



Università degli Studi di Padova

A Nanoroadmap Conference
PRESENT FORECASTS AT 2015
OF NANOTECHNOLOGY APPLICATION IN:
MATERIALS, HEALTH AND MEDICAL
SYSTEMS, ENERGY

Nanomaterials through sol-gel

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Nanotechnology applied to materials

may be defined as the creation of functional materials, through control of matter on the nanometer length scale (1-100 nanometers), and exploitation of novel phenomena and properties (physical, chemical, biological) at that length scale.



Nanomaterials

➤ Zero-Dimensional

Nanoparticles (oxides, metals, semiconductors, core-shell np, fullerenes, ...)

➤ One-Dimensional

Nanowires, Nanorods, Nanotubes

➤ Two-Dimensional

Thin films (multilayer, monolayer, self-assembled, mesoporous, ...)

➤ Three-Dimensional

Nanocomposites, Nanograined, Micro- and Mesoporous, Organic-Inorganic Hybrids, Intercalation, ...



Nanomaterials: how?

- Bottom-up techniques (building things by combining smaller components)
- Top-down techniques (fabrication of components from larger materials)
- A combination of both



Nanomaterials through sol-gel at DIM-SM

Nanoparticles (oxides, metals, semiconductors, core-shell np, fullerenes, ...)

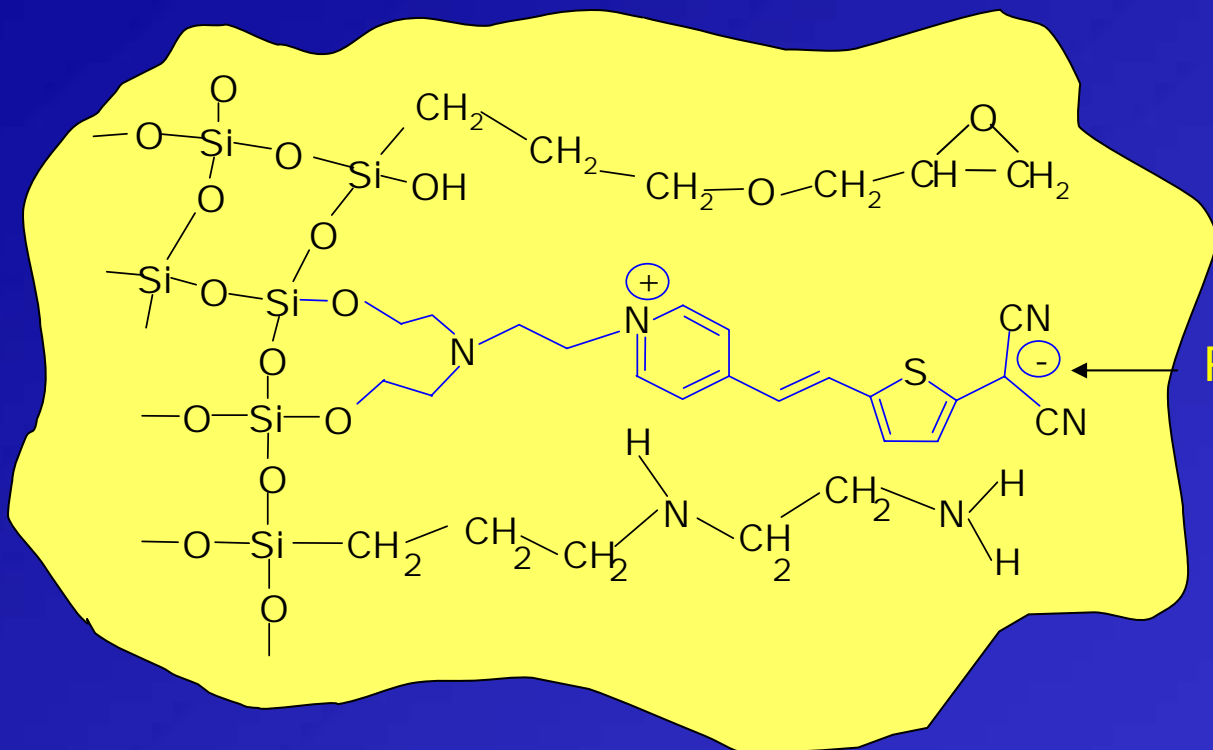
Nanowires, Nanofibers, Nanorods, Nanotubes

Thin films (multilayer, monolayer, self-assembled, mesoporous, ...)

Nanocomposites, Nanograined, Micro- and Mesoporous, Organic-Inorganic Hybrids, Intercalation,



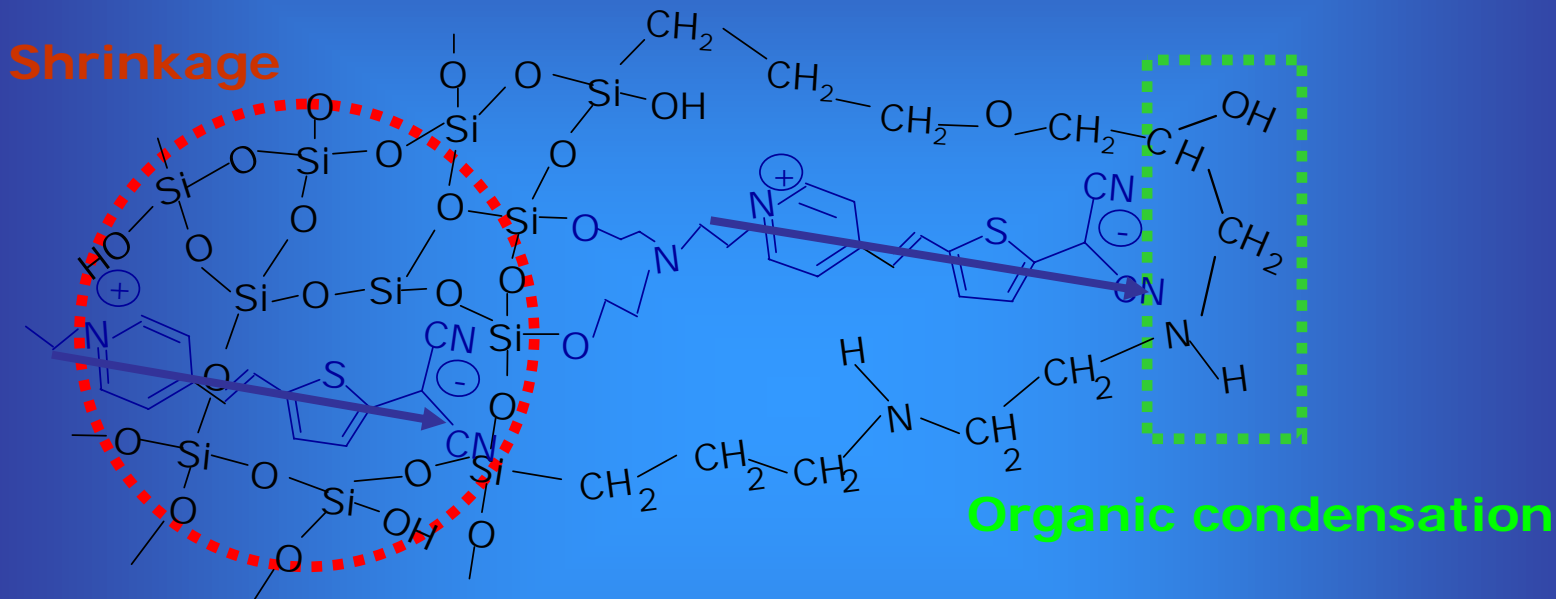
Organic-inorganic hybrid materials: an example of structural control at molecular level



Push-pull chromophore



an ELECTRO-OPTIC material



**Poling
at 140°C**



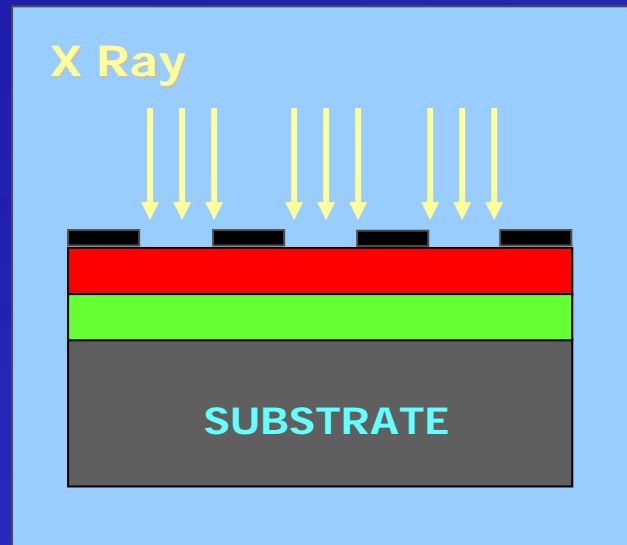
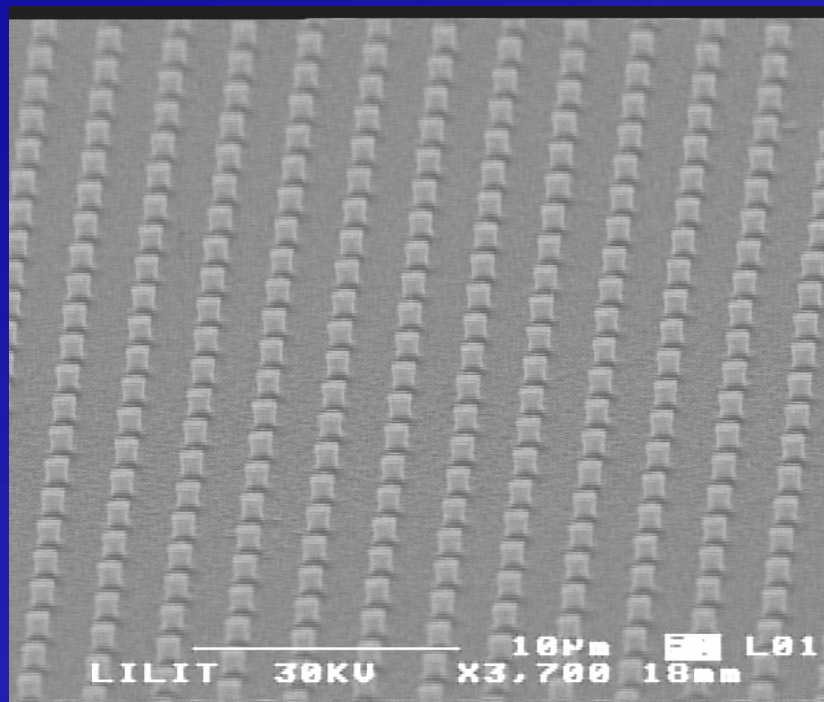
Cromophore orientation,
organic condensation, matrix
shrinkage



**large time
stability**



X-ray lithography + Reactive Ion Etching (RIE) on hybrid film: an example of bottom-up & top-down approach



SEM image of an example of periodic structure on a hybrid film



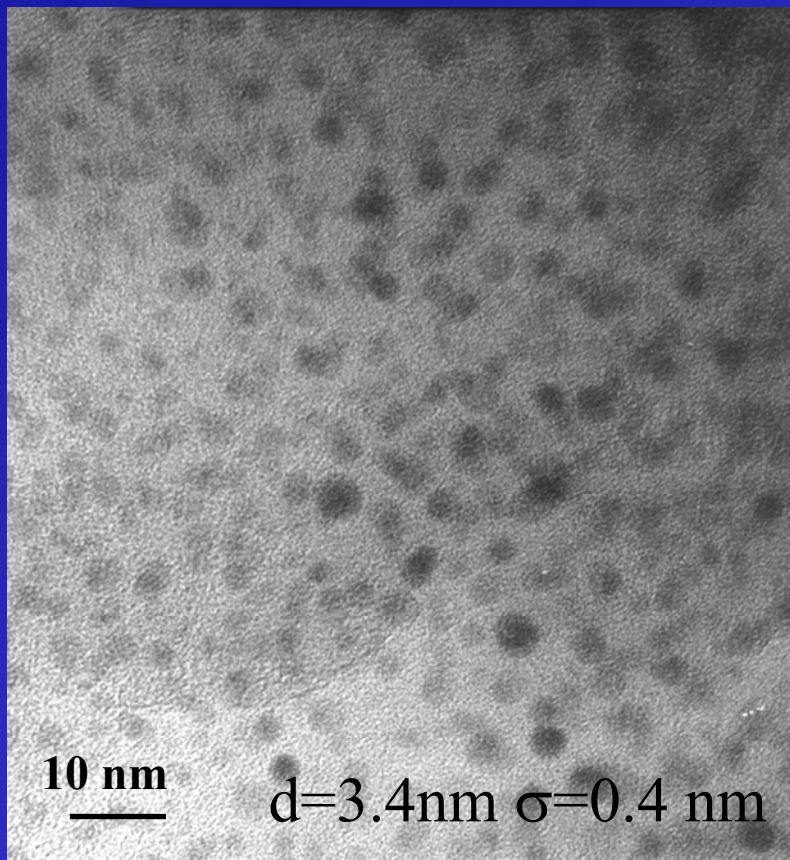
Nanoparticles and nanocomposites

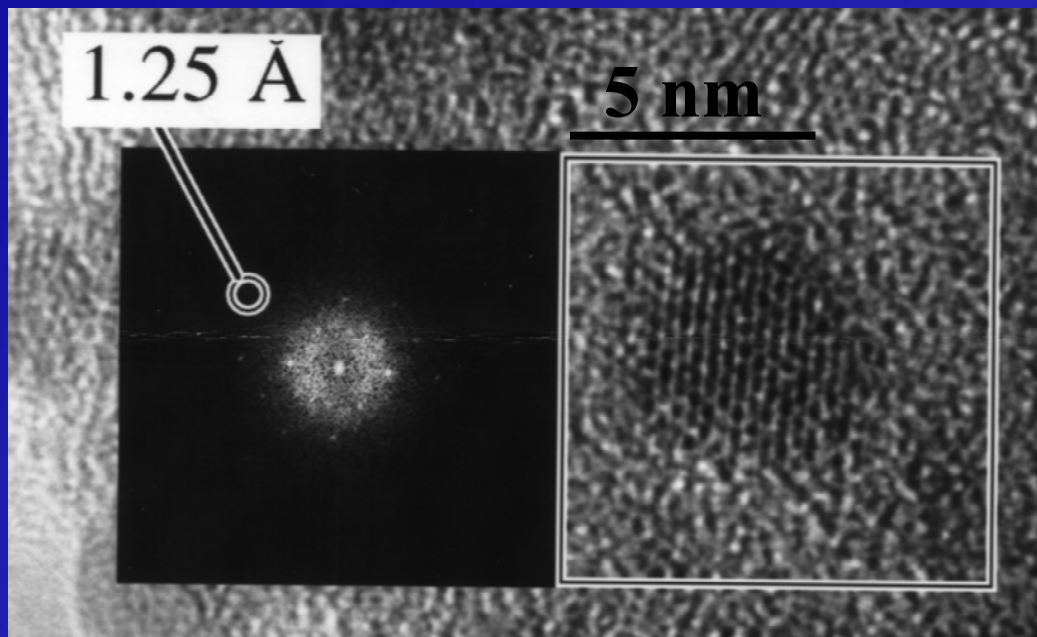
bottom-up approach \Rightarrow colloidal chemistry: control of nucleation and growth through surfactants

incorporation in a sol-gel matrix by mixing sols



TEM image of NiO doped silica films

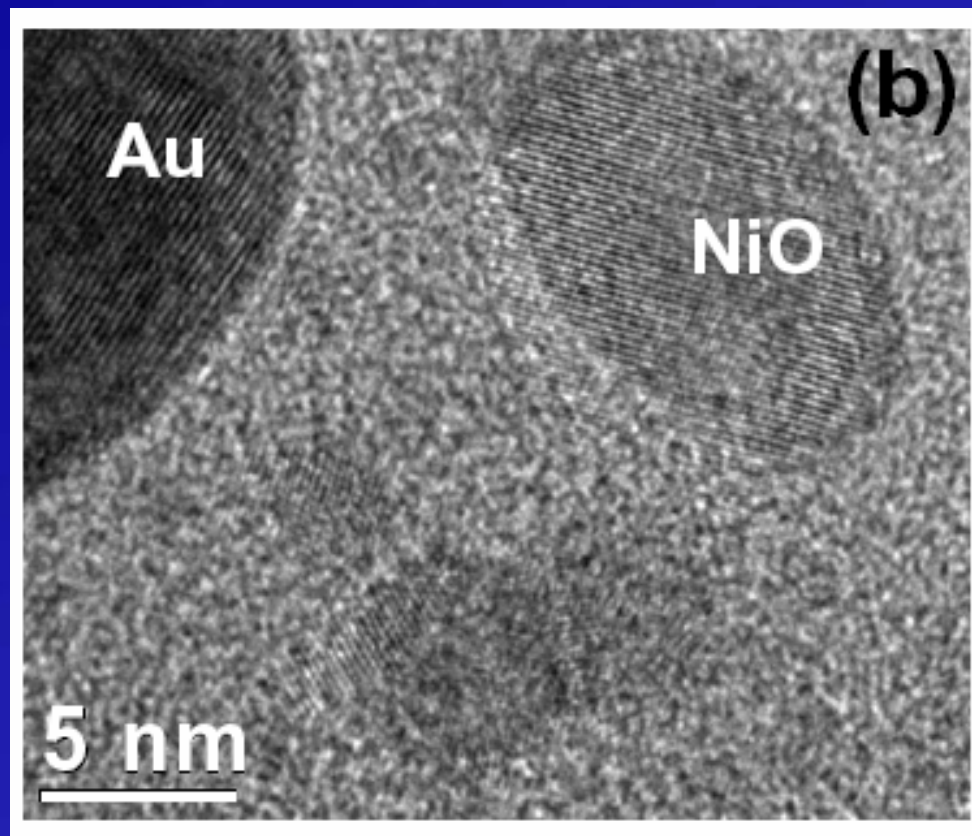




PbS nanocrystal in $\text{SiO}_2\text{-TiO}_2$ sol-gel film



60SiO₂-40NiO films co-doped with Au

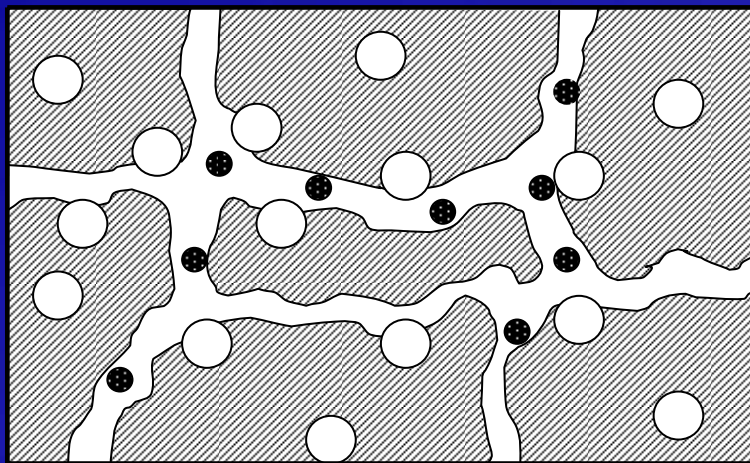


$$D(\text{Au}) = 25.5$$
$$\sigma(\text{Au}) = 6.6 \text{ nm}$$

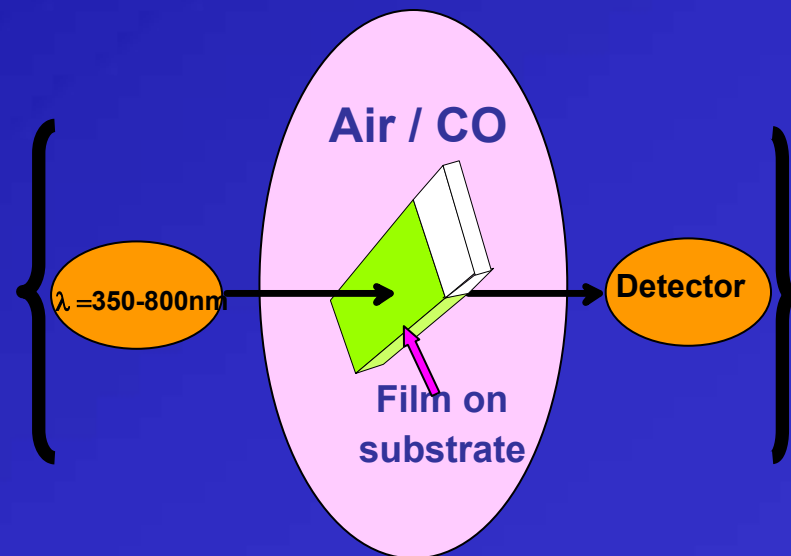
$$D(\text{NiO}) = 5.0 \text{ nm}$$
$$\sigma(\text{NiO}) = 0.6 \text{ nm}$$



SiO₂-semiconductor nanocomposite sol-gel films may be used as CO optical or electrical gas sensor



- Functional oxide nanoparticle
- Gas molecule
- ▨ Porous matrix



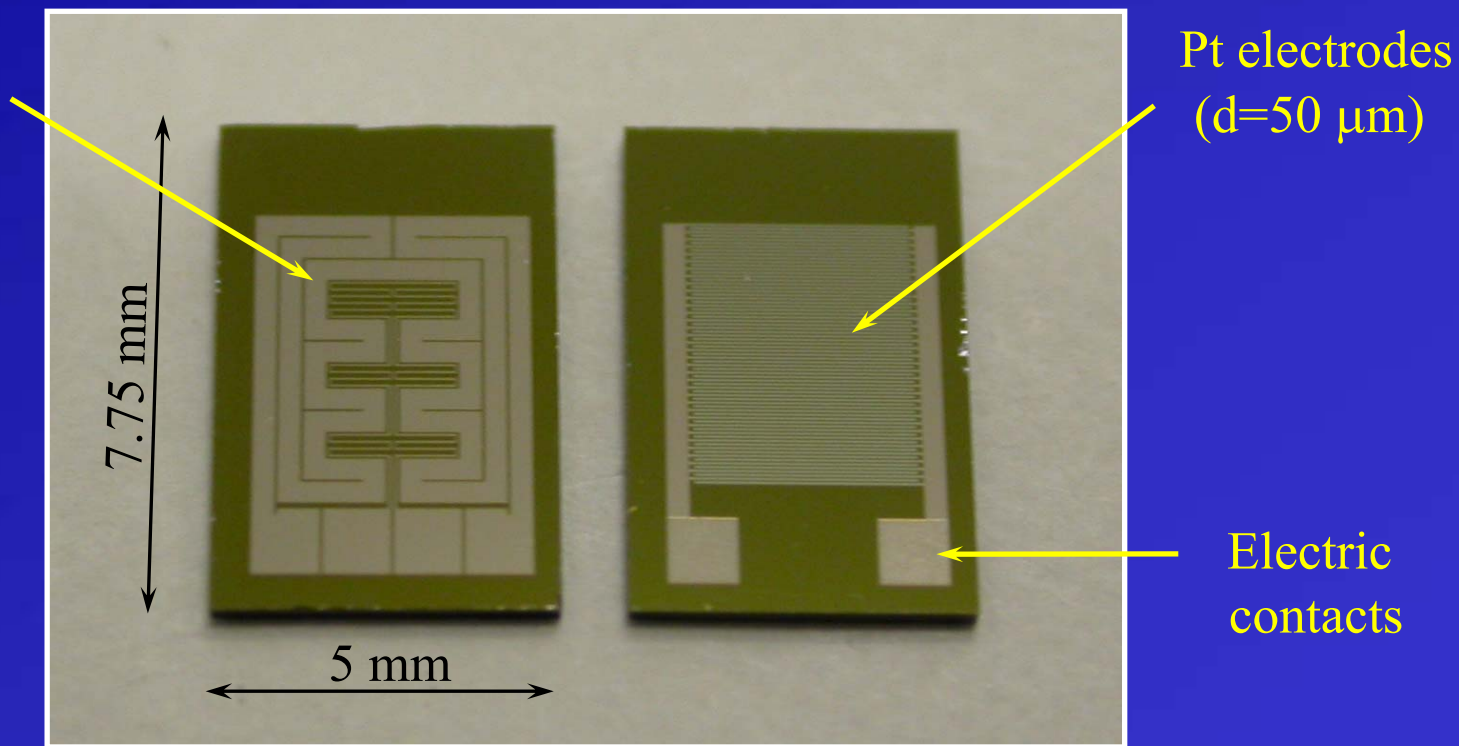
Optical measurements



Electrical measurements

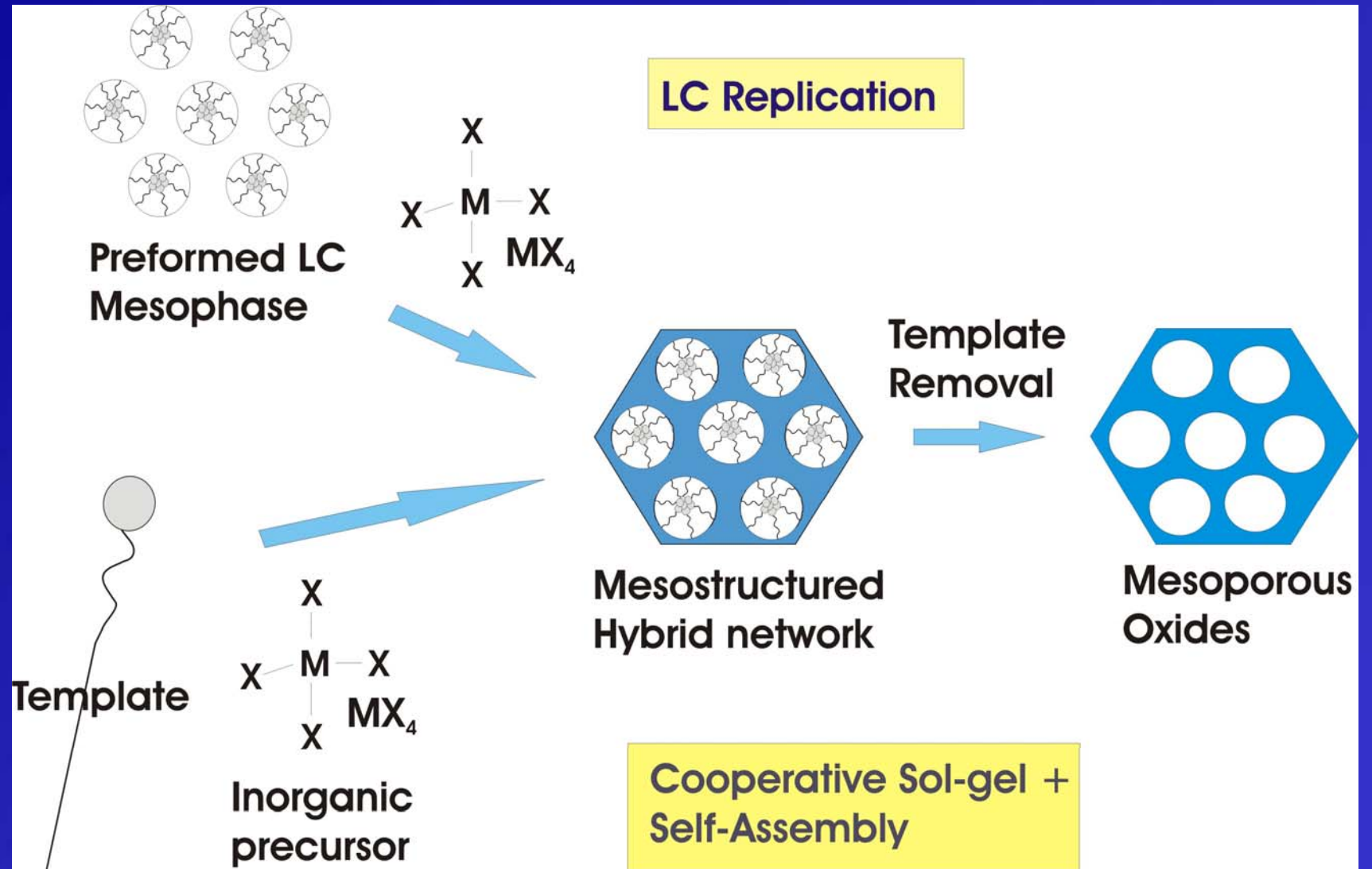
Si/Si₃N₄ substrates provided with Pt interdigital electrodes

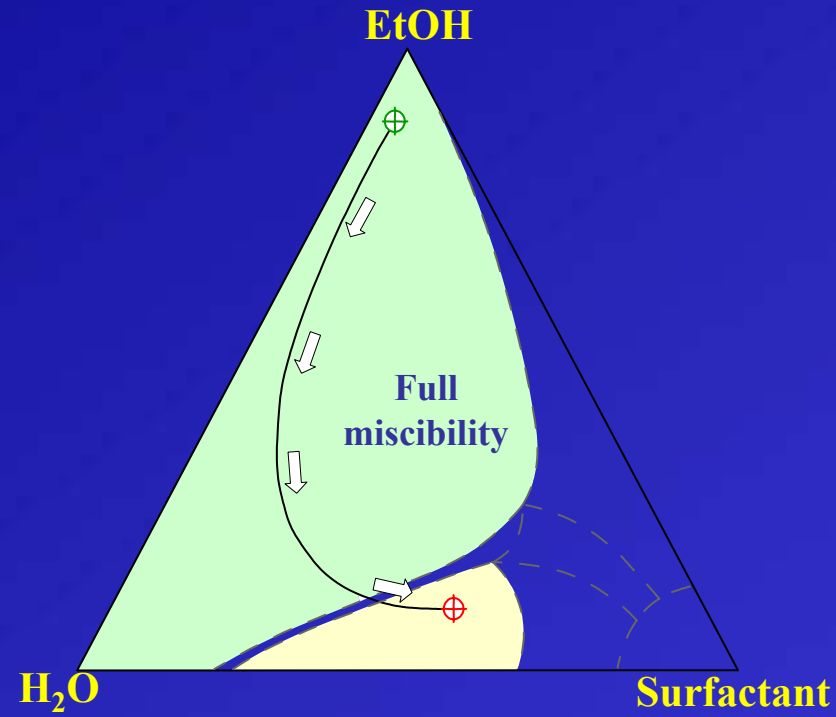
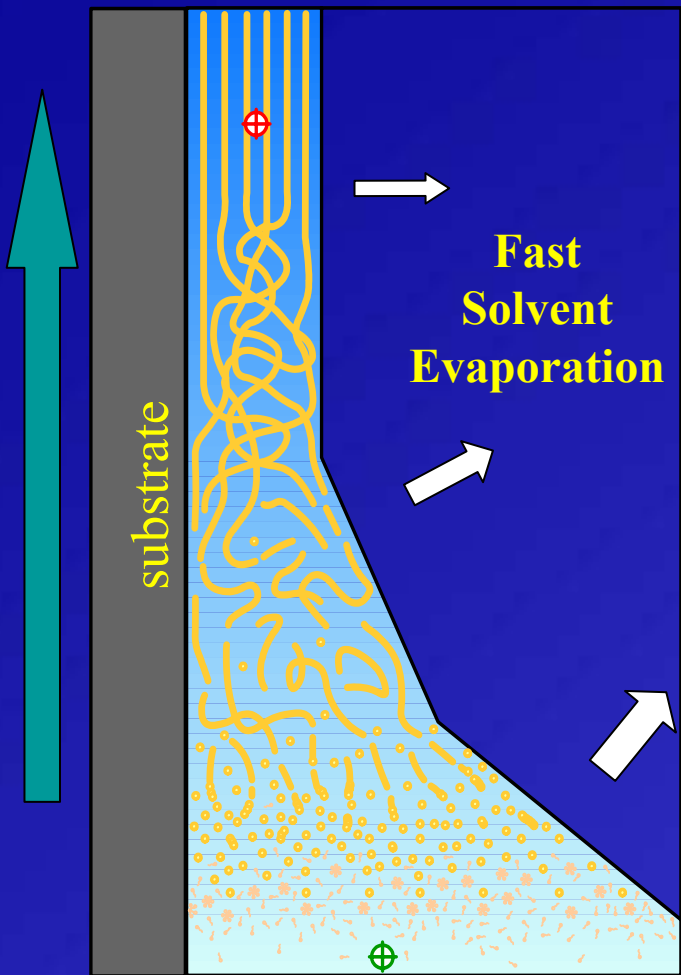
Heating resistances





Mesoporous films



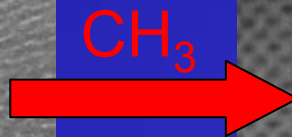
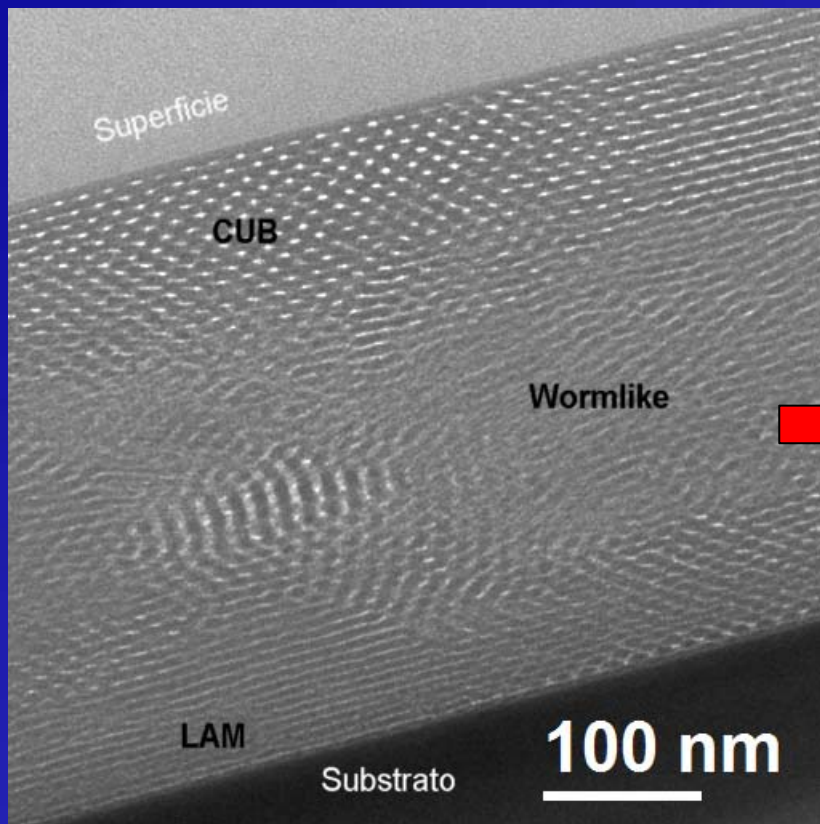


EISA: Evaporation Induced Self-Assembling

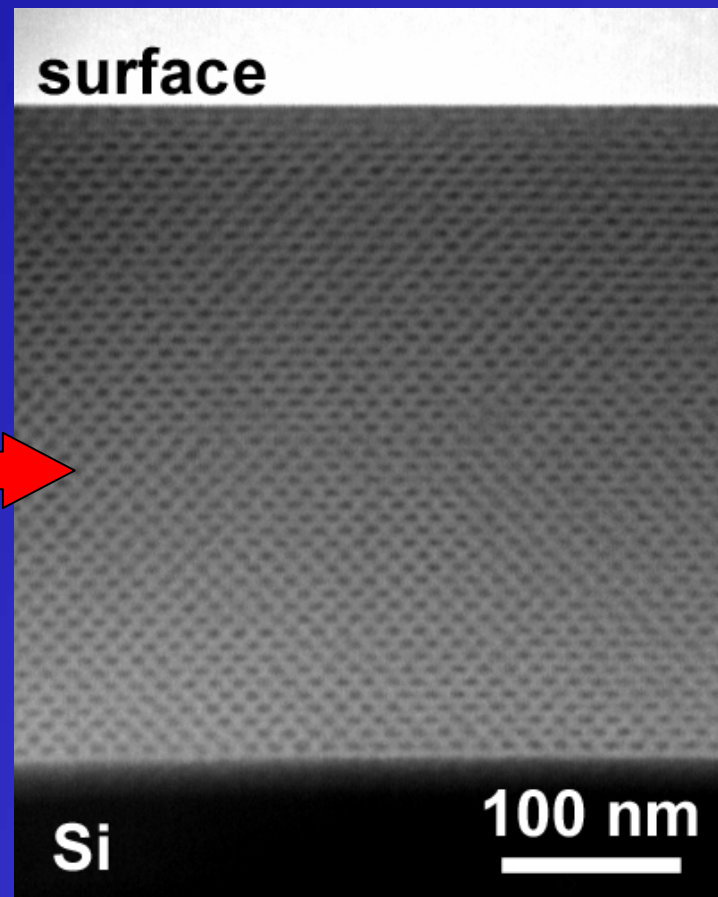


Mesoporous films

Mesoporous silica film

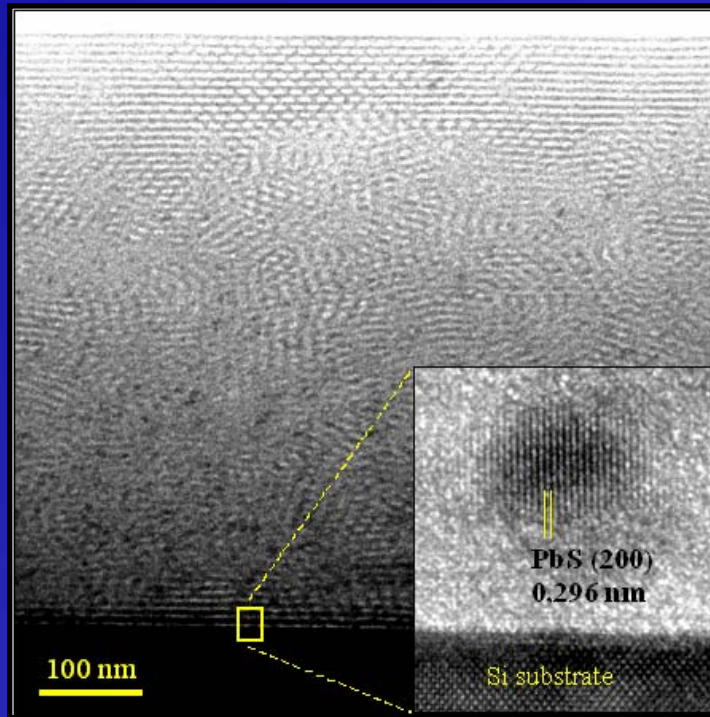


Mesoporous **hybrid** silica film



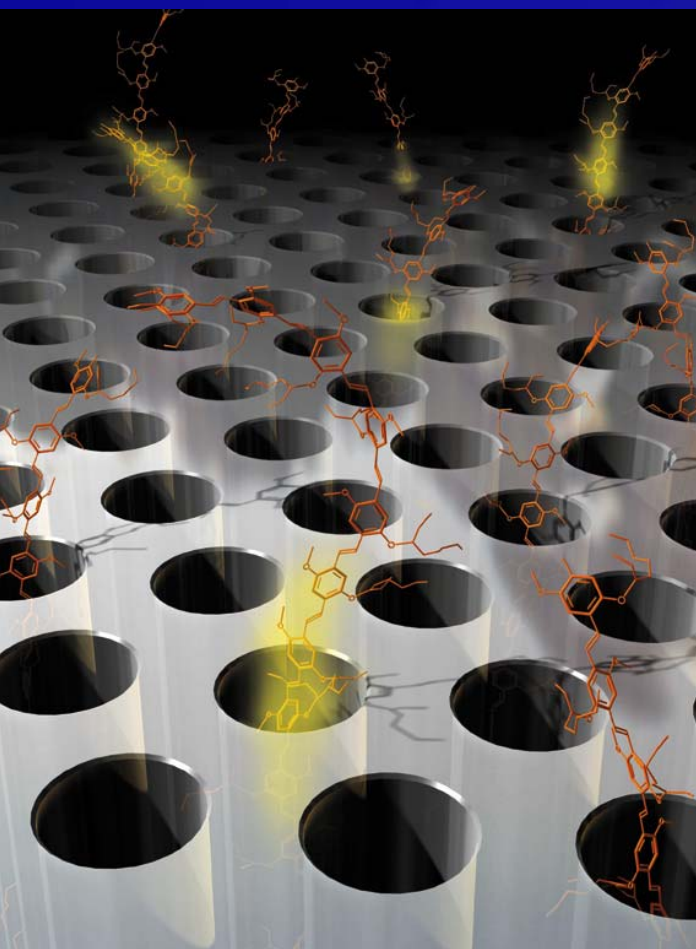


PbS-doped mesoporous SiO₂





Applicazioni e prospettive

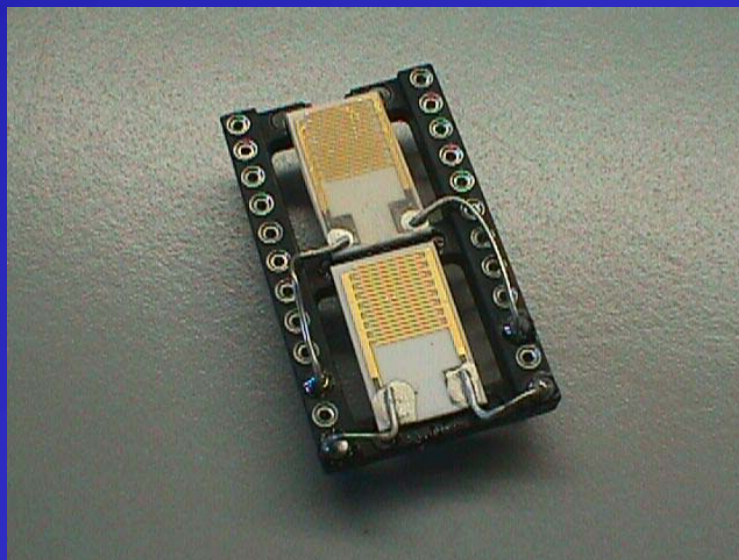


Ottica non lineare

Sensoristica

Cristalli fotonici

Microelettronica





Nanostructured surfaces

An example :

super-hydrophobic surfaces through chemical and morphological control to take advantage of the Lotus Effect by a simple sol-gel process.

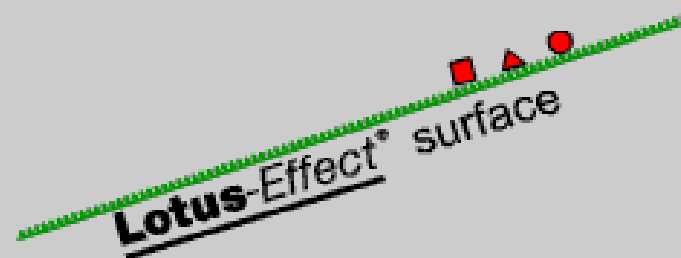
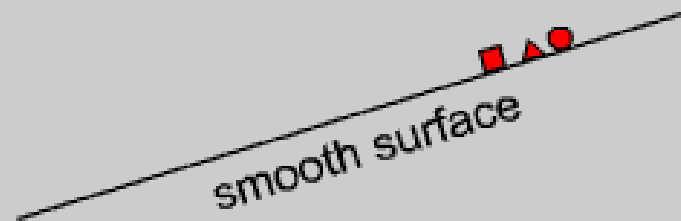
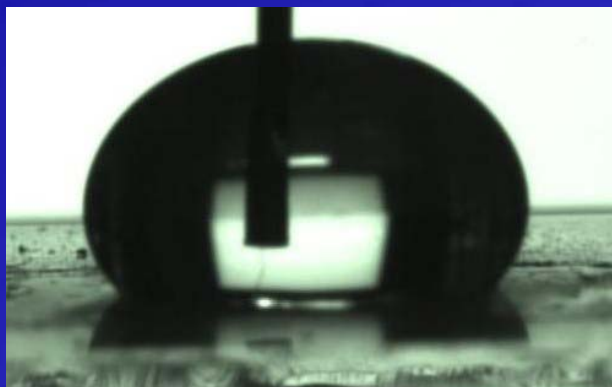


Silica glass surface

$\theta \approx 40^\circ$

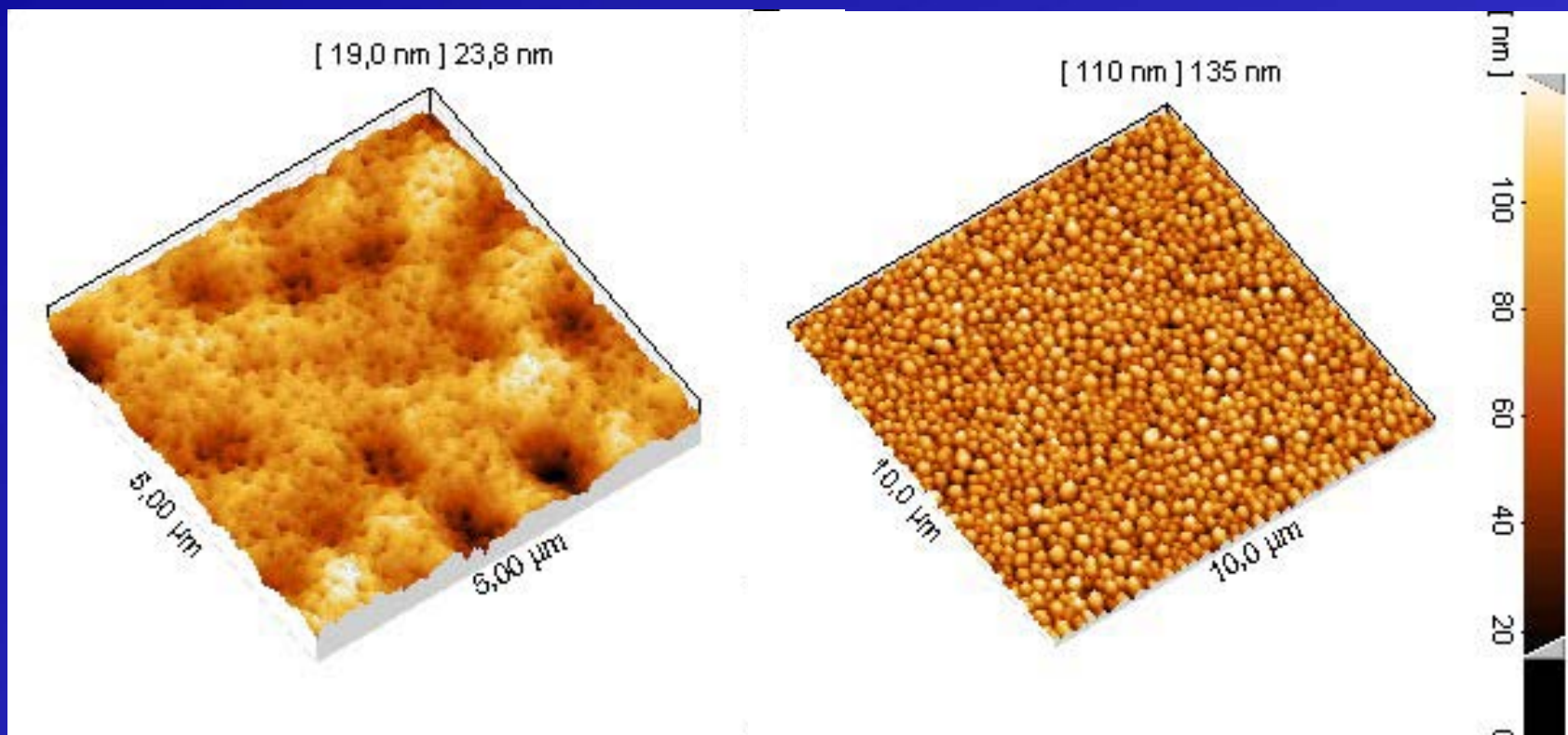


Chemically and topologically modified surface, $\theta \approx 140^\circ$





A great variety of morphologies on chemically modified surfaces may be obtained through sol-gel. Two examples of silica films modified with fluoroalkoxysilanes (FAS) is shown





What about the future?

Some key words:

- Education
- Farsightedness
- Basic research
- Aids to technological transfer



Aknowledgements

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Paolo Falcaro

PhD:

Enrico Miorin

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