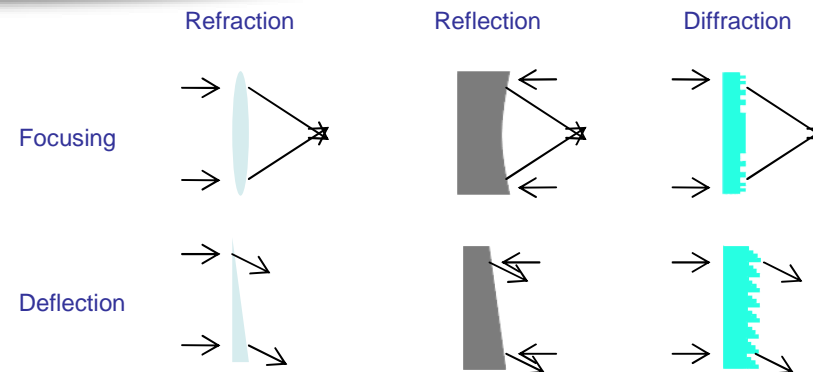




EUMINAFab: Micro and nanofabrication technologies for  
optical and sensor applications

Tekniker  
Jorge Ramiro  
14-09-10



## Advantages:

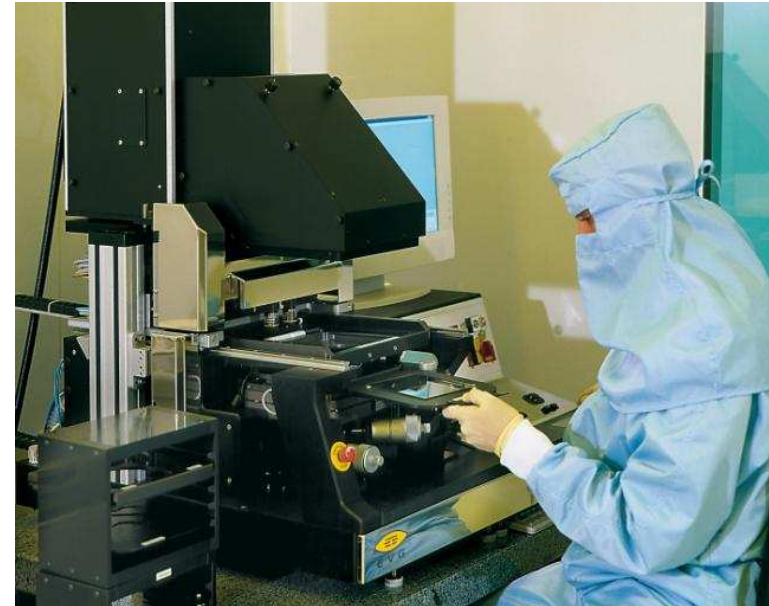
- Thermally and mechanically more robust
- Match the scale of sources and detectors
- New optical components to access to physical optics regime, affecting properties such as polarization through subwavelength features

## Disadvantage:

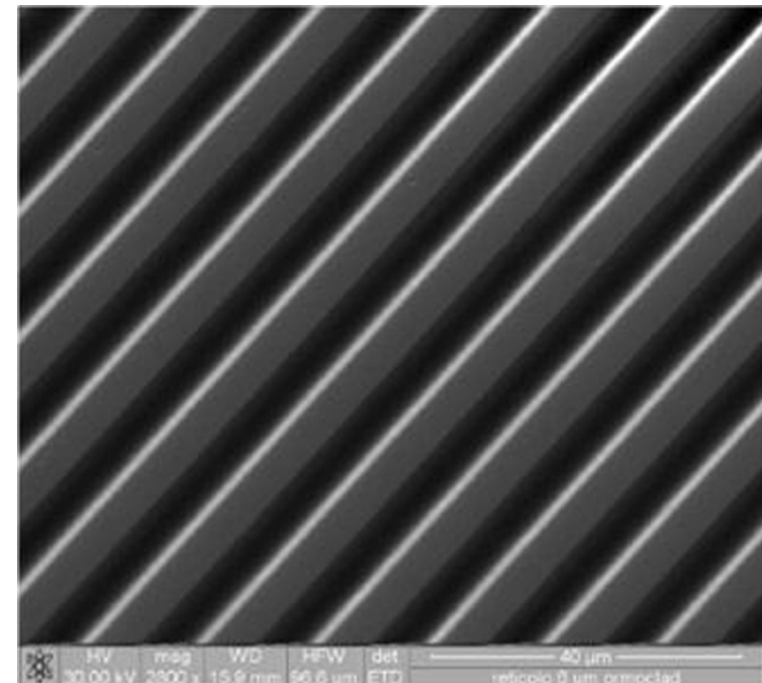
- Fabrication constrained by material selection, component lateral extent and minimum feature size

## ★ UV lithography (Tekniker, CRF)

- Most popular
- Possibility of using positive or negative photoresists
- Contact (hard, soft, vacuum) or proximity printing
- Resolution:  $\geq 1 \mu\text{m}$



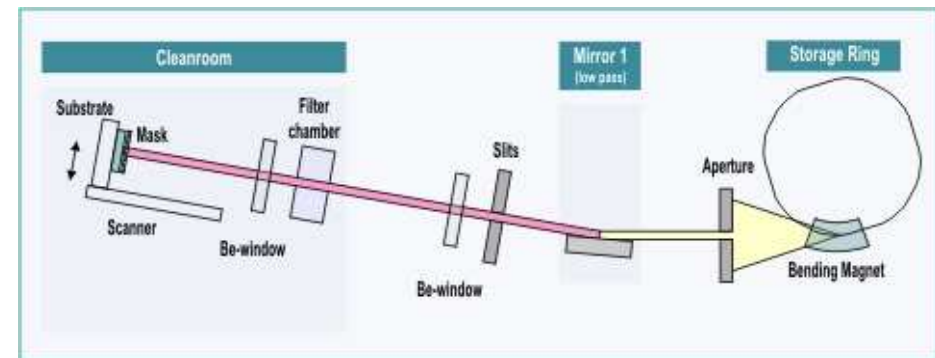
- ✧ Diffractive grating, 6  $\mu\text{m}$  pitch
- Dispersive element that splits and diffracts light
- Possible use: monochromators, spectrometers, lasers,...



© CRF

## ★ X-ray lithography (KIT)

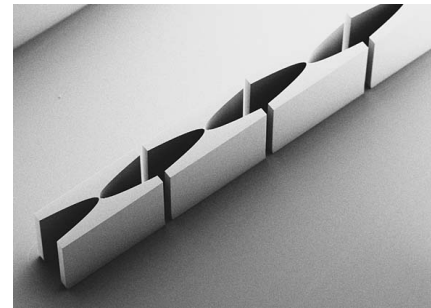
- Short wavelength ( $<10$  nm): higher resolution, reduced diffraction effects
- High penetration depth: deep structures, high aspect ratios
- Smooth ( $R_a \approx 10$  nm) and steep ( $<1$  mrad) sidewalls
- Potential interest for refractive microoptical components



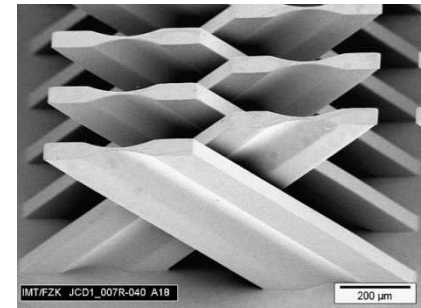
© KIT

## ★ X-ray lenses

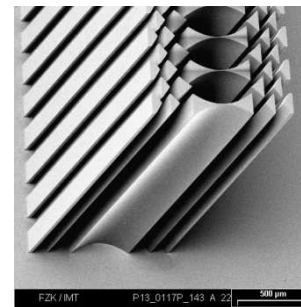
- X-ray microscopes: resolution far above of light-optical microscopes
- X-ray spectroscopy: focusing of X-ray beam to a spot on the surface of the sample to be analysed



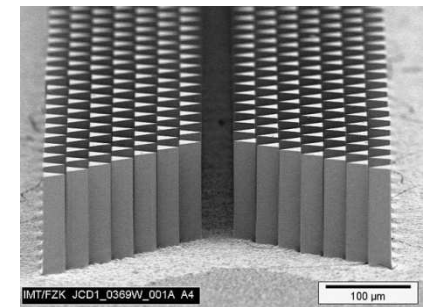
Row of parabolic lenses (© KIIT)



Crossed parabolic lenses (© KIIT)



Mosaic lenses (© KIIT)



Prismatic lenses (© KIIT)

## ★ Micro-optical bench

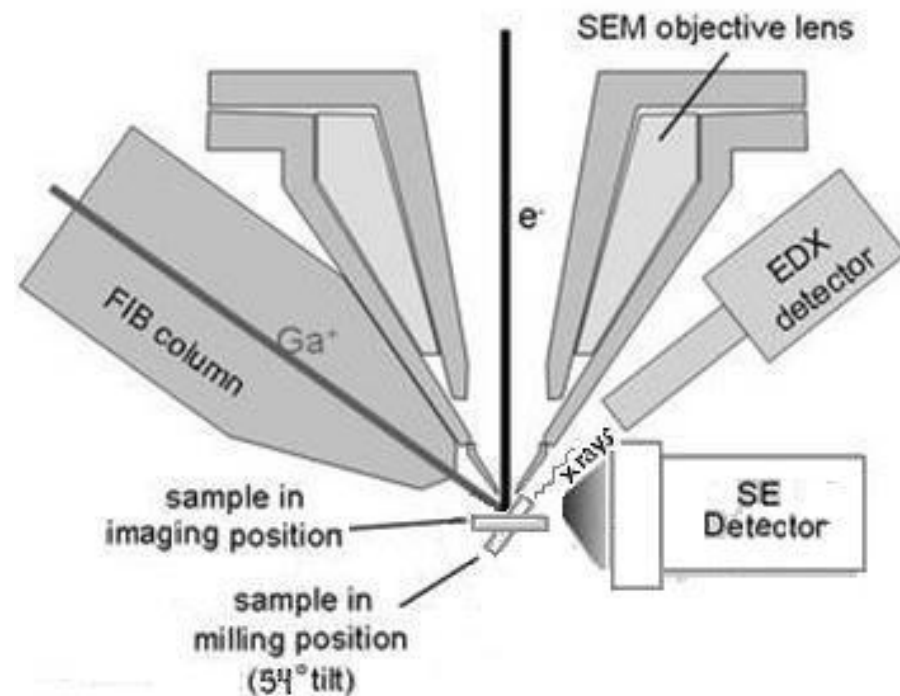
- Combination of simple optical elements (cylindrical lenses, prisms, gratings,...) to form light beams
- Uses: systems which require to form optical beams in a very small volume (microsensors, fiber connectors,...)



© KIT

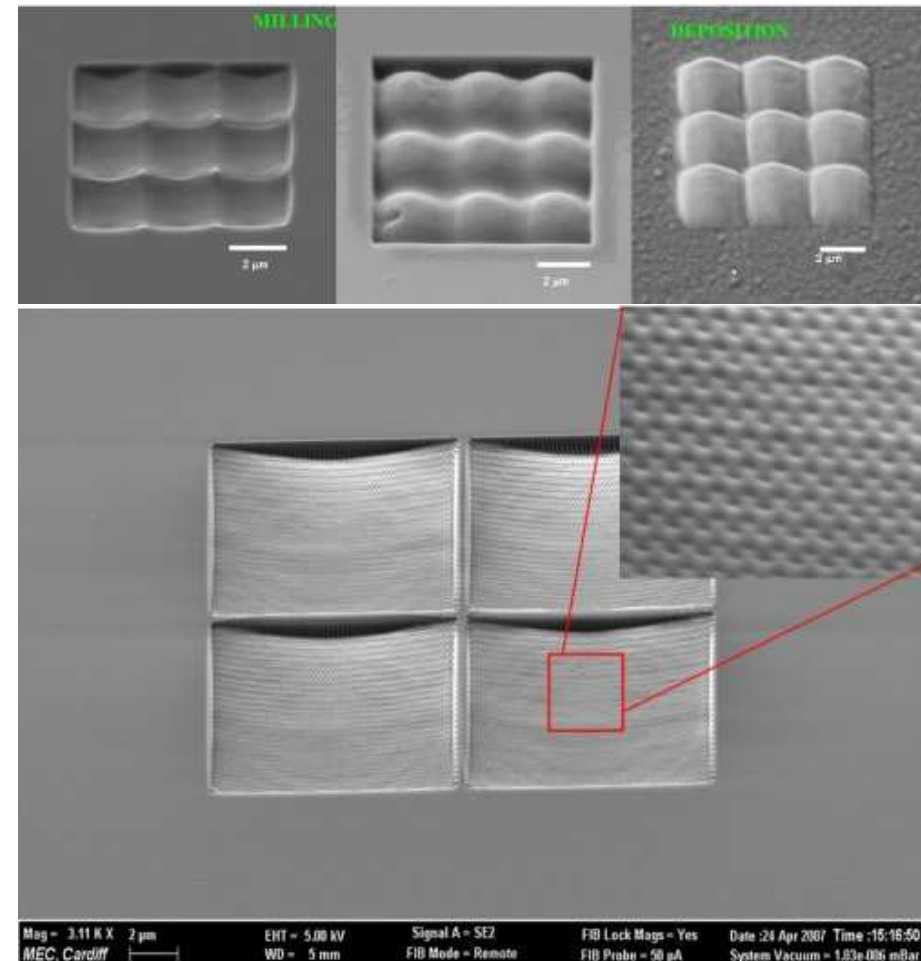
## ✧ Focused ion beam (Cardiff University):

- Possibility of milling/deposition
- Minimal feature size  $\approx 30$  nm
- Aspect ratio  $> 3$
- Surface roughness  $\approx 5$  nm



## ✧ Fabrication of lenses

- Arrays of  $2 \times 2 \mu\text{m}$  microlenses fabricated using the different possibilities of the FIB
- Mould for fabrication of  $2 \times 2$  array of moth-eye lenses (anti-reflective properties):  $10 \times 10 \mu\text{m}$  microlenses,  $120 \text{ nm}$  nanolenses

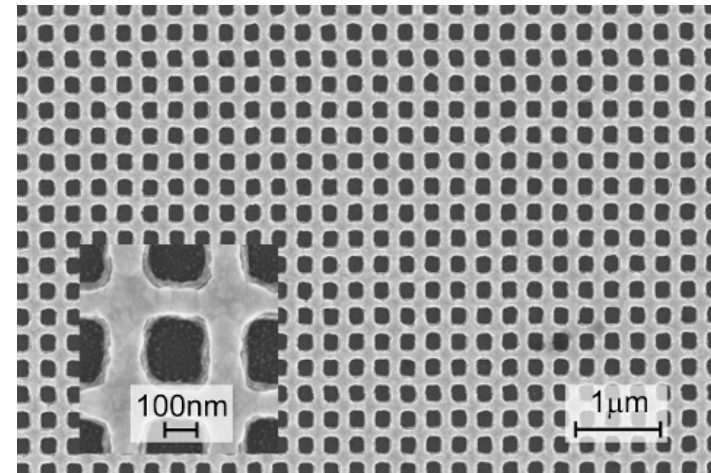


## ✧ Electron beam lithography (MiPlaza, KIT):

- Short wavelength, structural details  $\approx 20$  nm, resolution below 1 nm
- Charged particles: modulation by electric and magnetic fields
- Long writing times
- Proximity effects



- ✧ Photonic metamaterial
- Fishnet structure made from Ag and  $\text{MgF}_2$
- Negative index of refraction at 780 nm



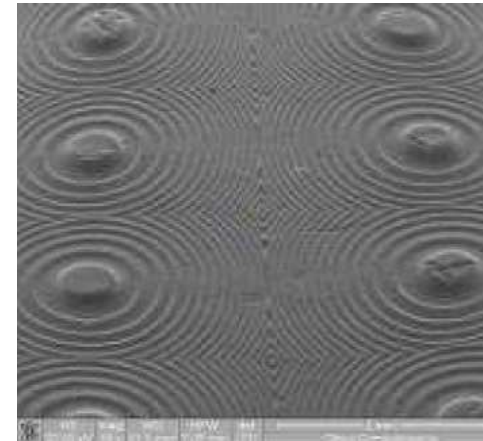
© KIT

- ✪ Alternative lithography (Tekniker, CRF, MiPlaza):
  - Polymer printing, possible use as a mask or as a final device
  - High resolution (<10 nm lateral size)
  - Possibility of UV-NIL (CRF) and SCIL (MiPlaza)
  - Commercial applications: near-IR and visible polarizers, optical waveplates, LEDs, microlens arrays, DOEs,...



## ★ Array of Fresnel lenses

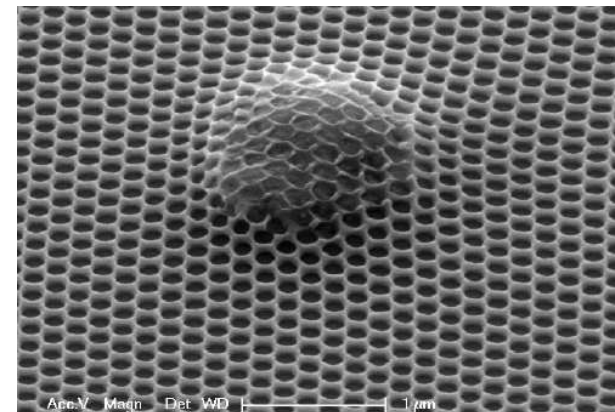
- Relief height: 40  $\mu\text{m}$
- Minimal depth 10  $\mu\text{m}$



© CRF

## ★ Honeycomb grid

- Patterned by SCIL

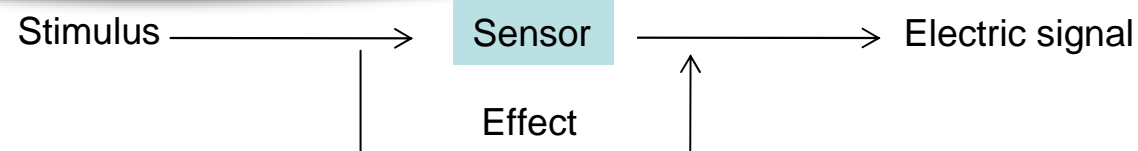


© MiPlaza

## ✪ More equipment:

- DRIE and RIE etching processes to transfer resist pattern
- Laser (DOEs and waveguides) and micromachining processes (deep surface relief and blazed diffractive elements)
- Replication ( $\mu$ -injection moulding, hot embossing)
- Thin-film deposition techniques (PVD, CVD,...): antireflective coatings
- Physical and optical (electro-optical laboratory at CRF) characterization of microoptical components

# Sensor applications



Stimulus	
Mechanical	Position
	Displacement
	Acceleration
	Force
	Flow rate, ...
Thermal	Temperature
	Flux
	Thermal heat, ...
Electrostatic and magnetic magnitudes	Fields
	Charge
	Permeability
	Conductivity, ...
Viscosity	
Radiation	
Chemical	Component identity
	Concentration,...
Biological	Concentration of antigen
	Concentration of antibody,
	...
...	

Effect

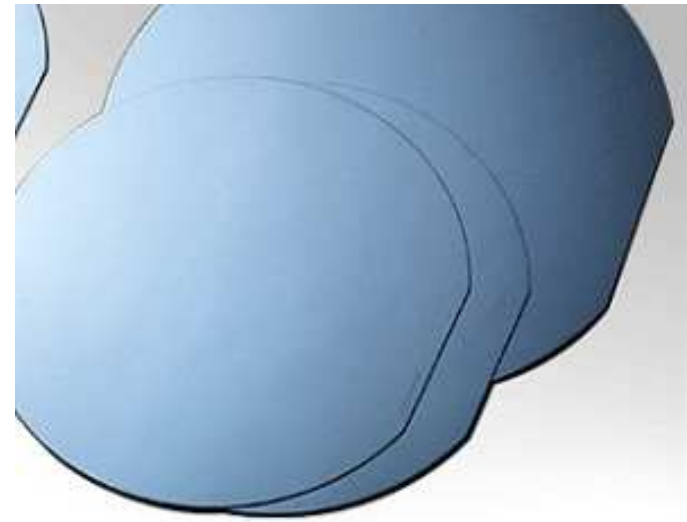
- Piezoelectricity
- Pyroelectricity
- Seebeck effect
- Hall effect
- ...

Material

- Semiconductor
- Glass
- Ceramic
- Metal
- Polymer

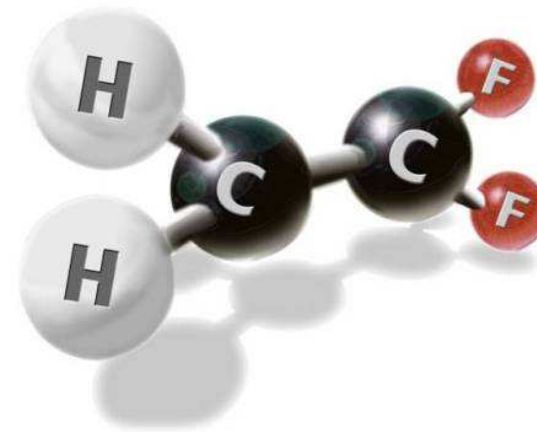
## ★ Silicon

- Large number of effects useful for sensor applications: pressure transducers, temperature sensors and force and tactile detectors
- Various possibilities of processing
- LTPS line at MiPlaza: temperature and fingerprint sensors



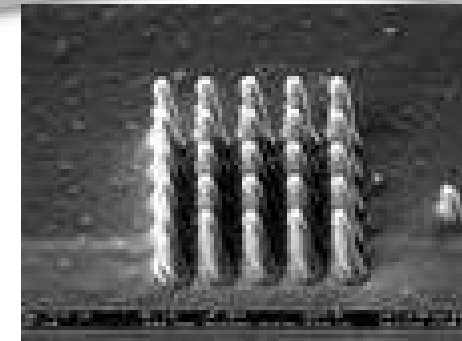
## ★ Polymers

- PVDF and related copolymers: strong piezoelectricity
- Possibility of processing using hot embossing and  $\mu$ -injection moulding

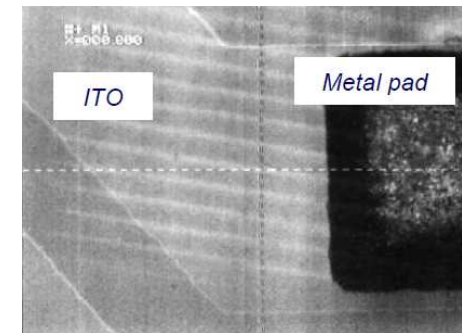


## ★ Metals

- Ferrous metals: magnetic sensors
- Non-ferrous metals: thin films (PVD, CVD), structuration possible
- Noble Metal installation at MiPlaza: capability of etching Pt (temperature sensors) and Au using ion beam
- FIB/SEM CrossBeam installation at Cardiff University: tungsten and platinum deposition
- Screen printing at CRF: deposition of metals on different substrates



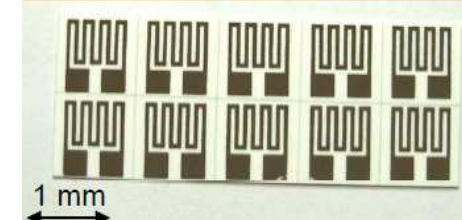
© Cardiff University



© CRF

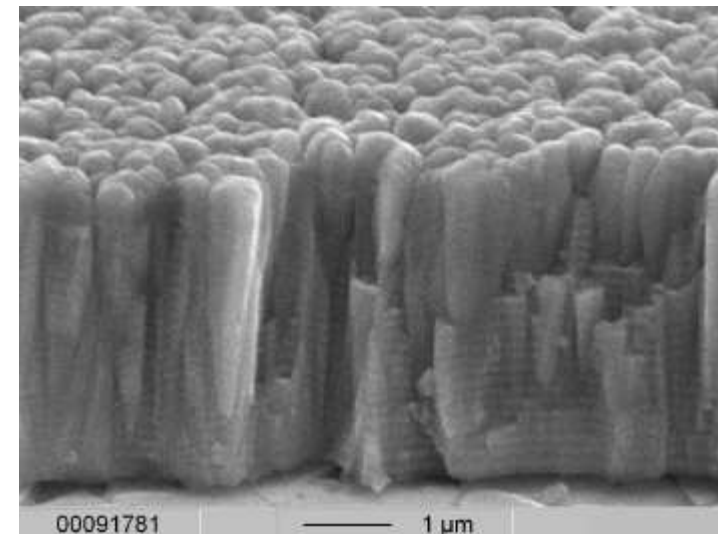


© CRF



## ★ Ceramics

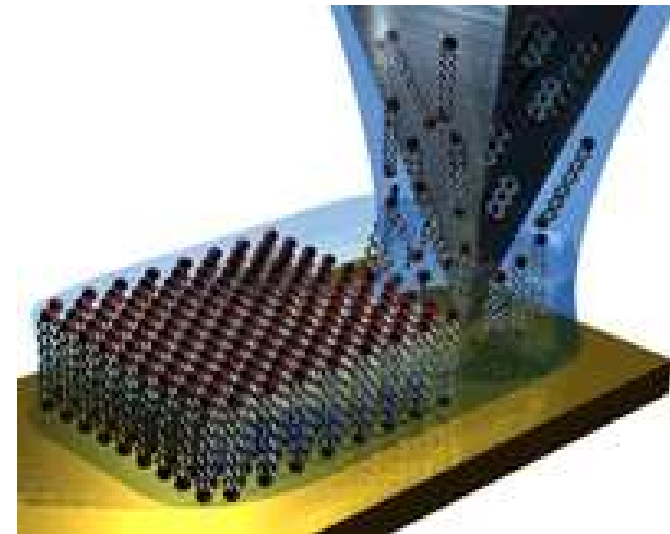
- Very useful due to their properties
- $\text{Al}_2\text{O}_3$  in humidity sensors, ITO in gas sensors, AlN and PZT in piezoelectric sensors
- Deposition using reactive vapour deposition techniques
- Possible machining using laser processing



© CEA-LITEN

## ✧ Dip-pen nanolithography

- Available at KIT
- AFM tip used to deliver molecular inks to a surface
- Thiols on gold, phospholipids with fluorescent or biotinylated groups on various surfaces
- Possible applications in biosensing



- EUMINAfab provides open access to state of-the-art micro and nanotechnologies for a broad user community from industry and academia
- A large number of the offered installations could be of great interest for optical and sensors fabrication.
- A detailed description of the equipment available for micro- or nanopatterning, thin film deposition, replication and characterisation, as well as the access conditions can be found on <http://www.euminafab.eu>

- *EUMINAfab partners, scientists and experts at FZK-KNMF, CU-MEC, CEA-liten, CRF, KTH, TEKNIKER, PHILIPS, FhG, IMS-NANO, NPL*
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- You - for your kind attention