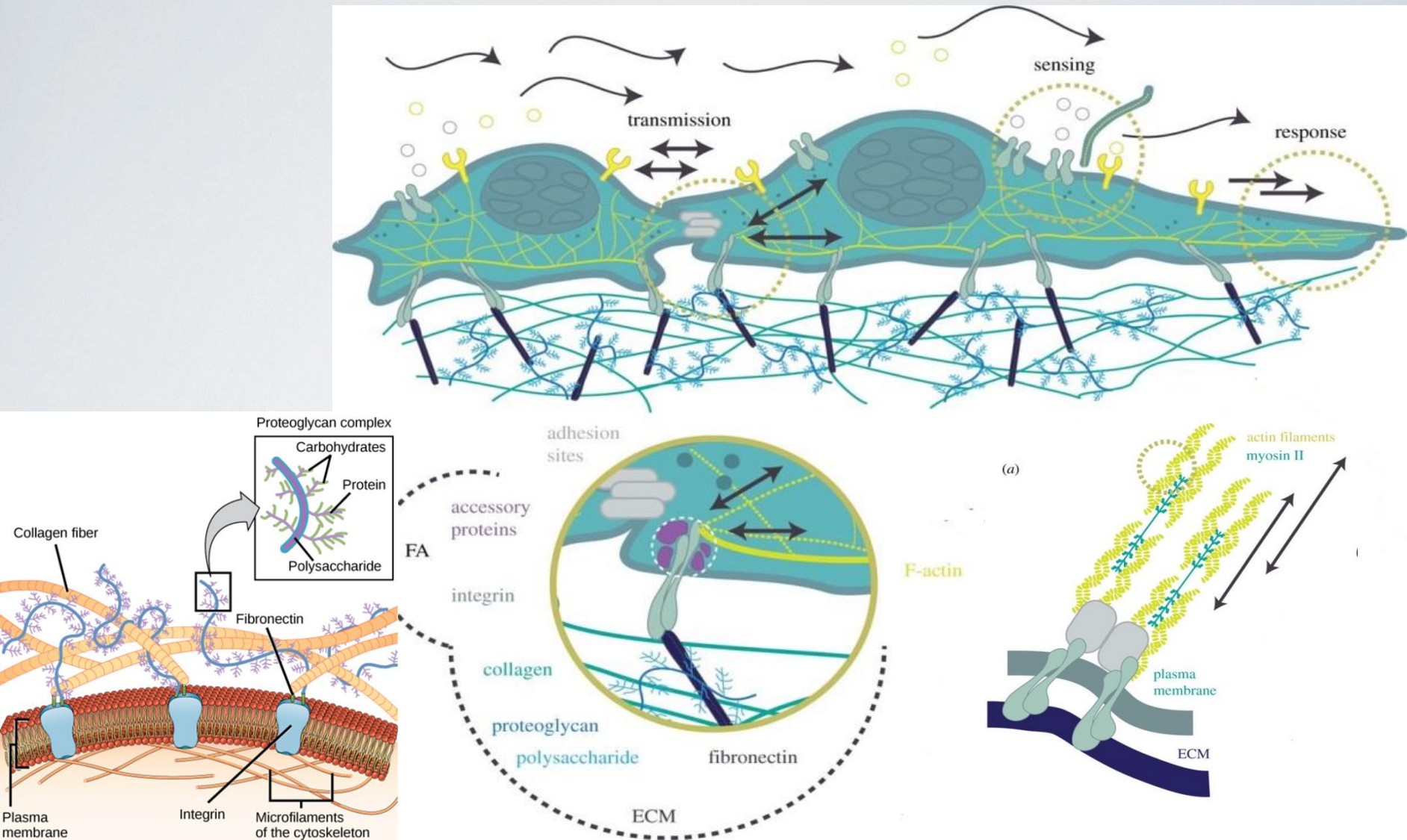


Artificial arm and hand

Tissue engineering: rigenerazione di organi/tessuti



Perché ci servono le nanotecnologie?



Mechanical cues:

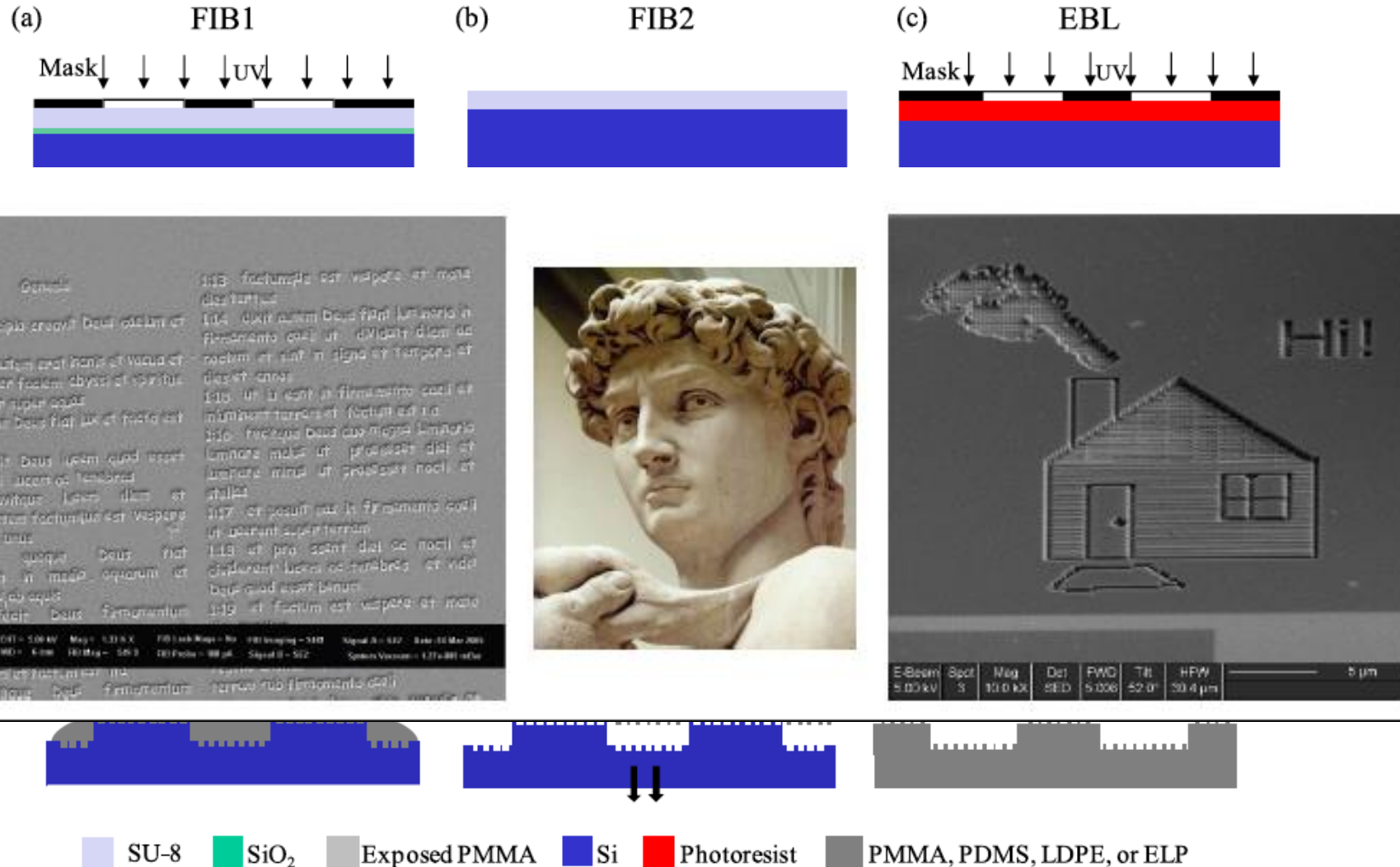
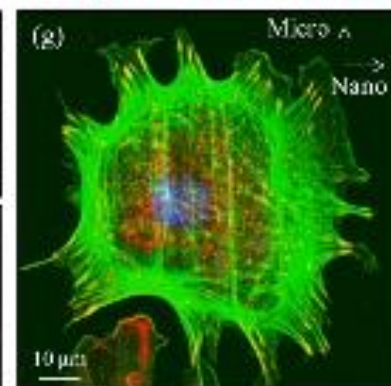
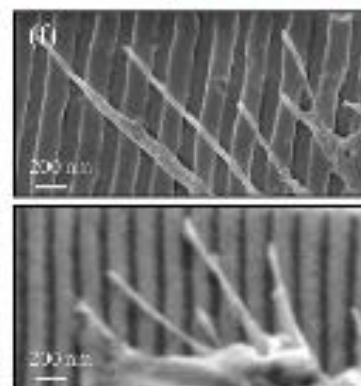
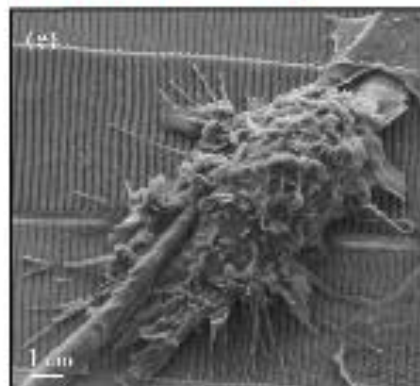
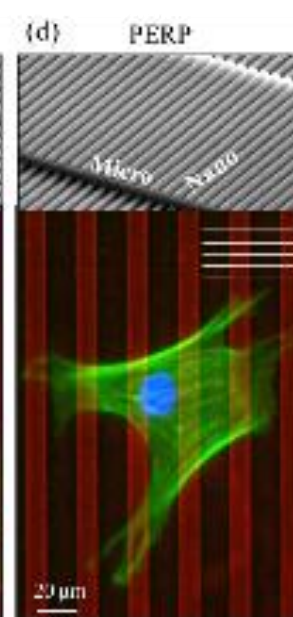
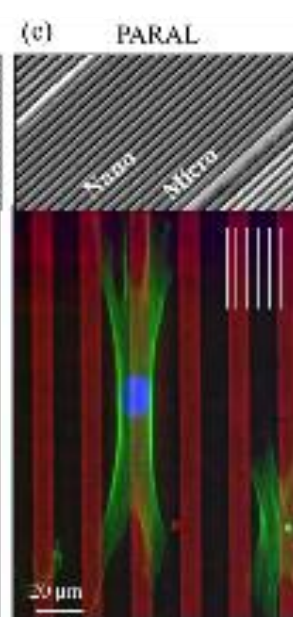
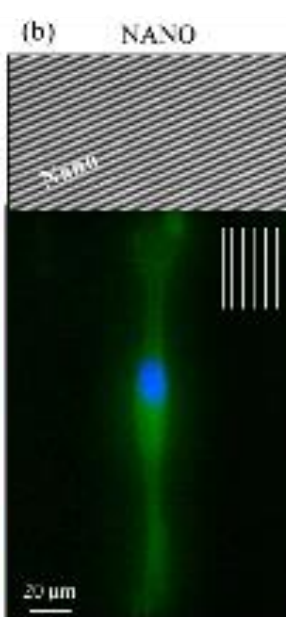
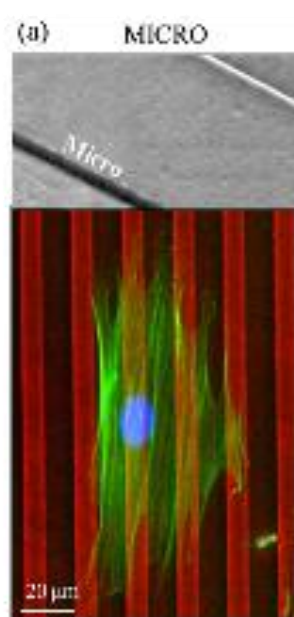
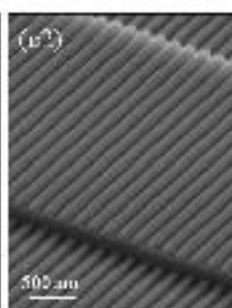
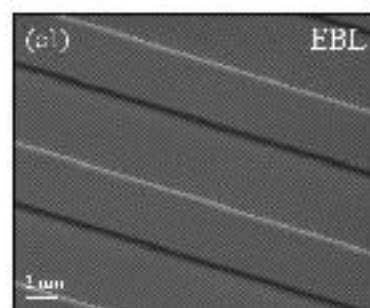
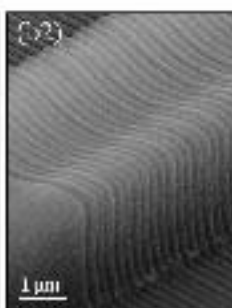
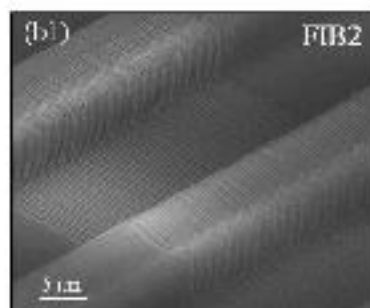
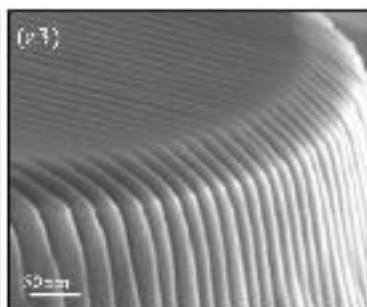
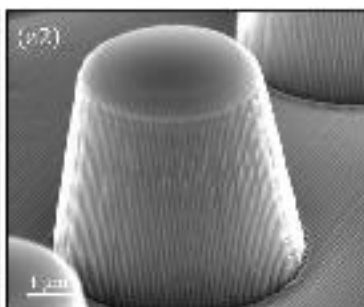
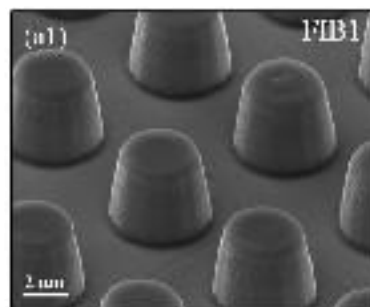
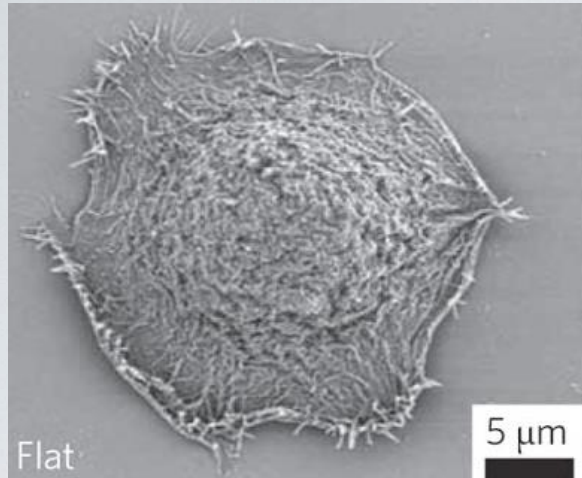


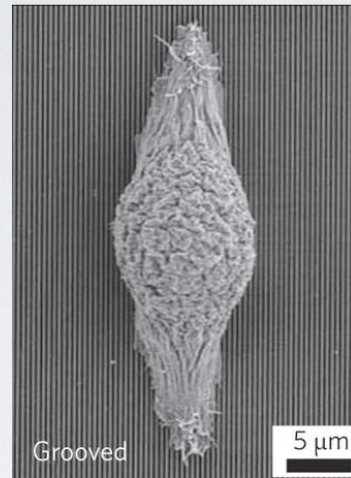
Figure 1. Fabrication processes for development of the hierarchical surface topographies including (a) FIB1, (b) FIB2, (c) EBL, and (d) the soft lithography technique used for transferring the patterns onto biocompatible polymers.



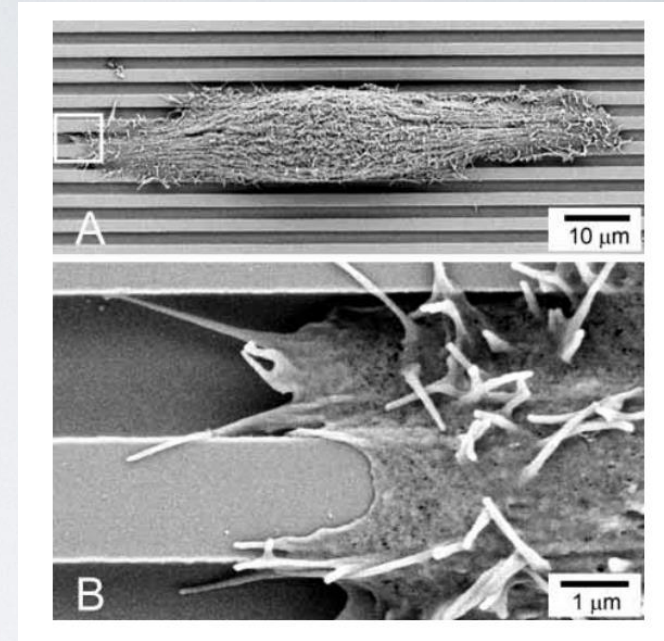
Epithelial contact guidance on well-defined micro- and nanostructured substrates



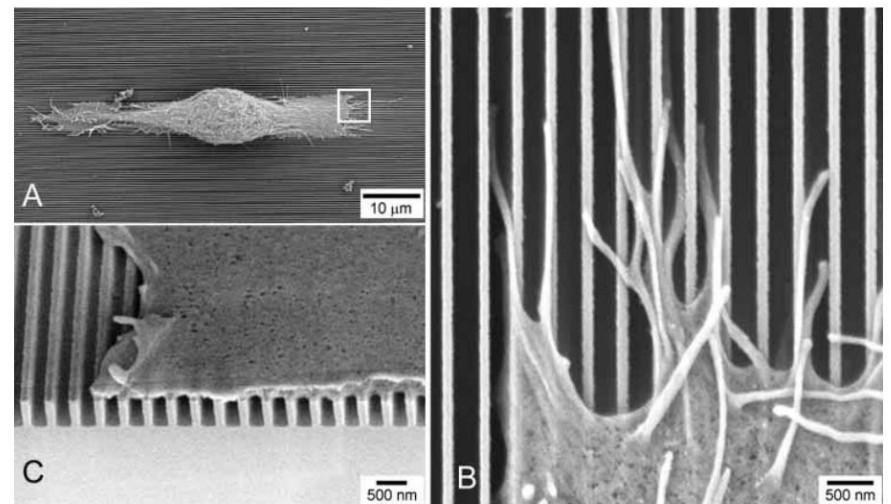
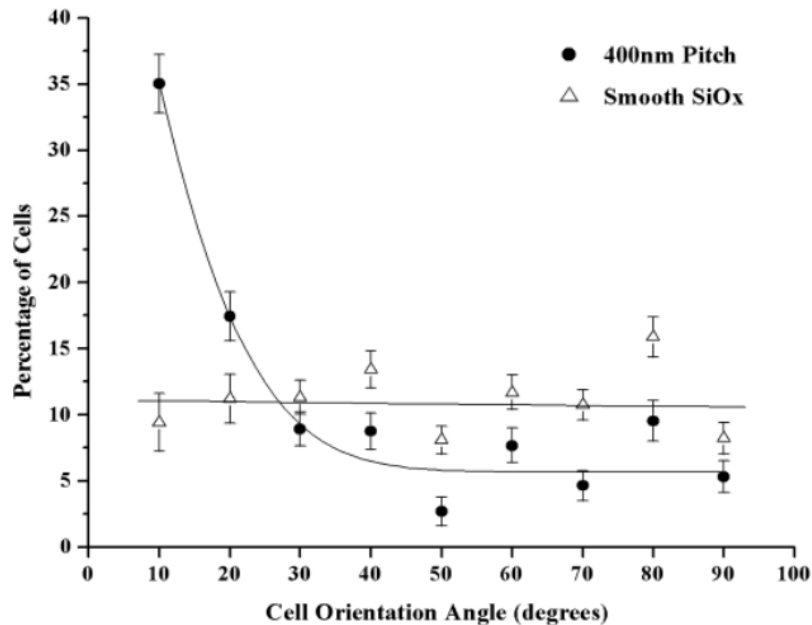
Flat topography



Grooved topography



400 nm pitch (70 nm ridge 330 nm groove) 600 nm depth



Different types of synthetic nanostructured surfaces

Nanostructured surface

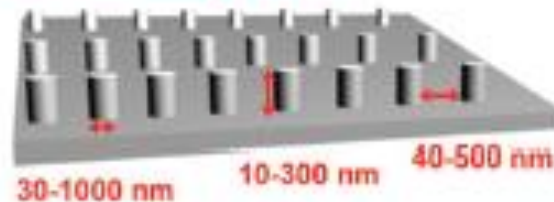
Cell behaviour trends

A - Nanogratings



- Cell alignment, elongation and migration parallel to the nanogratings.
- Increased cell migration speeds.

B - Nanoposts



- Cell morphology effects are more subtle in comparison to nanogratings.
- Small nanopost heights promote adhesion, whilst taller nanoposts produce a significant reduction in adhesion.

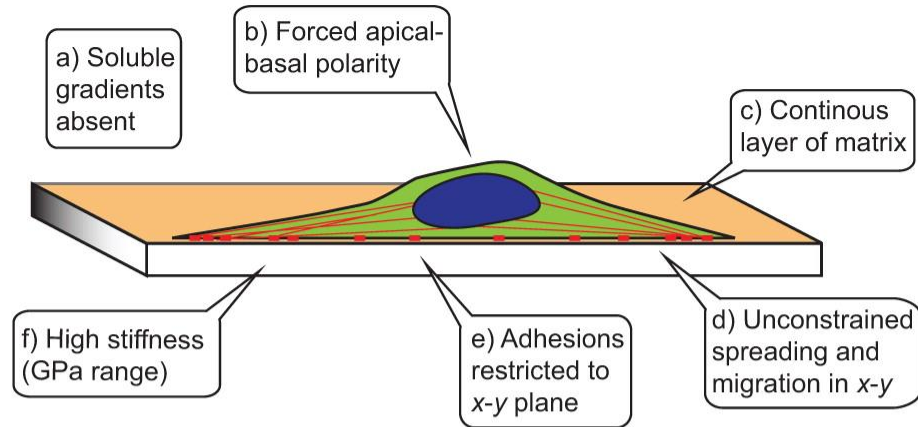
C - Nanopits



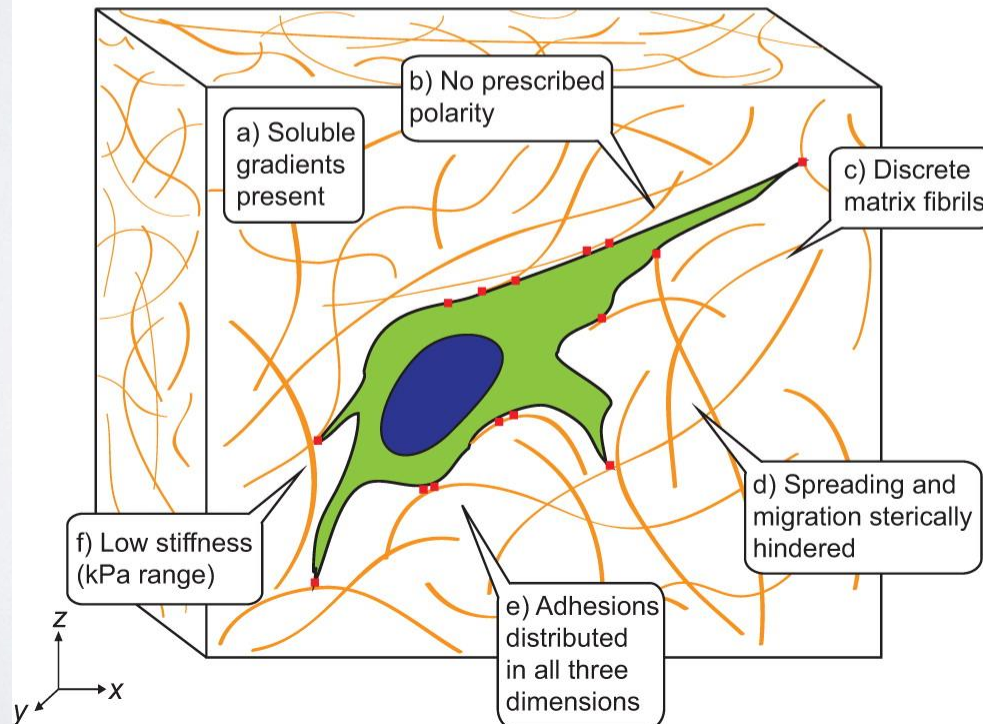
- Indications exist that shallow nanopits induce greater cell spreading and adhesion than deeper nanopits or flat surfaces.
- Pit symmetry has been shown to influence cell adhesion.

Perche' la terza dimensione e' cosi' importante?

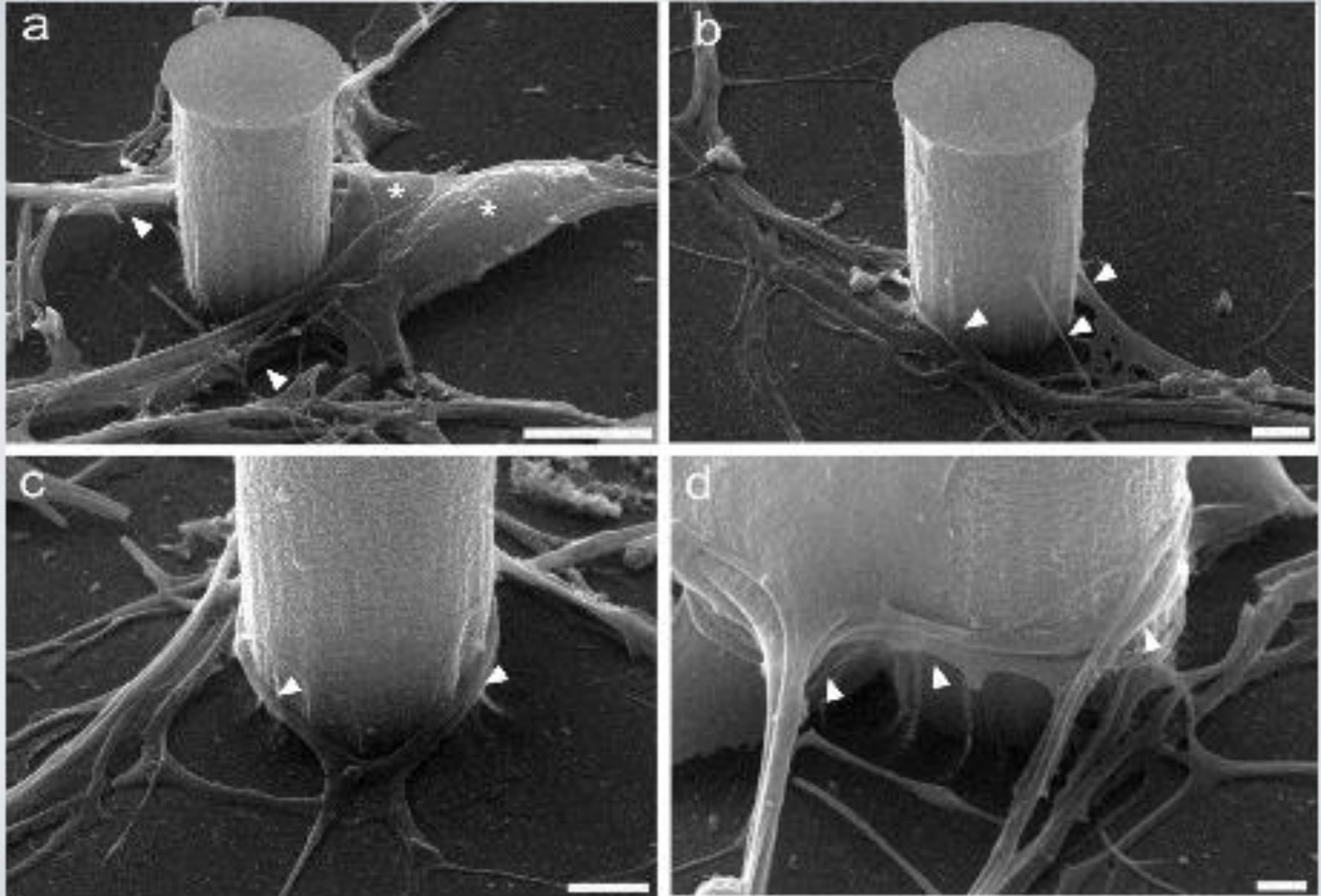
Collagen-coated glass (2D)



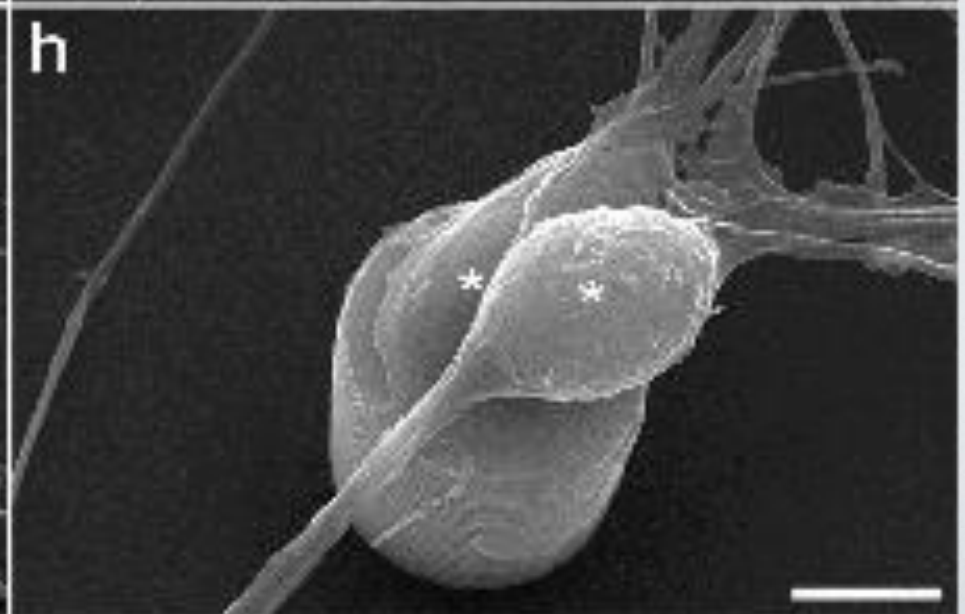
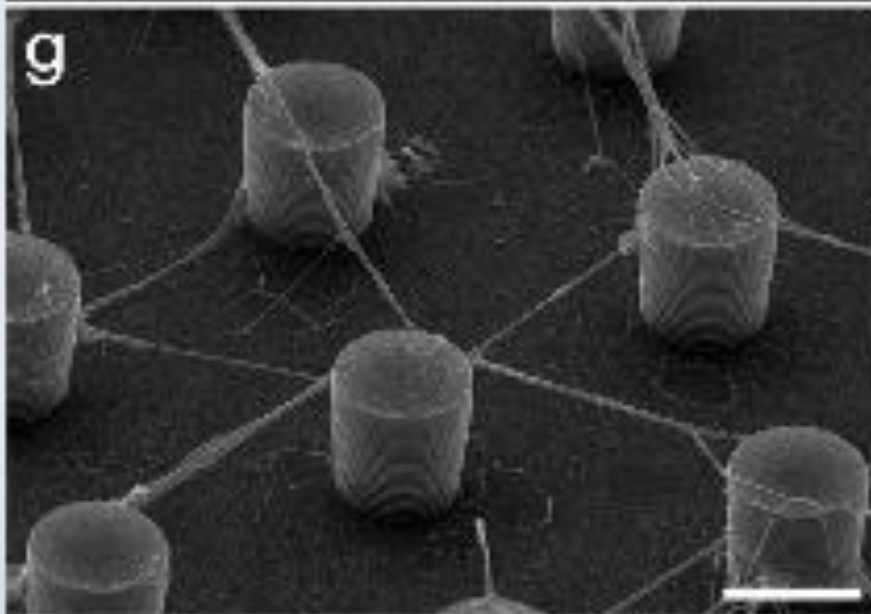
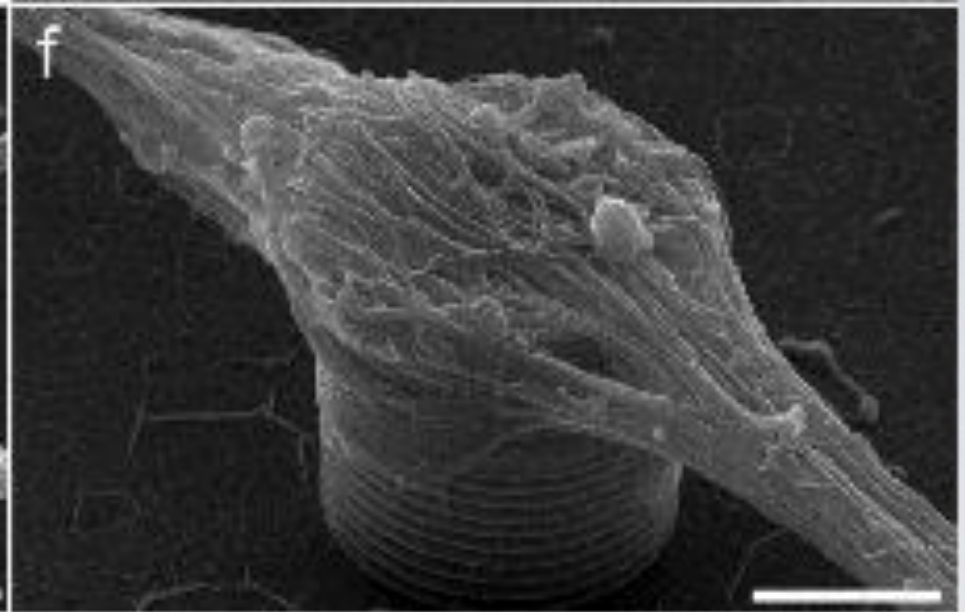
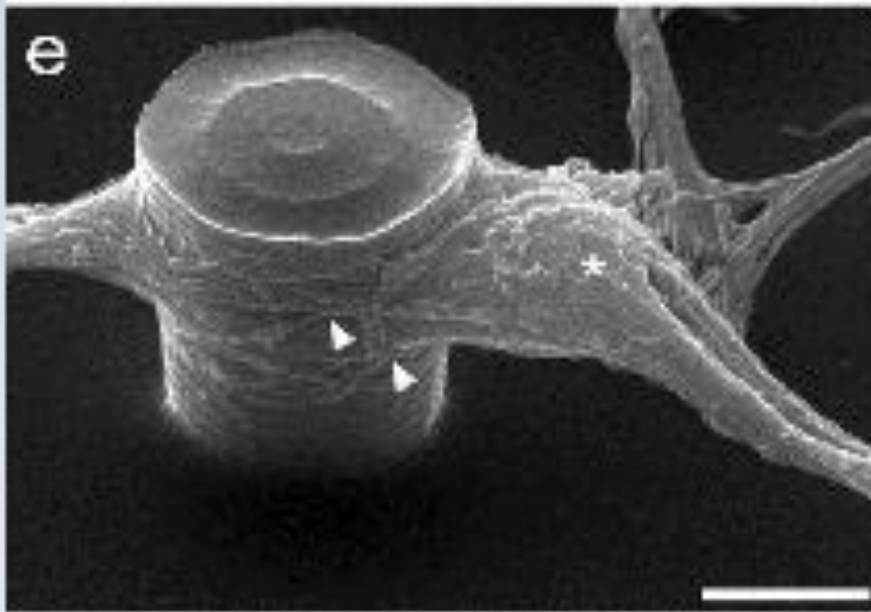
Collagen gel (3D)



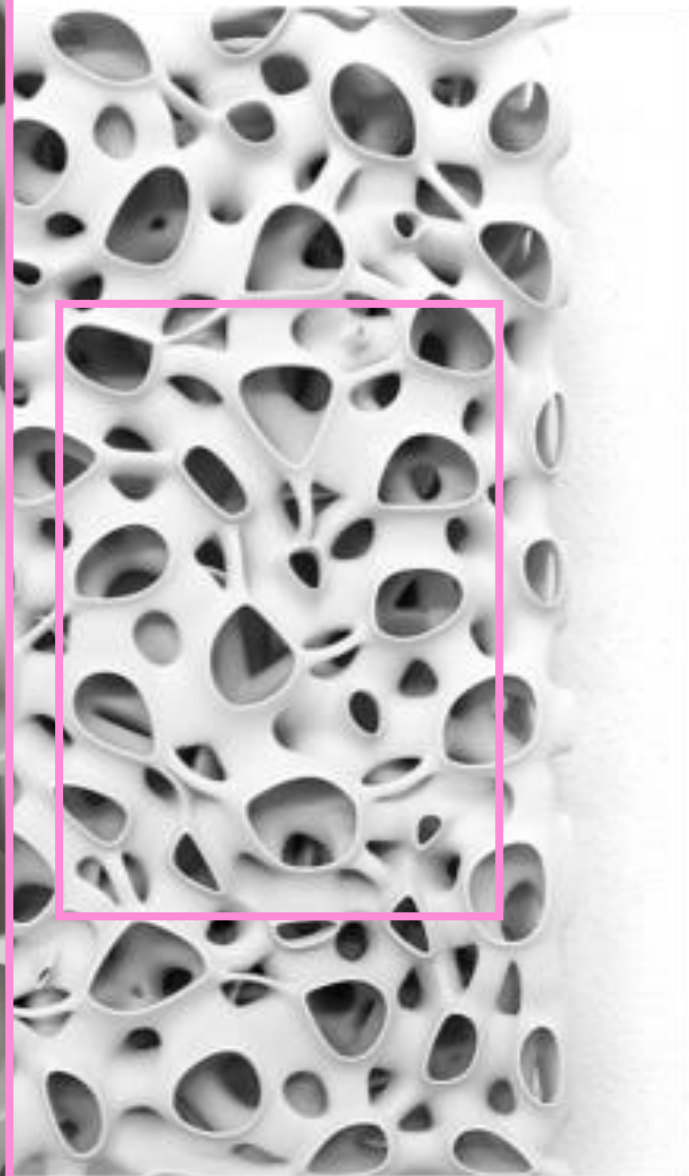
Scanning electron micrographs of neurons drop-plated on superhydrophobic smooth pillared substrate



...and on a nanostructured pillared substrates.

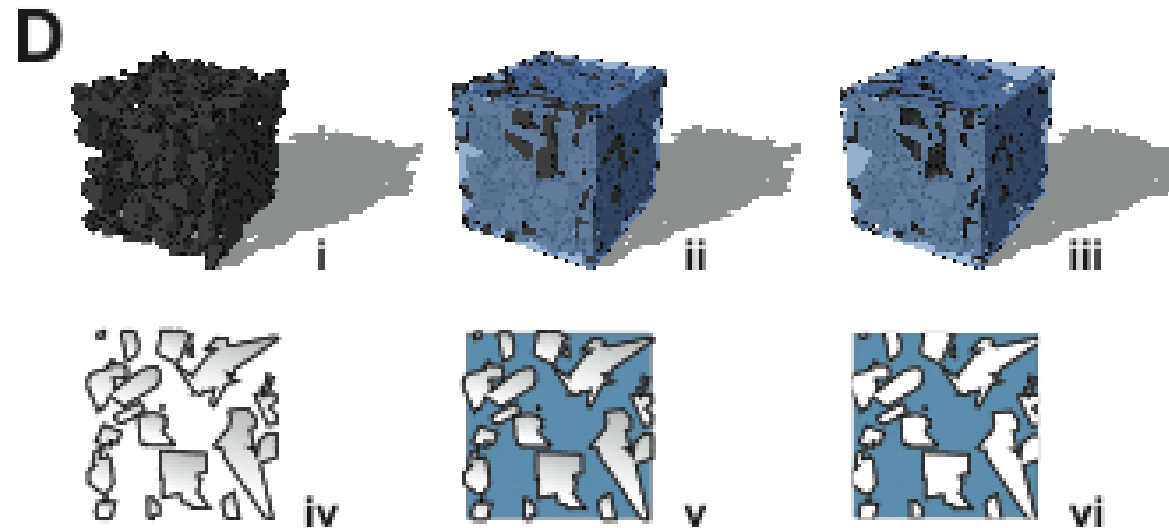
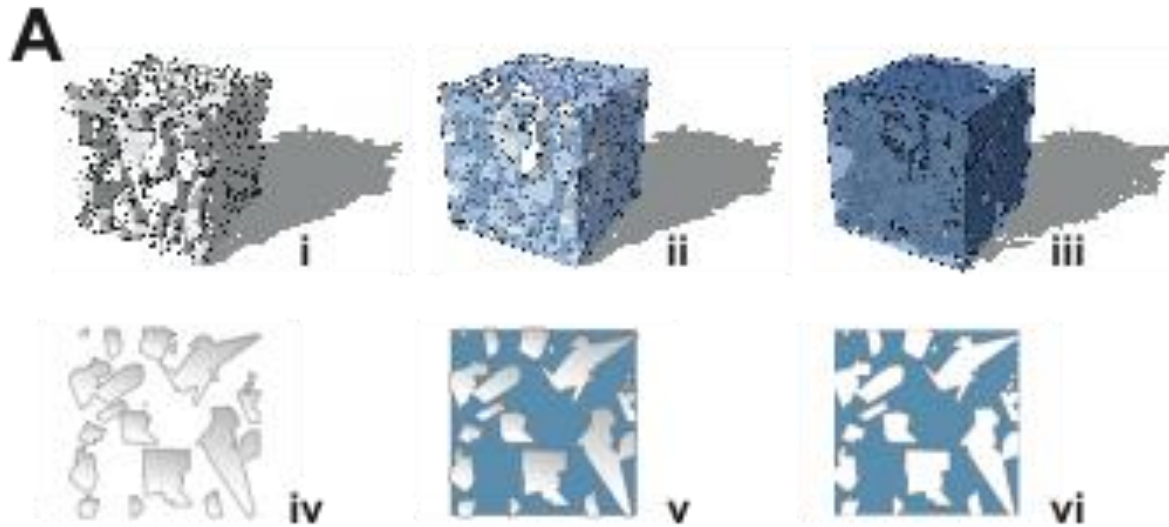


What about 3D?



Hybrid organic/inorganic cellular materials:
PDMS based synthetic scaffold (with and without CNTs)

MWCNTs (active) PDMS (control)



Materiali innovativi per I nostri ibridi: I Nanotubi di Carbonio (CNT)

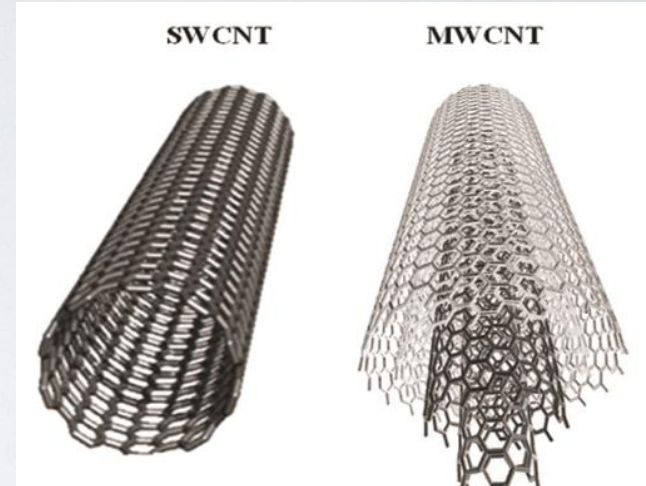
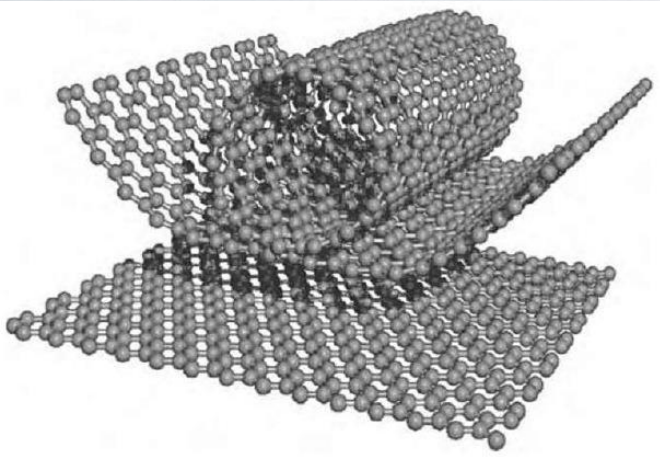
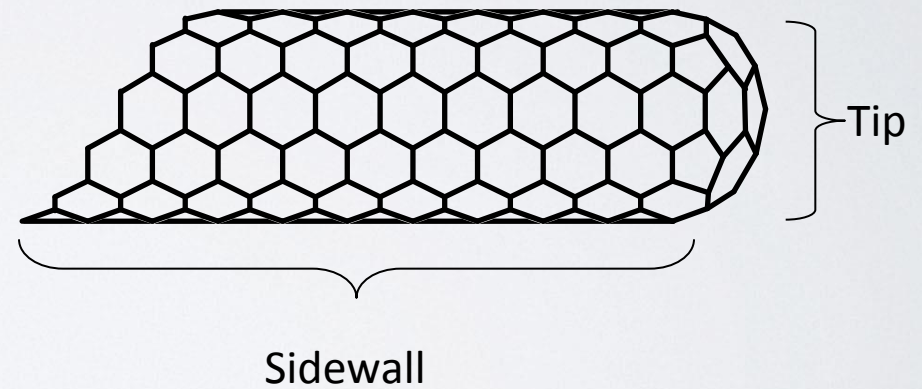
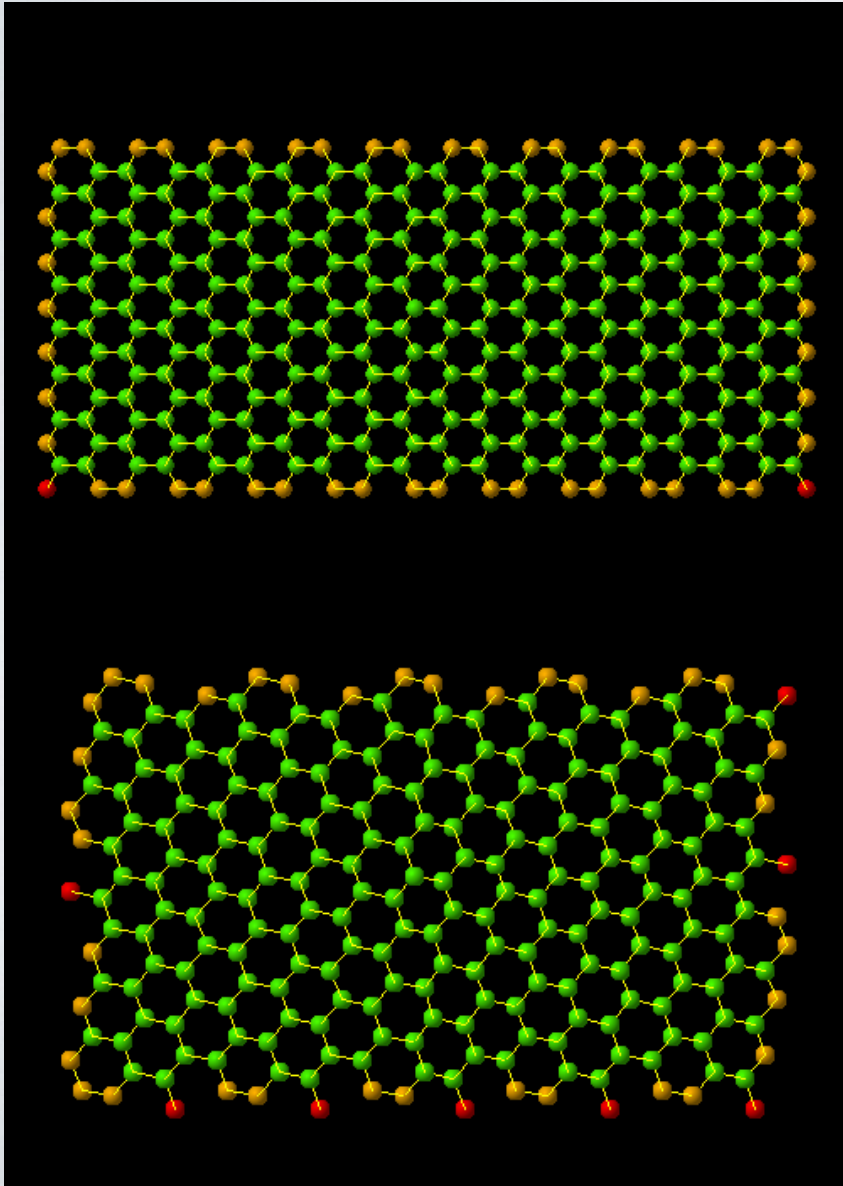


Table 1: Theoretical and experimental properties of CNTs (Xie et al., 2005)

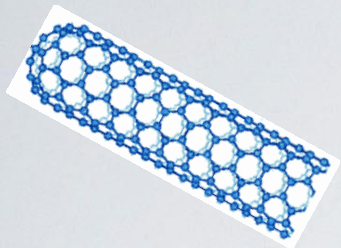
Properties	SWCNTs	MWCNTs
Specific Gravity	0.8 g/cm ³	1.8 g/cm ³
Elastic Modulus	~1 TPa	~0.3 – 1 TPa
Strength	50 – 500 GPa	10 – 60 GPa
Resistivity	5 – 50 $\mu\Omega$ cm	5 – 50 $\mu\Omega$ cm
Thermal Conductivity	3000 W m ⁻¹ K ⁻¹	3000 W m ⁻¹ K ⁻¹
Thermal Stability	>700 °C (in air); 2800°C (in vacuum)	>700 °C (in air); 2800°C (in vacuum)
Specific Surface Area	~400-900 m ² /g	~200 – 400 m ² /g

Dimensions comparable to fibril ECM constituents, excellent electronic and mechanical properties make CNTs potential candidates for nano-biomedical applications.

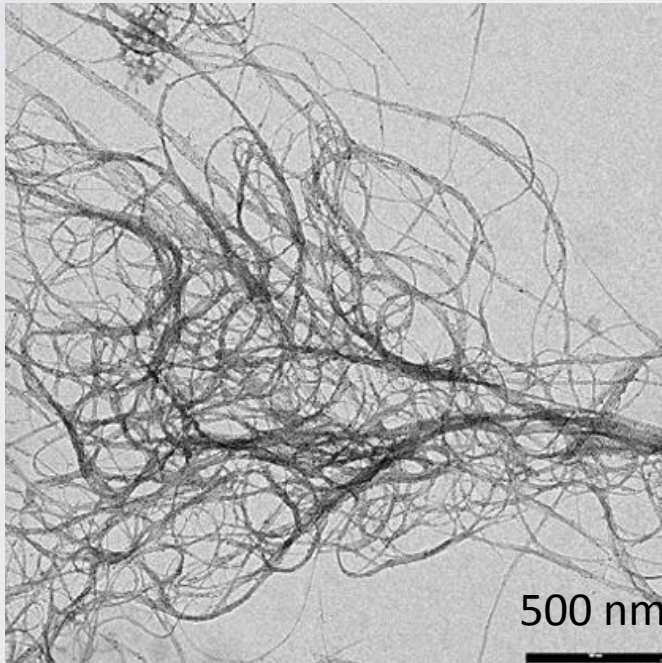
Materiali innovativi per I nostri ibridi: I Nanotubi di Carbonio (CNT)



NANOTUBI DI CARBONIO (CNTS): COME SI PRESENTANO?

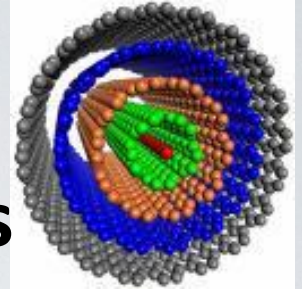


SWCNTs

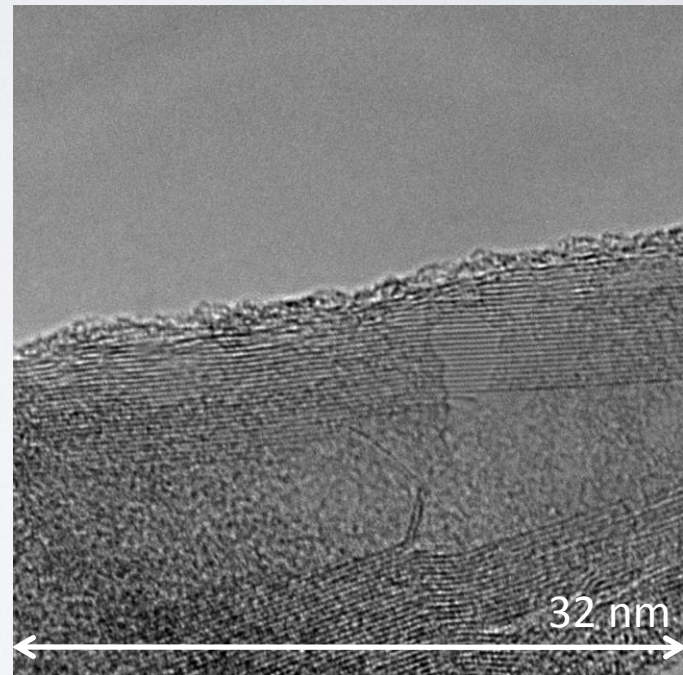


Cylinders of graphene rolled into tubes
(diameter 0.7-1.2 nm)

TEM



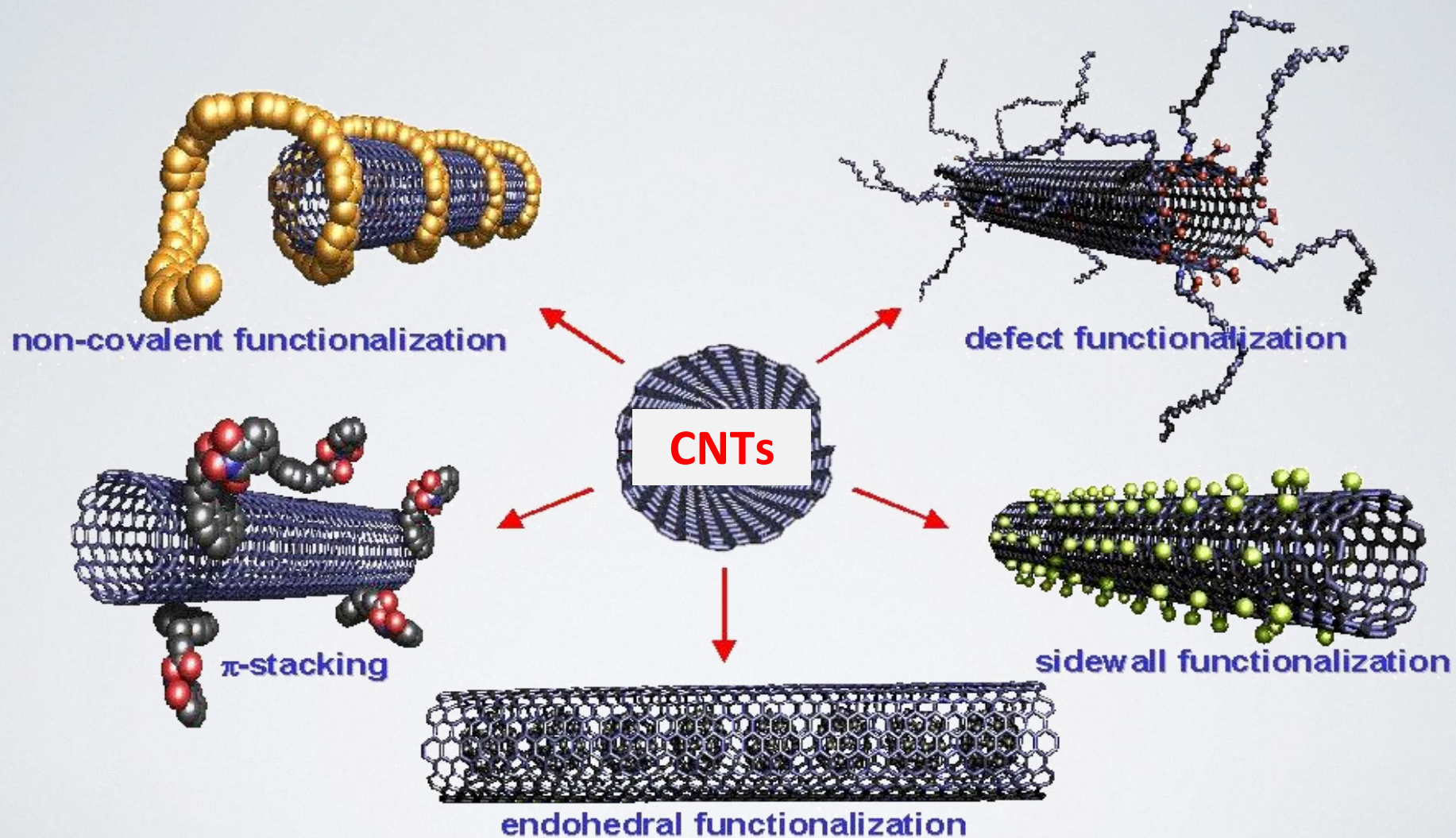
MWCNTs



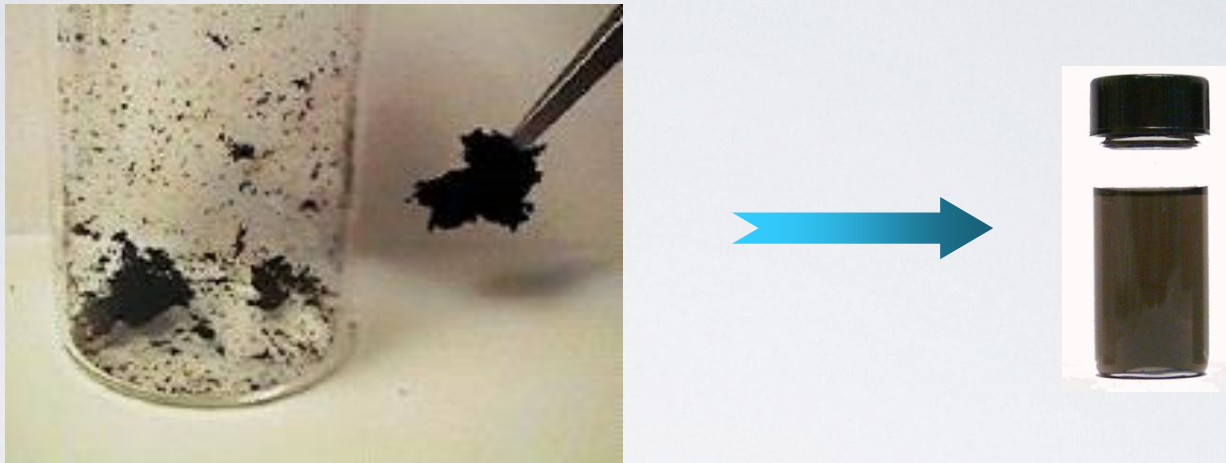
Concentric arrangement of numerous
cylinders (diameter up to 100 nm)

TEM

FUNZIONALIZZAZIONE DEI CNT

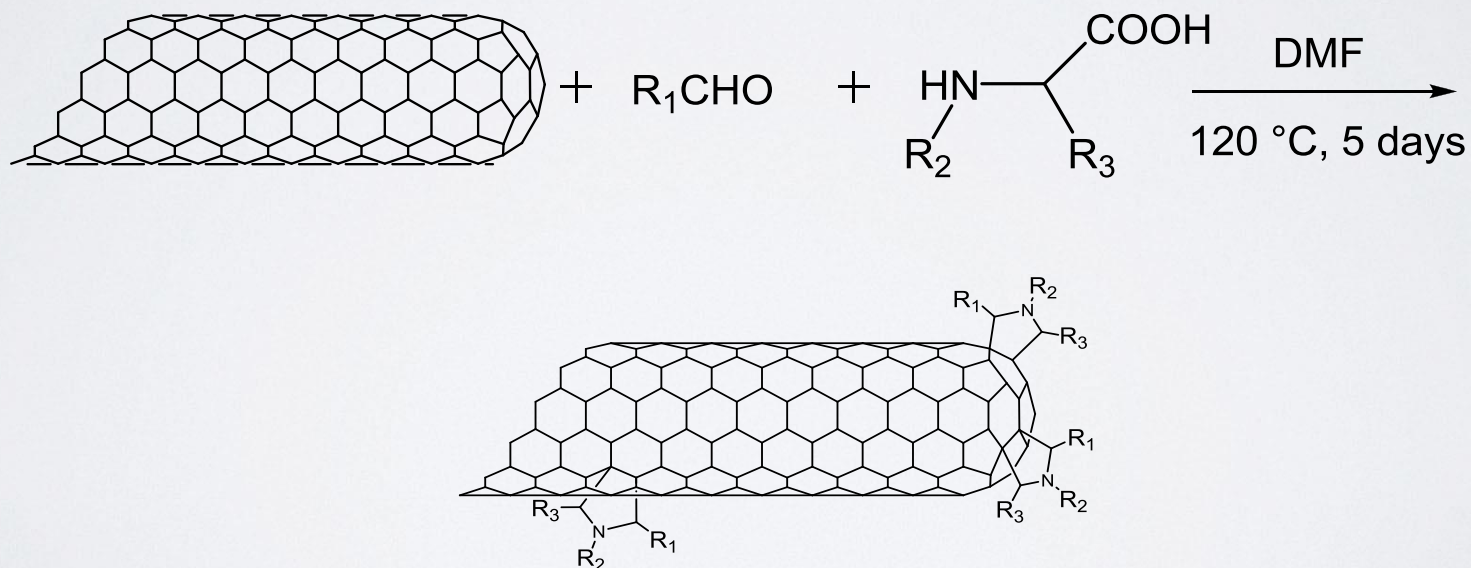


PERCHÉ FUNZIONALIZZARE I CNT?

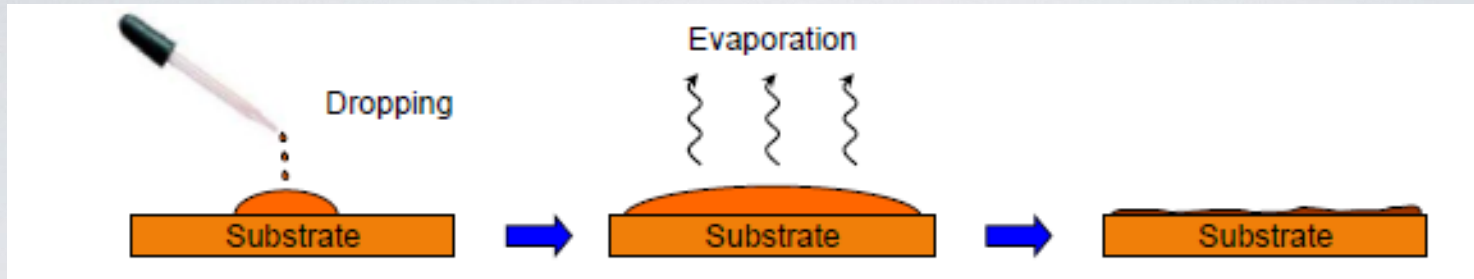


- Manipolazione più semplice
 - Studio delle proprietà dei CNTs in soluzione
- CNTs biocompatibili e integrazione nei sistemi viventi

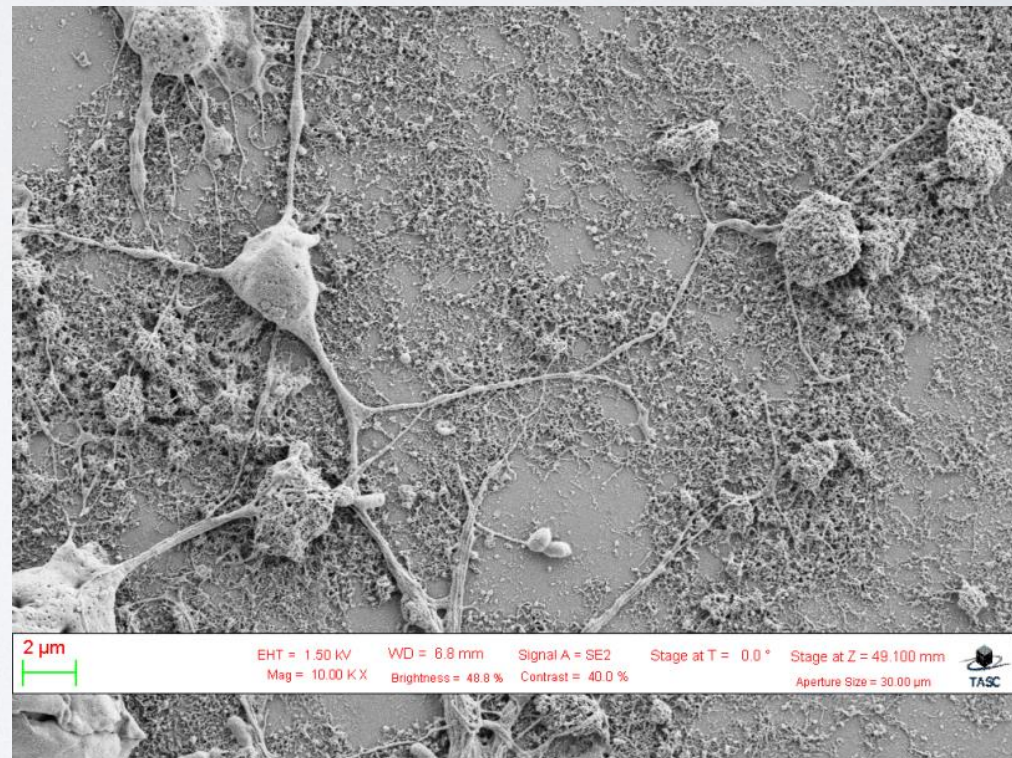
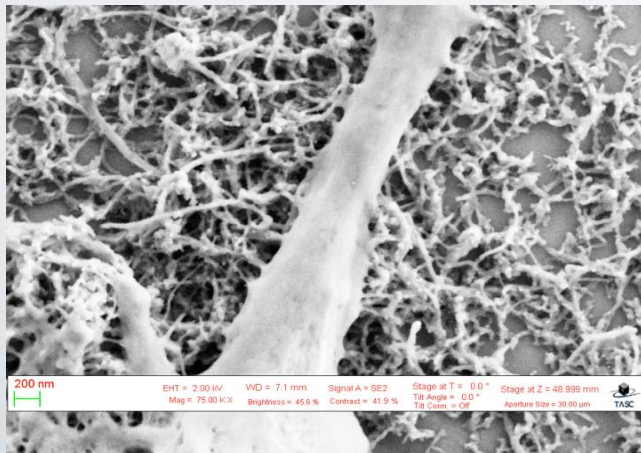
MWCNTs 20-30 nm



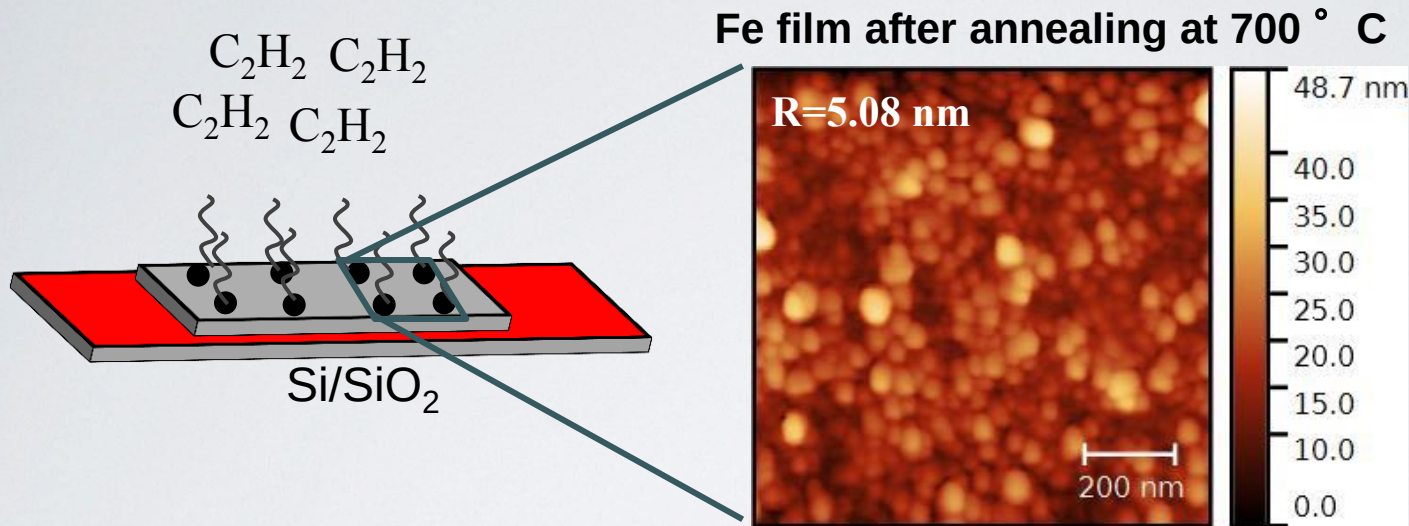
LIMITI DEL DROP CASTING



- ✓ Semplice
- ✓ Nessuno spreco di materiale
- ✗ Limitazioni nel ricoprimento di grandi superfici
- ✗ Spessori difficili da controllare
- ✗ Scarsa uniformità
- ✗ Scarsa adesione



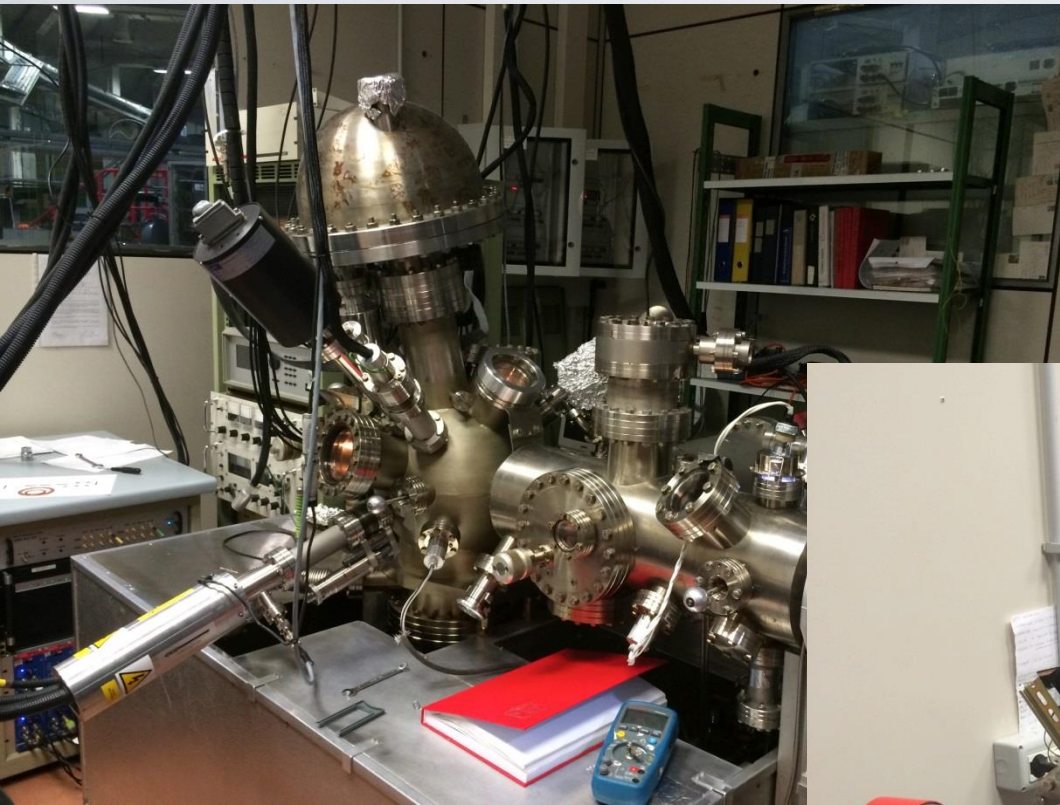
DEPOSIZIONE CHIMICA DA VAPORE CATALITICA (CCVD)



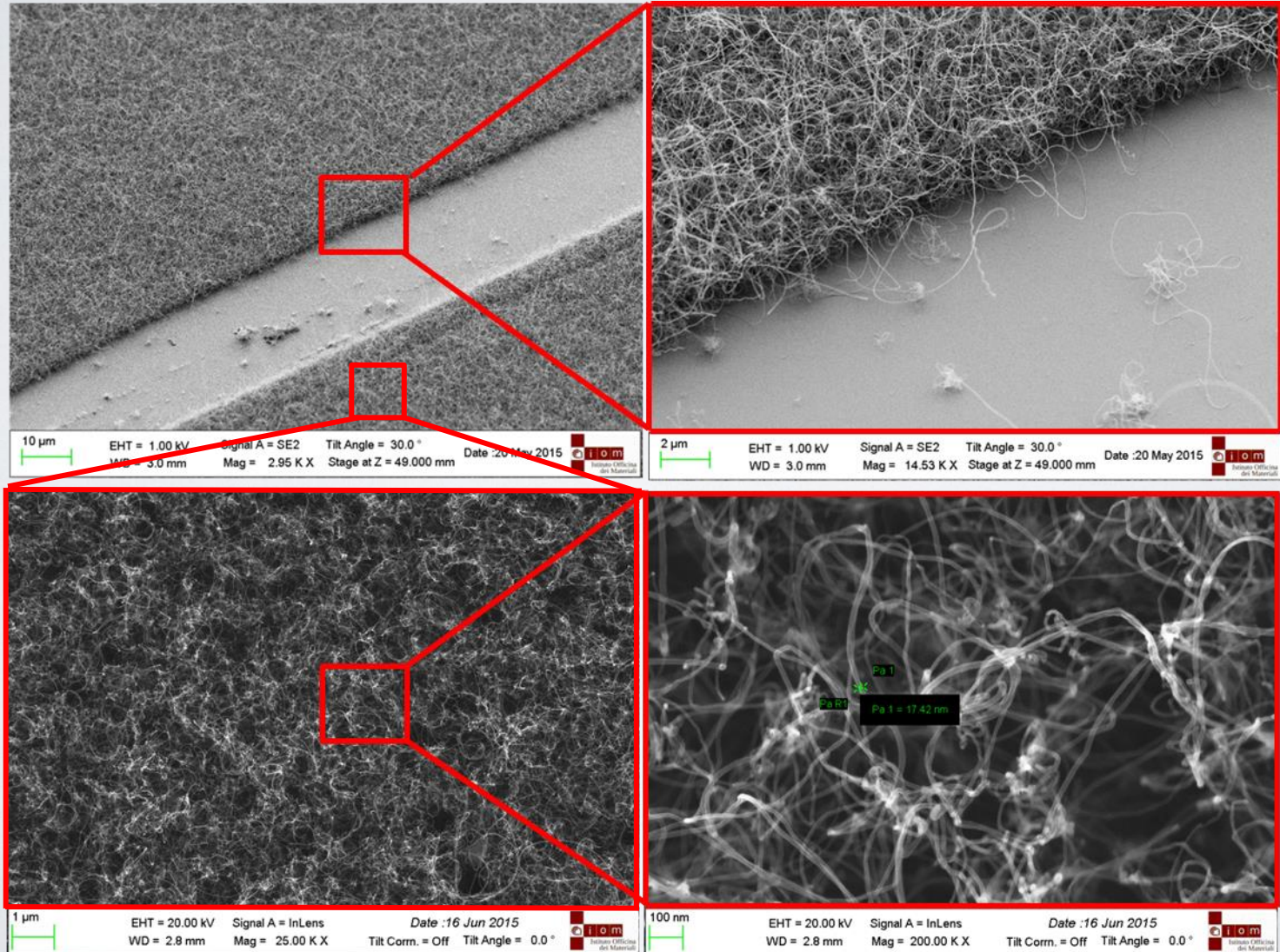
Il Ferro determina l'orientazione e le dimensioni dei CNTs.

- 1) Randomly oriented CNTs (RO-CNTs)
- 2) Vertically aligned CNTs (VA-CNTs)

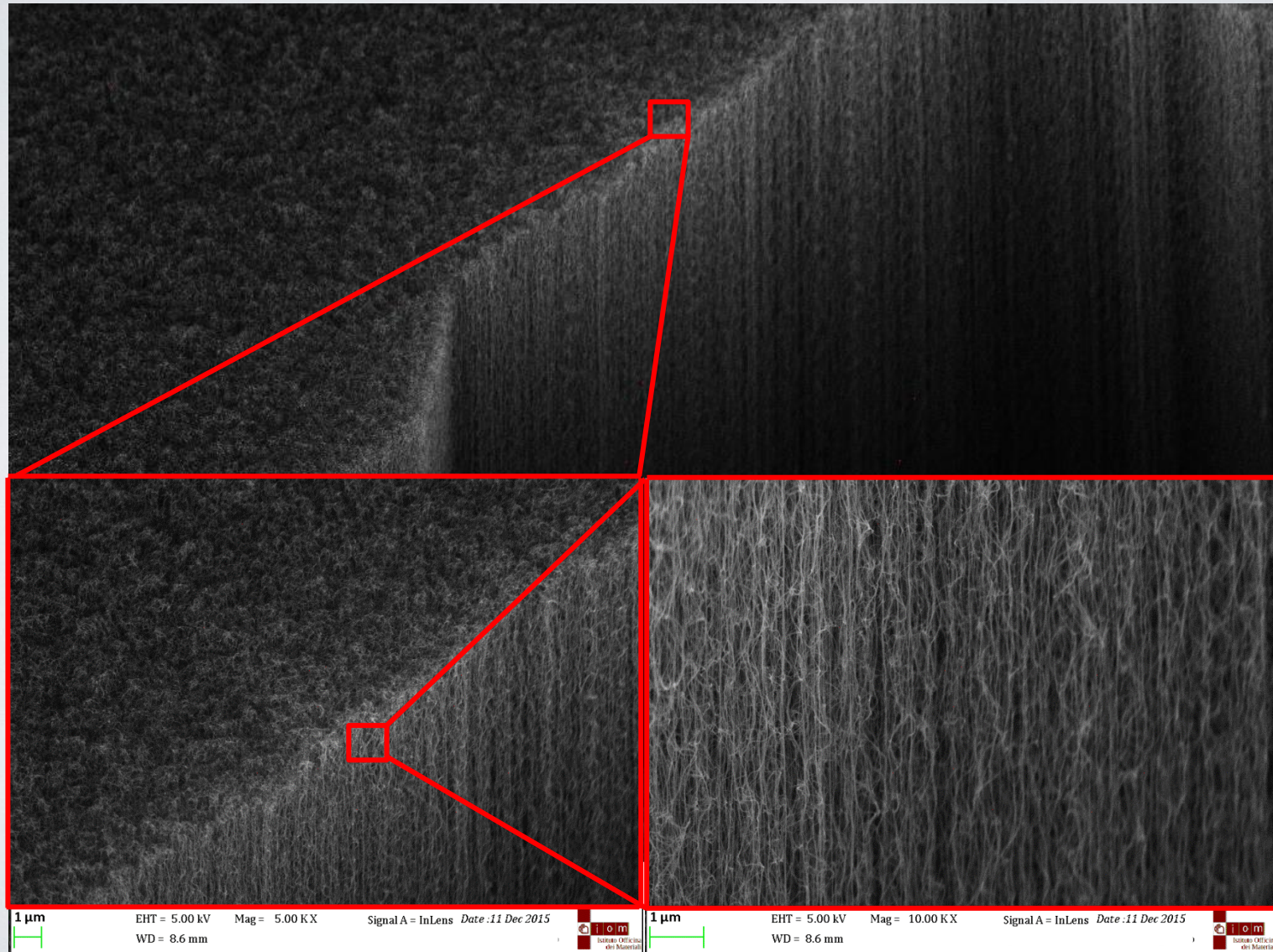
DEPOSIZIONE CHIMICA DA VAPORE CATALITICA (CCVD)



RO-CNTS: CARATTERIZZAZIONE SEM

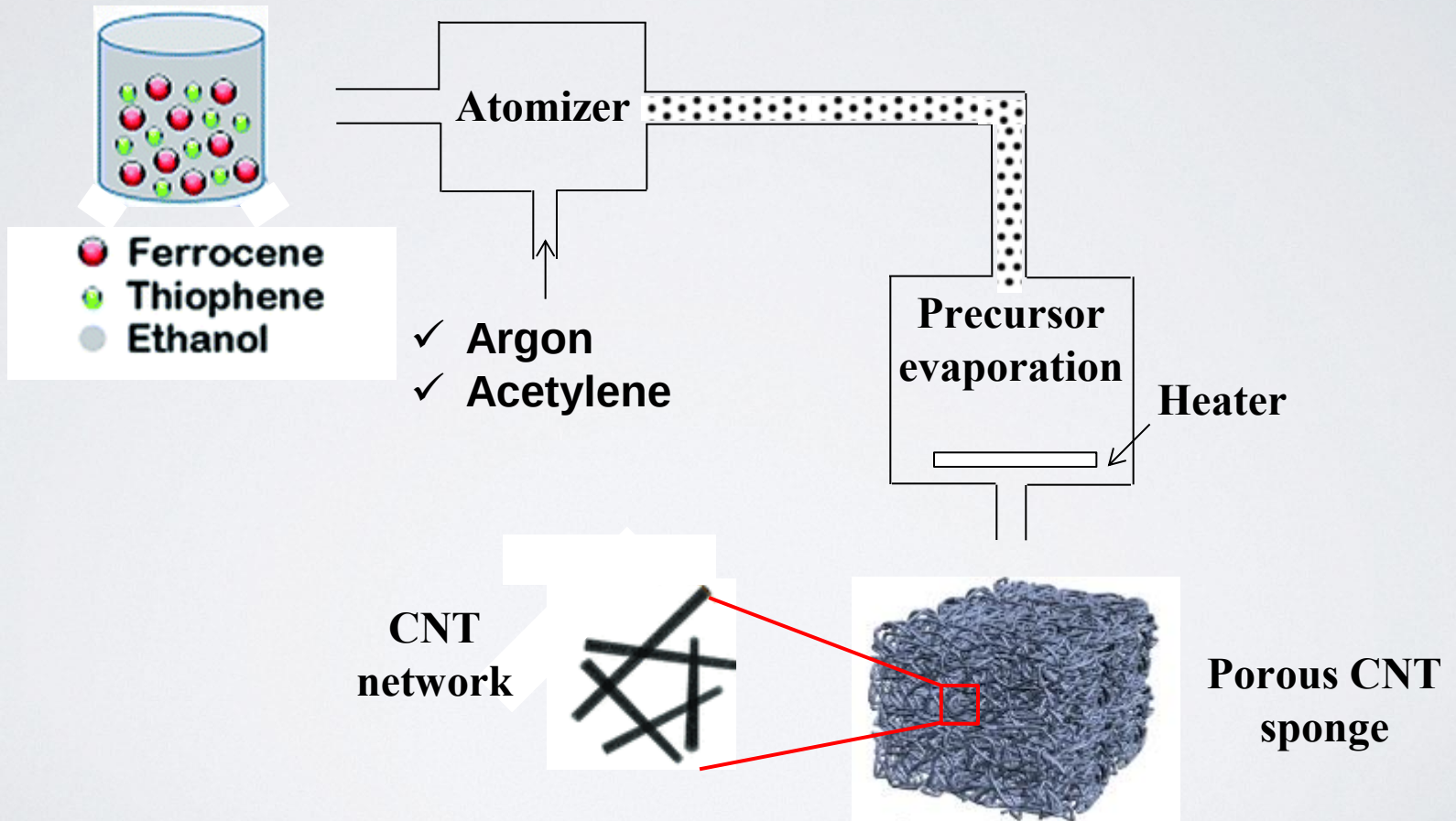


VA-CNTS: CARATTERIZZAZIONE SEM

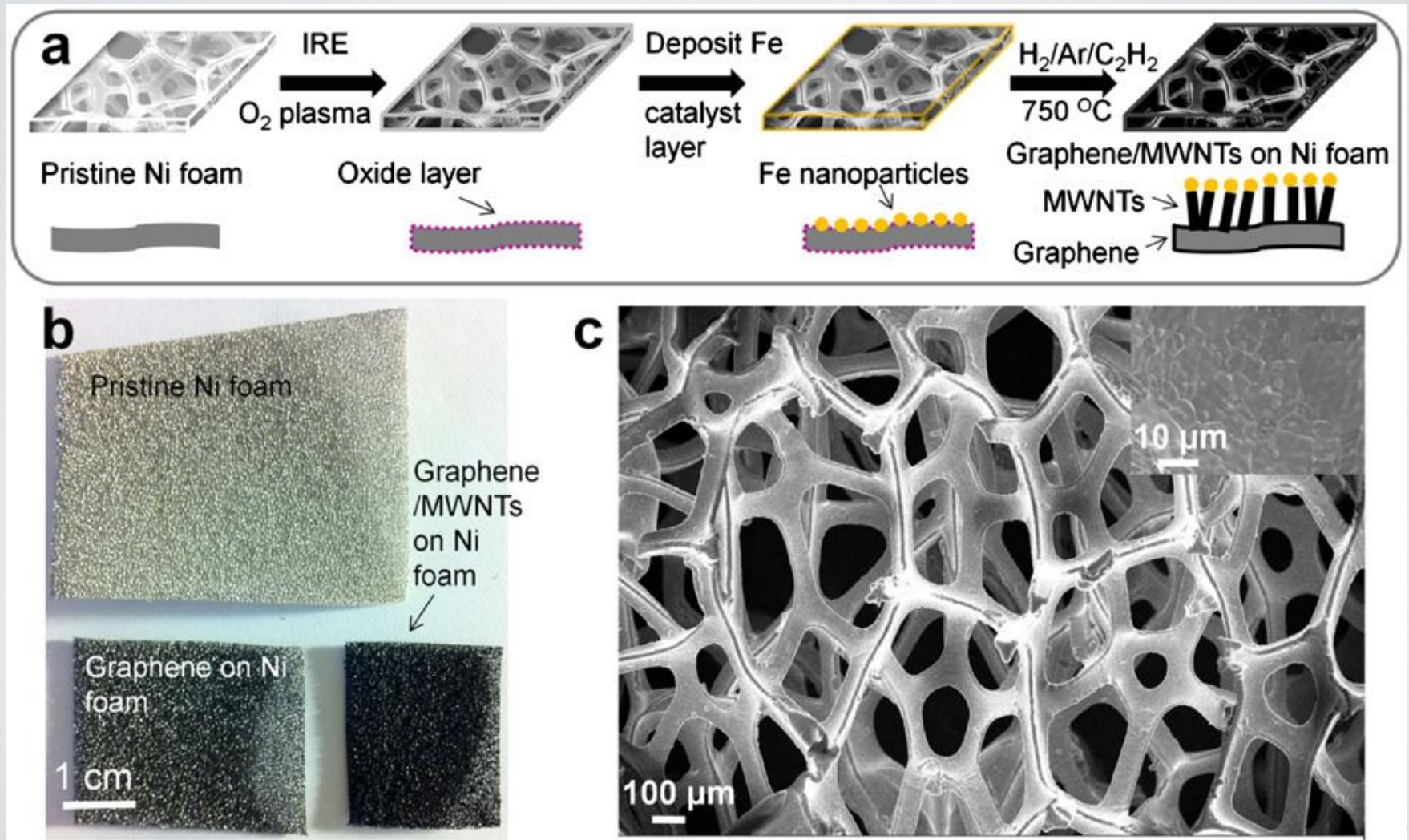


ARCHITETTURE TRIDIMENSIONALI POROSE DI CNT

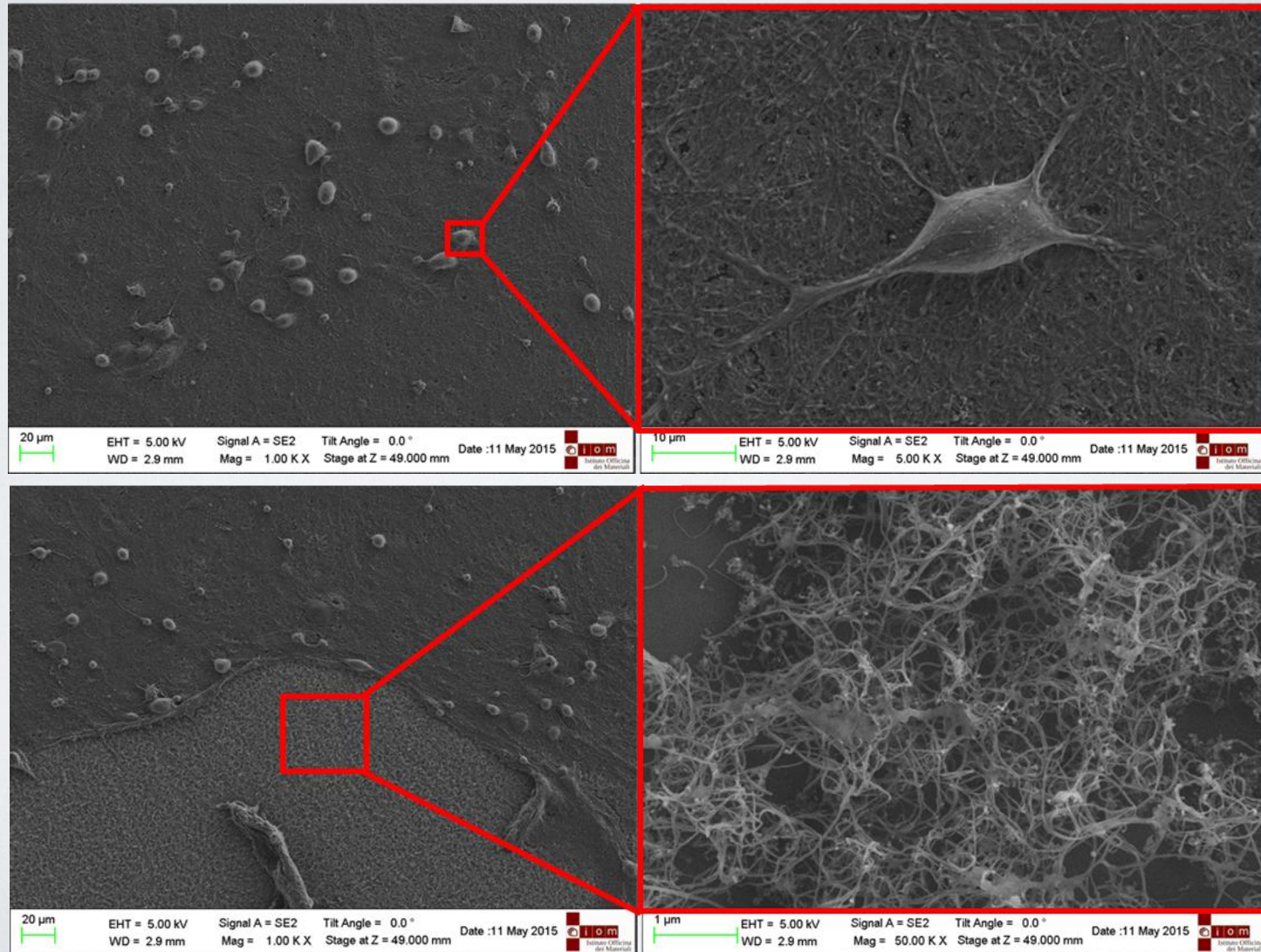
Precursor solution



SCHIUMA IBRIDA DI GRAFENE E CNT

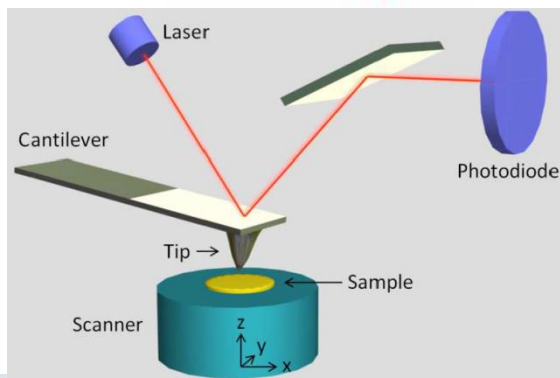
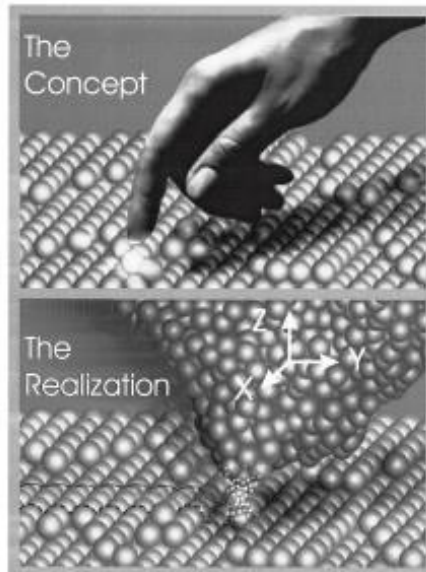


CELLULE NEURONALI-CNT: NUOVO MATERIALE IBRIDO?

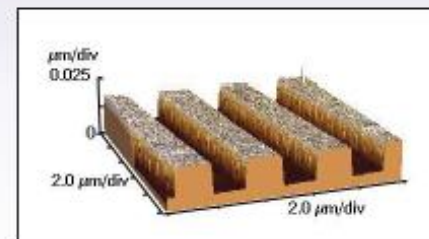
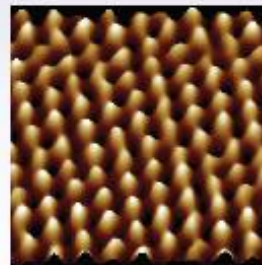
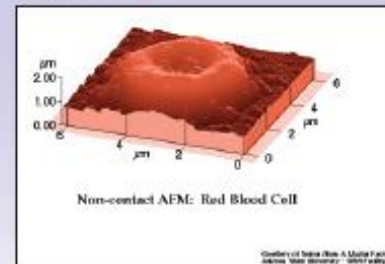
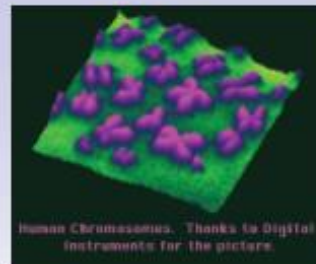


IL MICROSCOPIO A FORZA ATOMICA (AFM) PER STUDIARE I MATERIALI IBRIDI

Atomic Force Microscopy

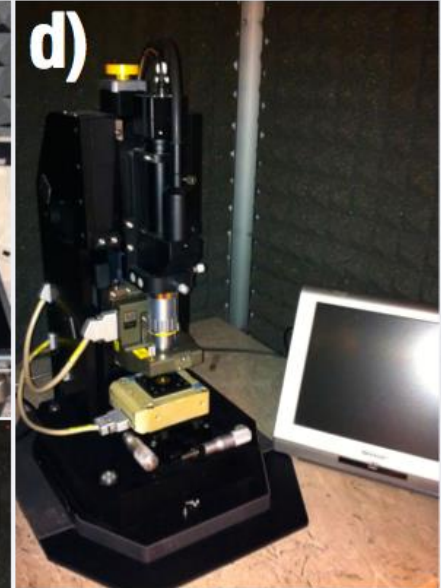
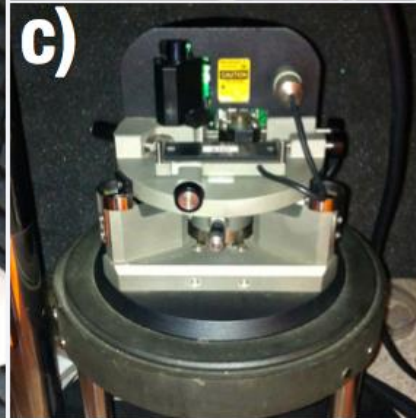
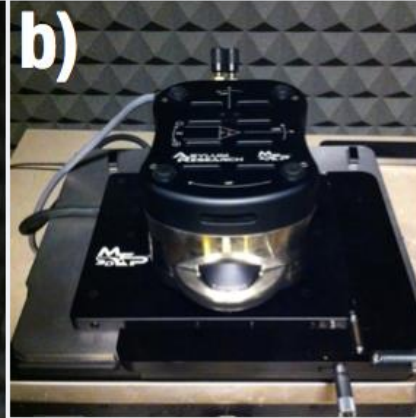
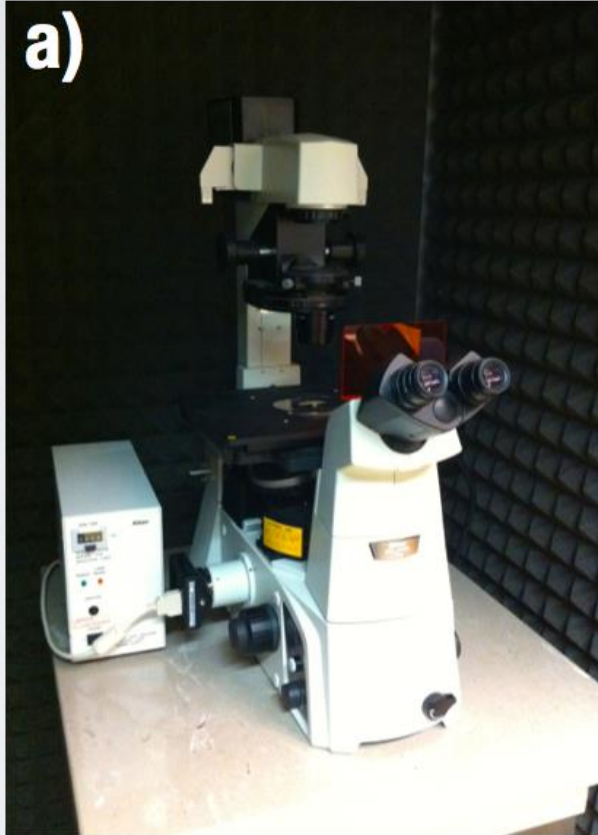


AFM Images



Mica: digital instruments; Grating: www.eng.yale.edu

IL MICROSCOPIO A FORZA ATOMICA (AFM) PER STUDIARE I MATERIALI IBRIDI



IL MICROSCOPIO A FORZA ATOMICA (AFM) PER STUDIARE I MATERIALI IBRIDI

