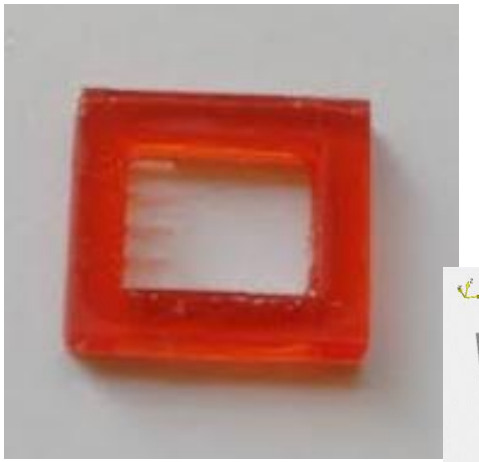
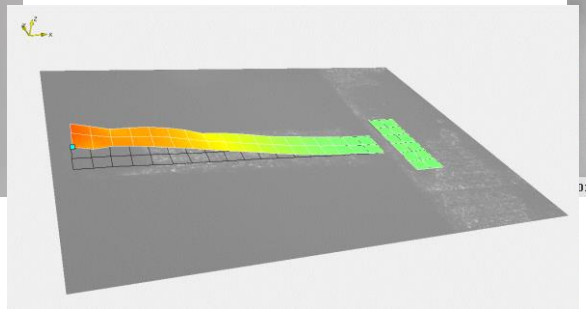
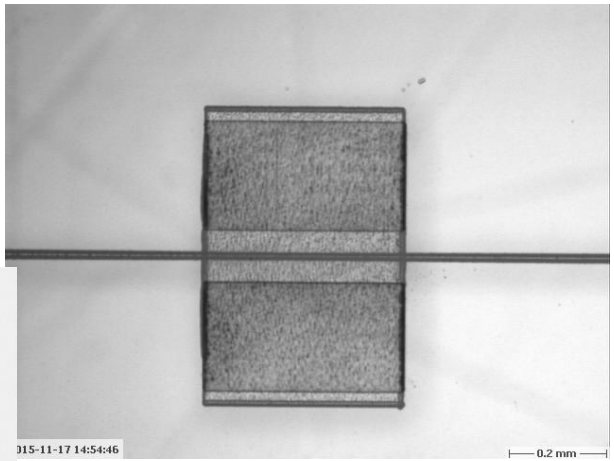
3D micro and nanostructuration of chemical and biological sensors







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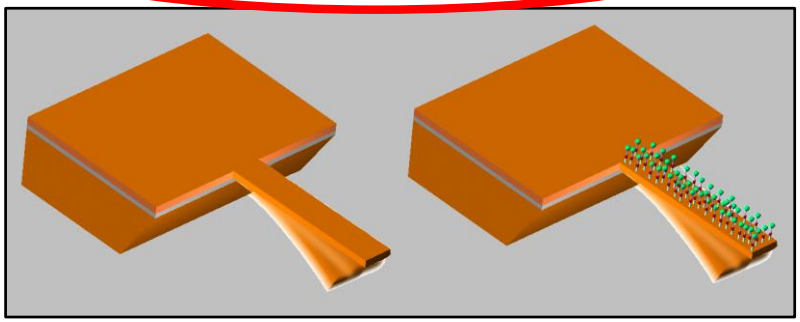
Politecnico di Torino

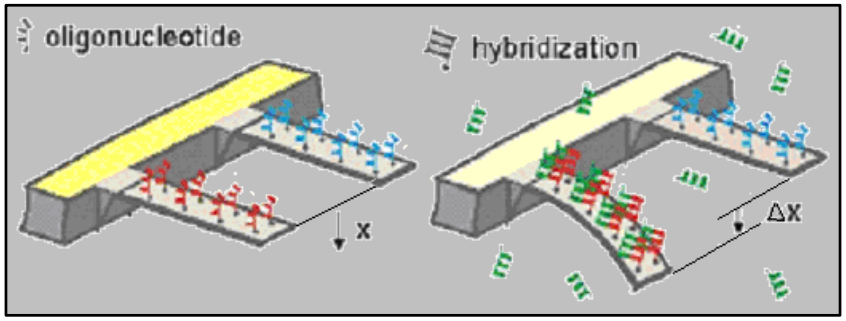
Nanoinnovation 2016, Rome, Italy

MicroCantilever (MC) resonators

- **Dynamic mode** (variation of resonance characteristics)



- **Static mode** (deformation due to stress)



Mass adsorption effect:

$$\omega_n = \sqrt{\frac{k}{m_n}}$$

k constant: ⇒ $\frac{\partial m}{m} = -2\frac{\partial \omega}{\omega}$ ⇒ $\boxed{\frac{\Delta m}{m} \cong -2\frac{\Delta \omega}{\omega}}$

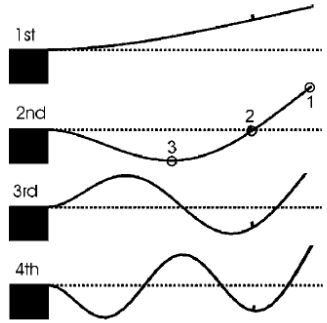
Q factor:

$$Q = \frac{f_{res}}{\Delta f_{res,-3dB}}$$

Different contributions:

Q_i: ambient, TED, clamping, internal friction, surface, etc…

$$\frac{1}{Q_{tot}} = \sum_i \frac{1}{Q_i}$$



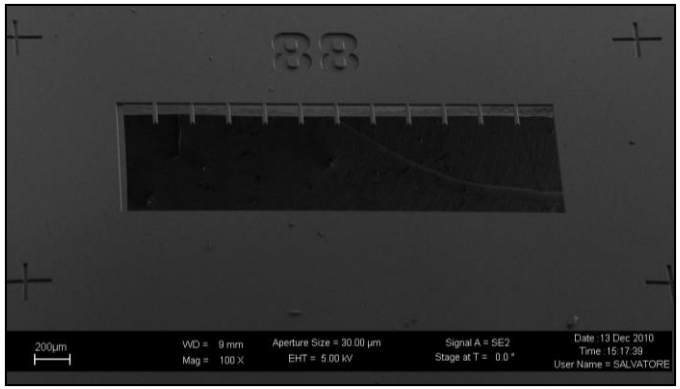
⇒ $\boxed{\Delta m_{\min} \propto \frac{m_n}{Q}}$ Limit of Detection (LOD)

MicroCantilever (MC) resonators

Fabrication

Array of microcantilevers

Standard clean room technology

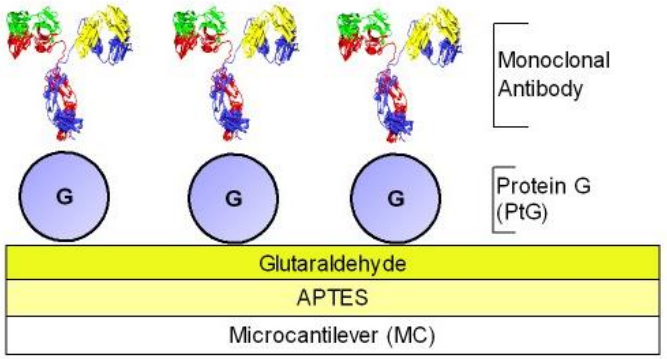


Biodesign

Chemical functionalization (APTES+GA)

Proteing G

Antibody



Measurement and Data Analysis

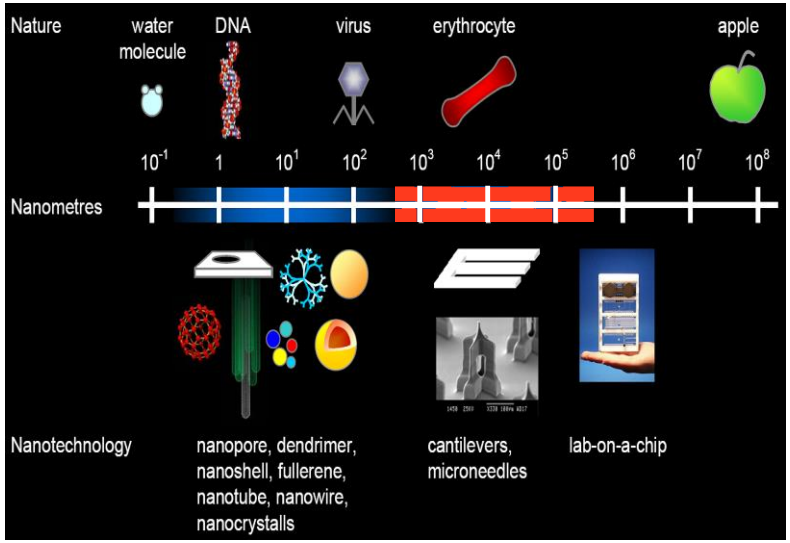
External piezo-disk actuator

Doppler Laser Vibrometer

Vacuum chamber

Statistics

MicroCantilever (MC) resonators



$$\Delta m = -2\frac{\Delta f}{f_0} m_0$$

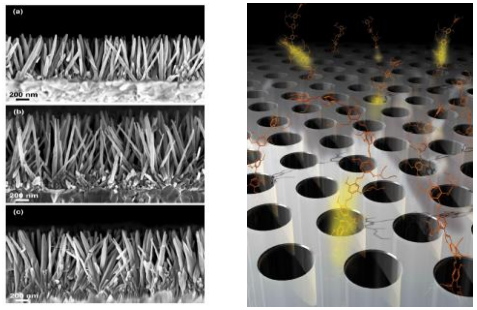
Virus
Bacteria

Fungal Spores

Proteins

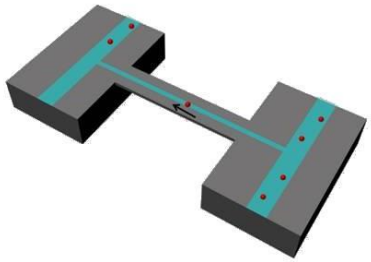
Nanoparticles

PROBLEMS WITH SMALL MOLECULES



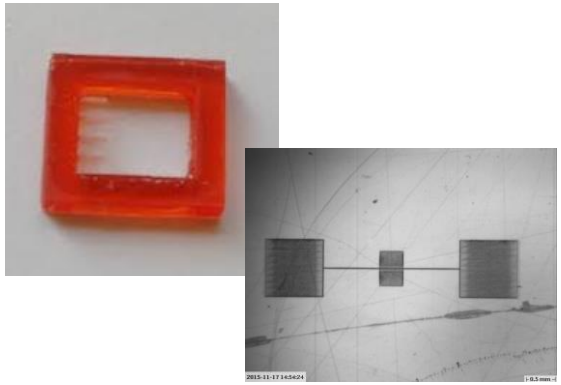
SURFACE NANOSTRUCTURATION

SINGLE NANOPARTICLES IN LIQUID



NANOFLUIDIC RESONATORS

CANTILEVER WITH FUNCTIONAL PROPERTIES

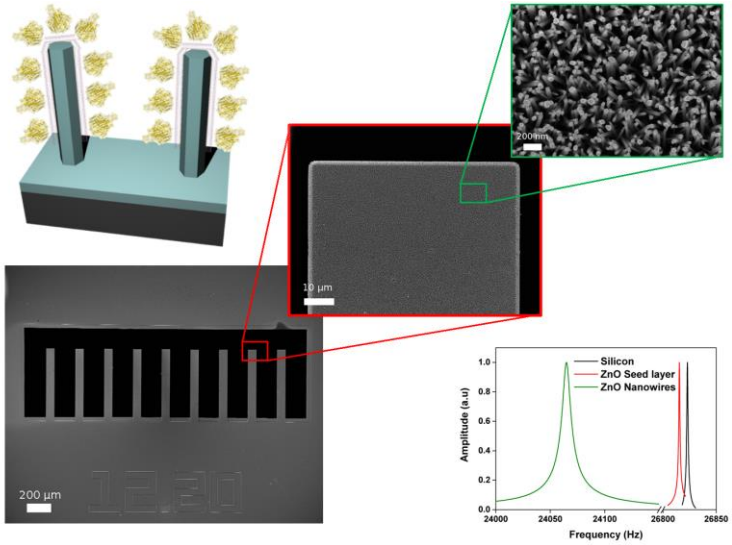


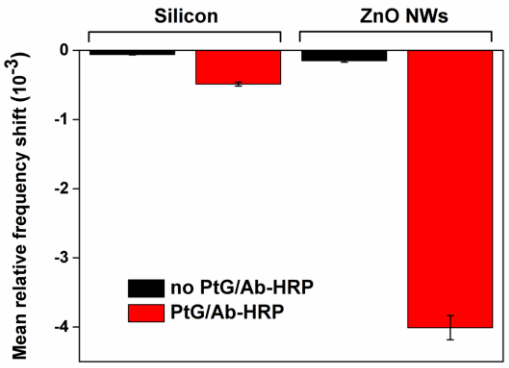
3D PRINTED SENSOR

Surface 3D Nanostructuration

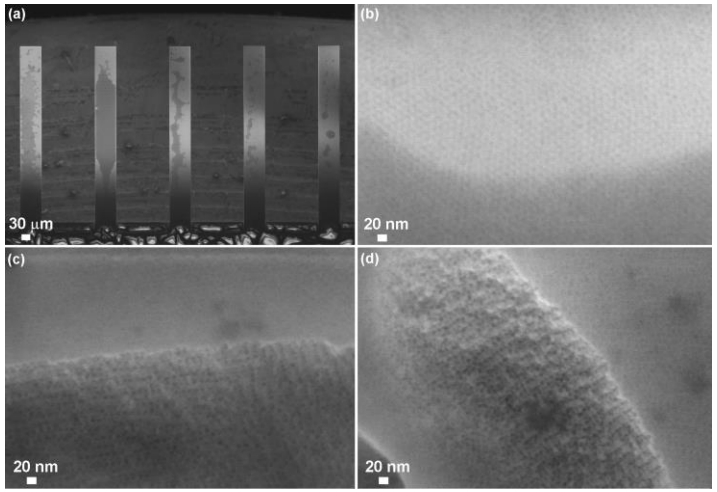
Problems with small molecules (toxins, chemicals…)
Same number of bonding sites, but lighter particles

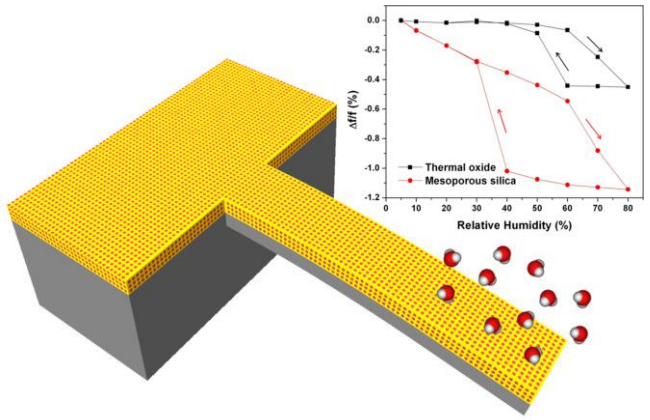
ZnO Nanowires
2 µm length





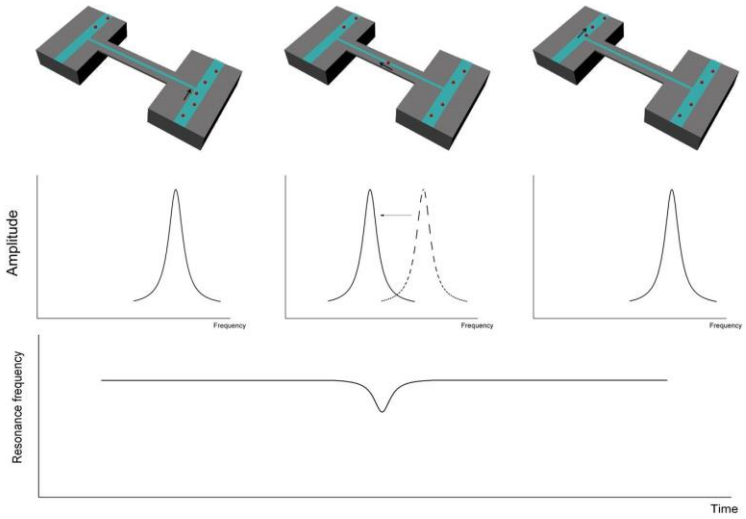
Mesoporous silica
8 nm pores

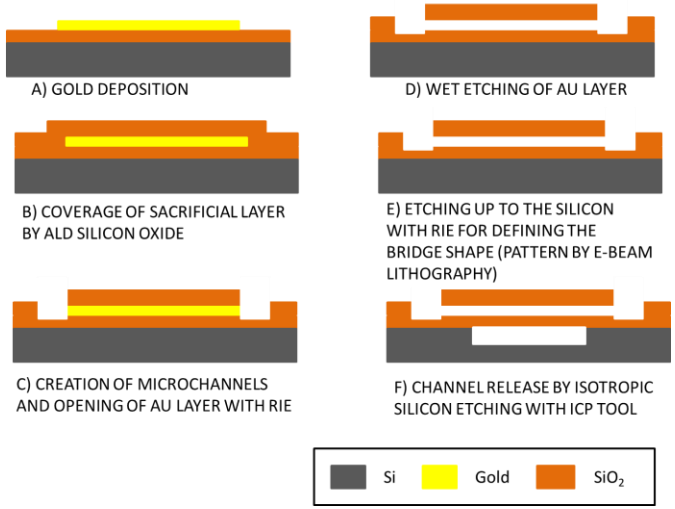


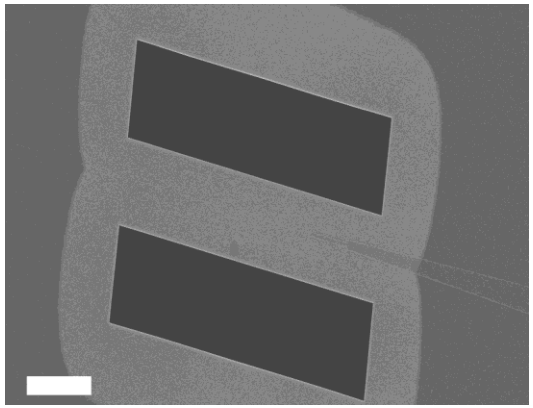


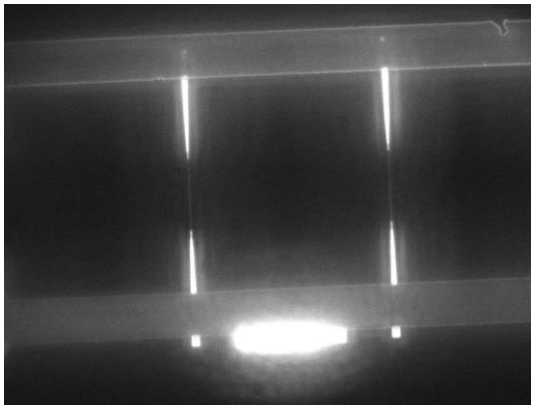
Nanofluidic resonators

- **Natural or engineered nanoparticles (NPs)**
  - ***Cell-secreted nano-vescicles (exosomes) → cancer and neurodegenerative diseases***
  - ***fate of NP → nanotoxicology***

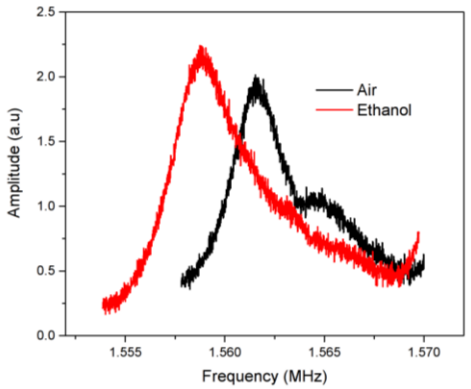








Measurement made in air
Large mass (fg) → Large Δf (10kHz)



3D printed microcantilever

3D printing of Microcantilever process

- Fast, simple and economic process

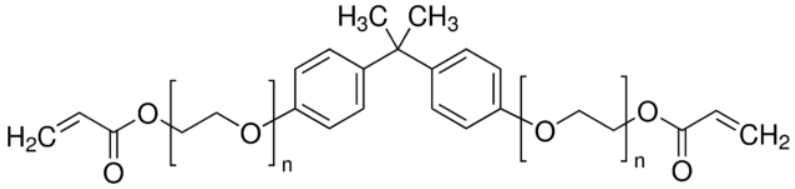
- Printing with functional resins

PRINTER

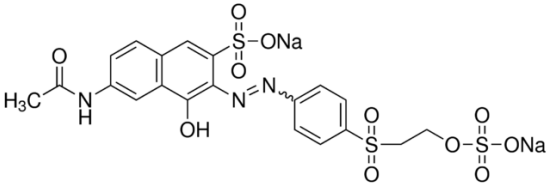
Resolution
X-Y 39 µm
Z 10 µm

Lamp
405 nm, 25 mW/cm^2

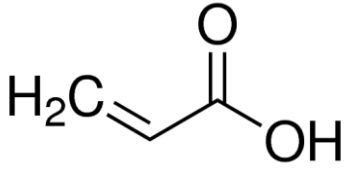
MATRIX: BEDA (Bisphenol A ethoxylate diacrylate)



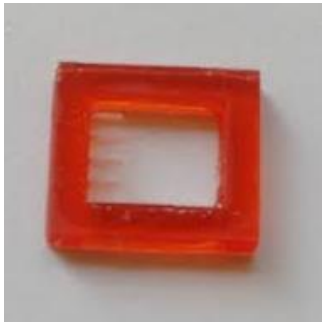
DYE: Reactive Orange 16



FUNCTIONAL AGENT: Acrilic Acid



Increasing of carboxyl group on the surface

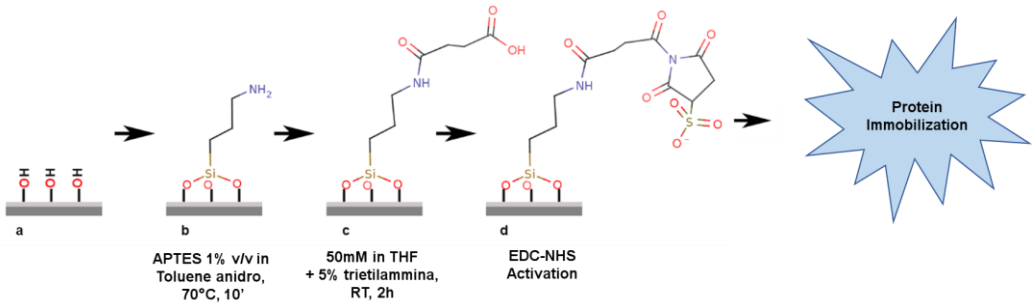


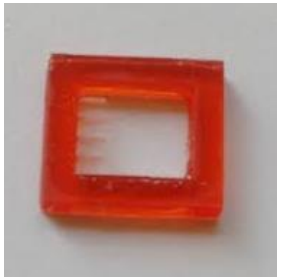
Cantilever dimension:

L 1500 µm
W 300 µm
T 50 µm

3D printed microcantilever

APTES FUNCTIONALIZATION

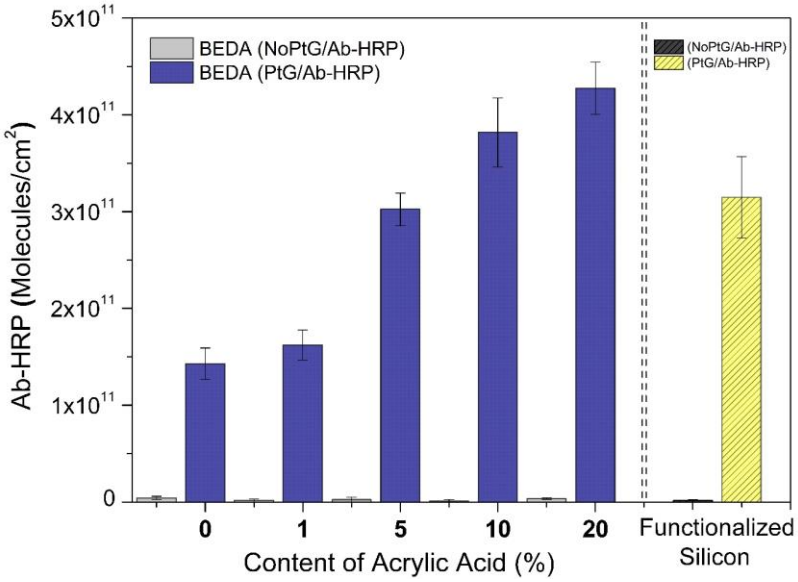


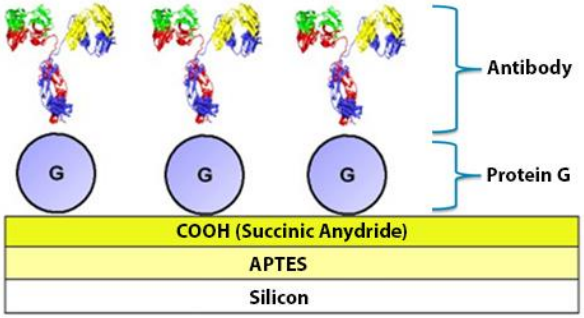


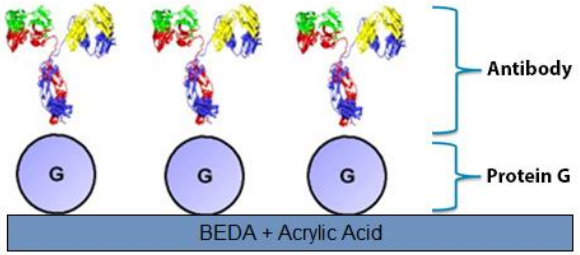
Disadvantages:

- Organic solvents
- Process in anhydrous condition
- 3 h functionalization + 45 min carboxyl group activation

(N.B. BEDA+Acrilico only 45 min)







ELISA colorimetric test

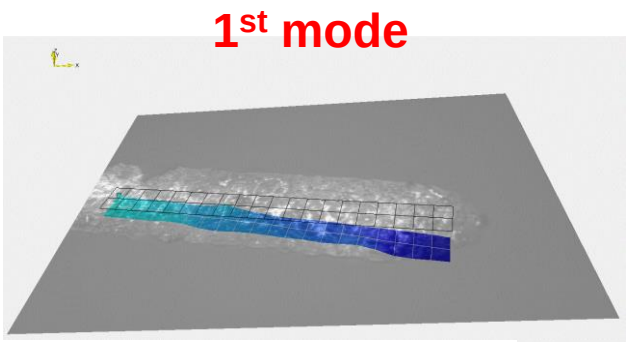
3D printed microcantilever

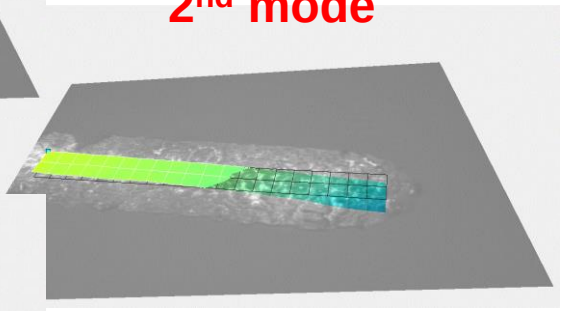
Doppler laser vibrometer MSA-500:

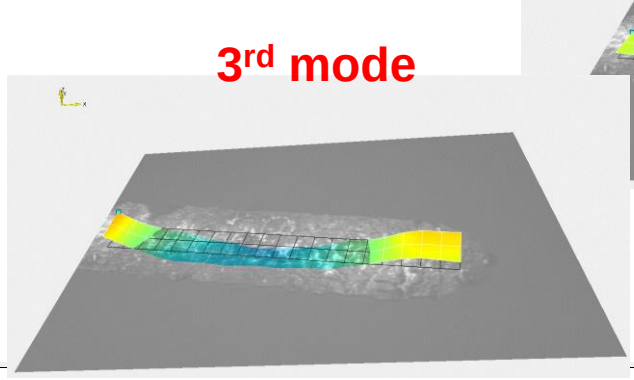
Range 0-24 MHz

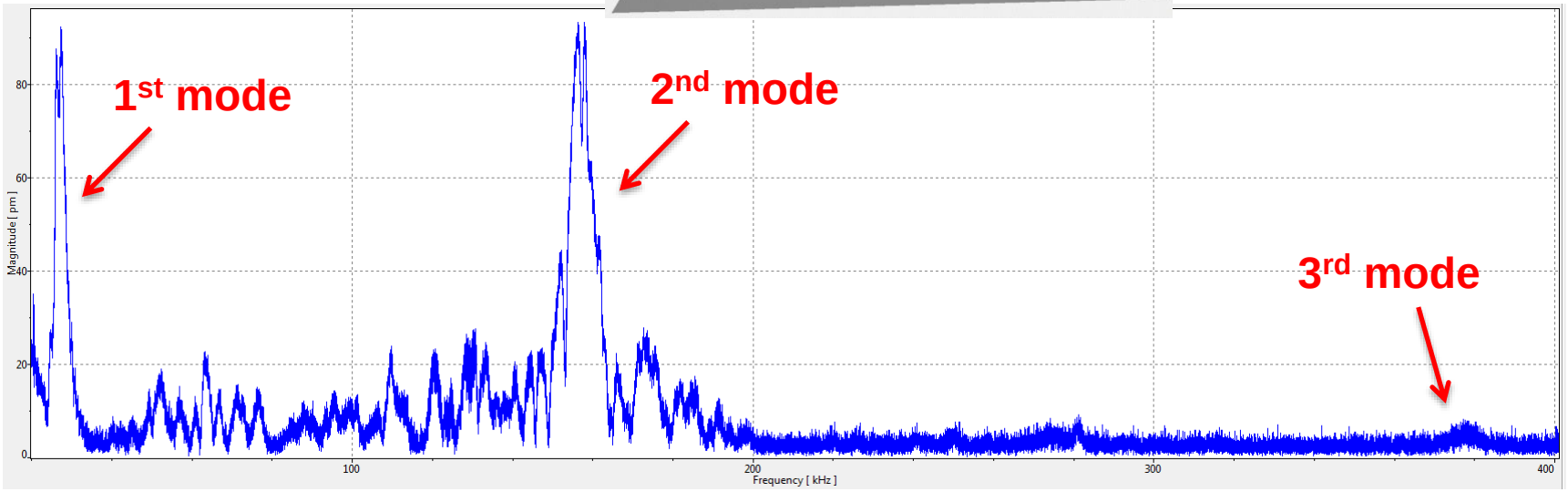
Resolution mHz

Displacement <1pm



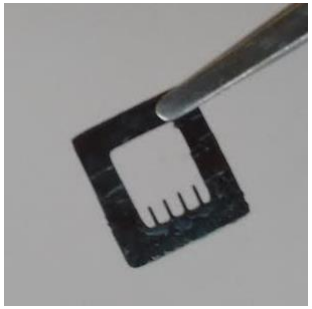




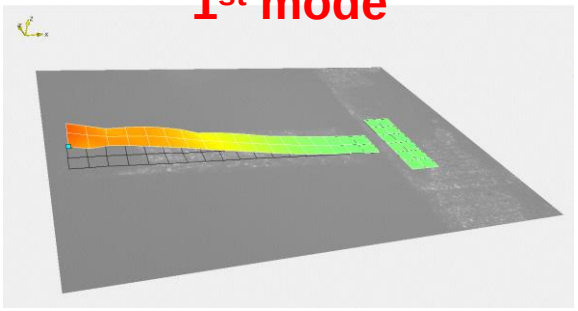


3D printed microcantilever

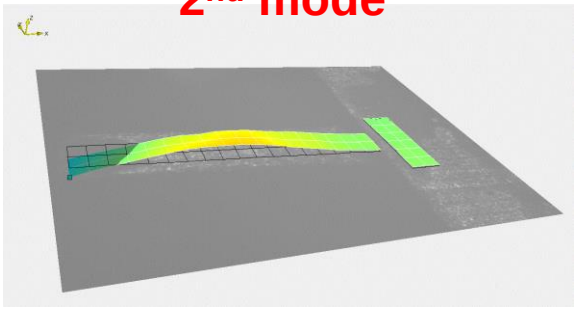
MC with silver nanoparticles on the top surface
Immunosassay with thiol group



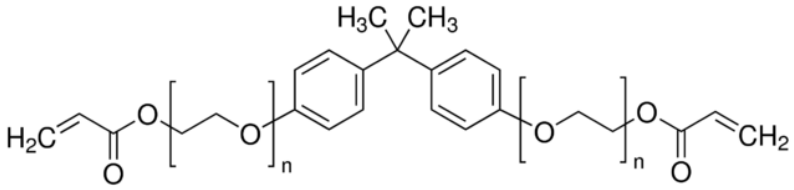
1st mode



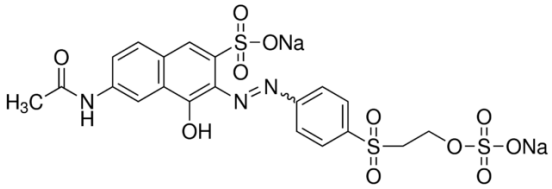
2nd mode



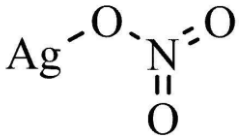
MATRIX: BEDA (Bisphenol A ethoxylate diacrylate)



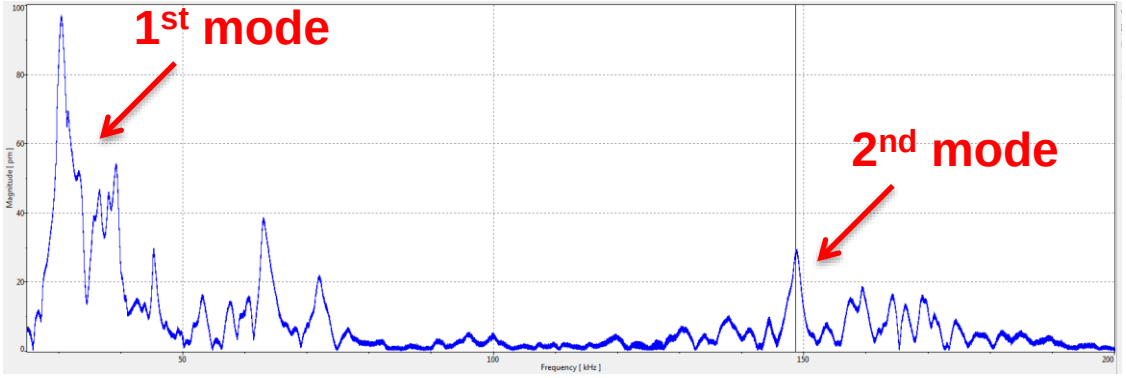
DYE: Reactive Orange 16



FUNCTIONAL AGENT: Silver nitrate

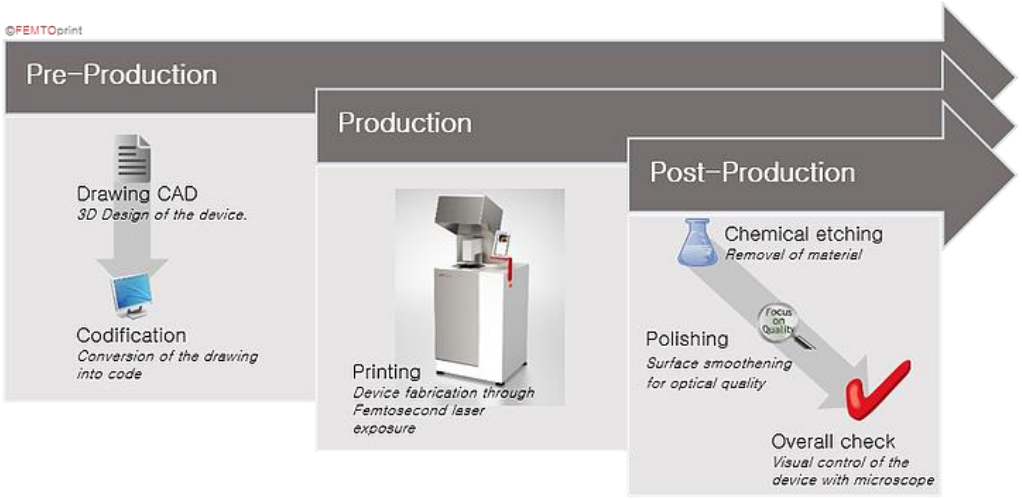


Ag nanoparticles precoursor



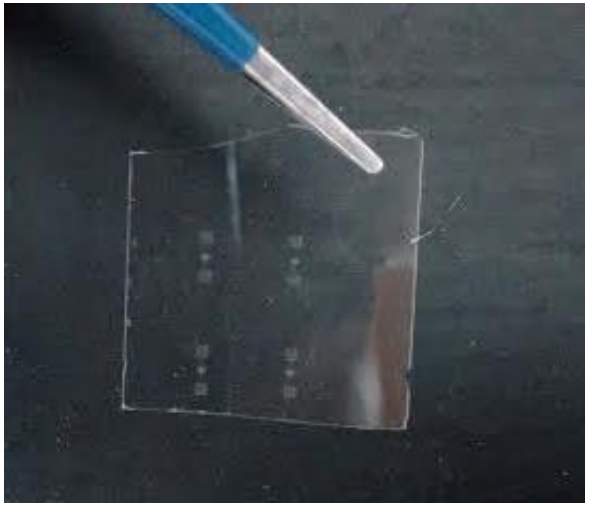
3D printed microchannel resonator

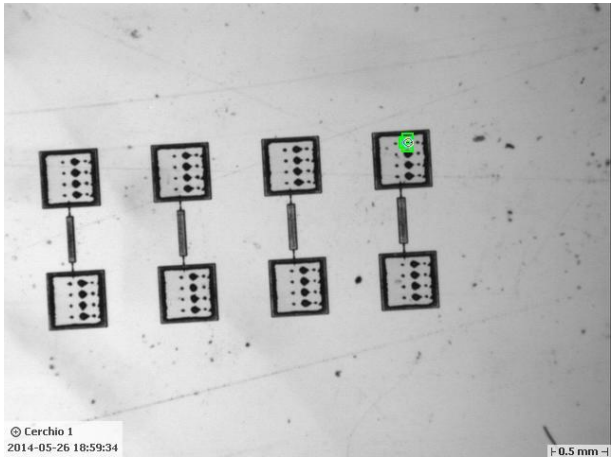
3D printing on glass substrate with a femptosecond laser source



FEMTOprint

Lugano, Switzerland

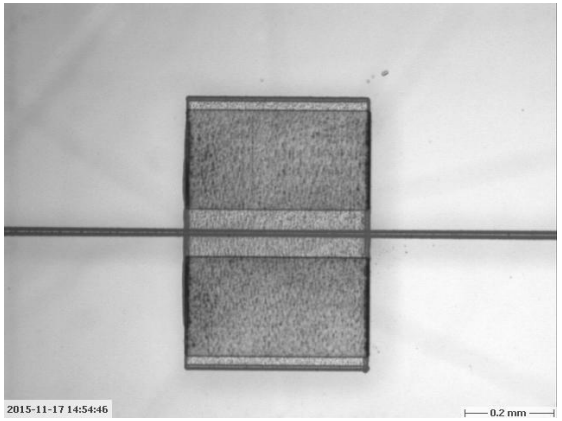




3D printed microchannel resonator

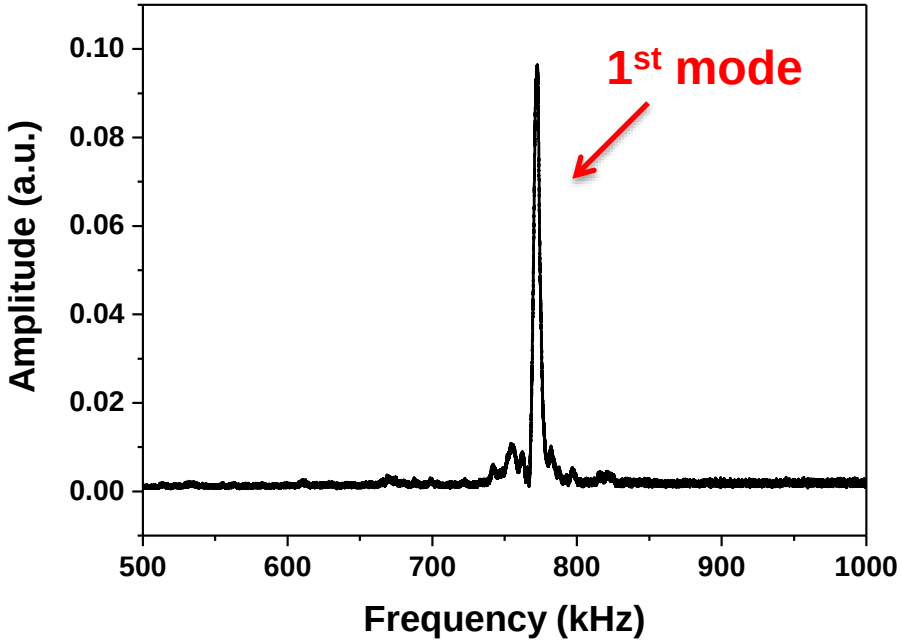
Top view

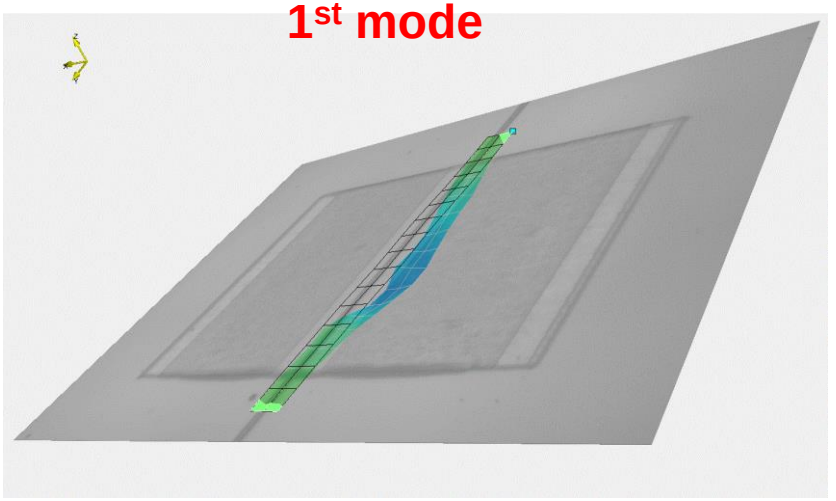
Side view



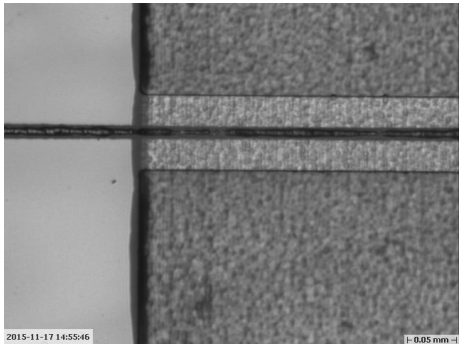
Bridge
L 500 µm
W 75 µm
T 20 µm

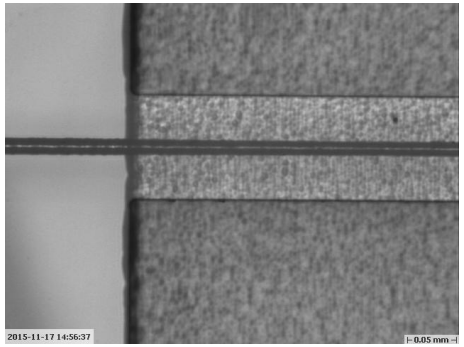
Channel
5µm x10 µm





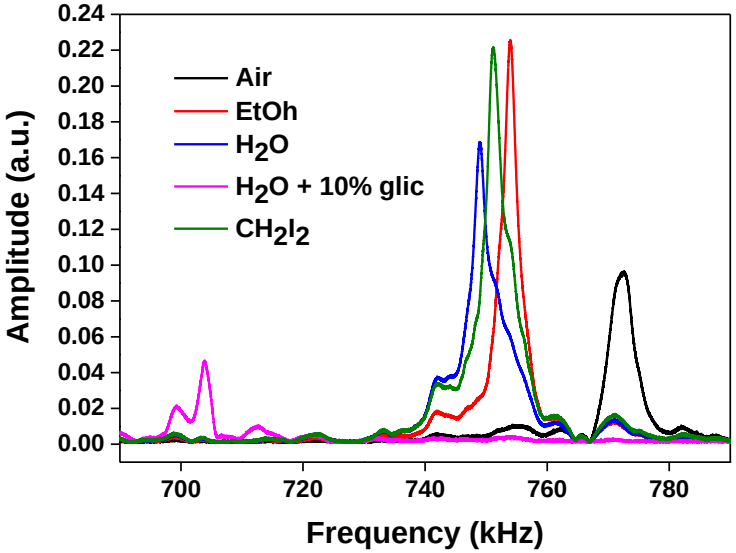
3D printed microchannel resonator



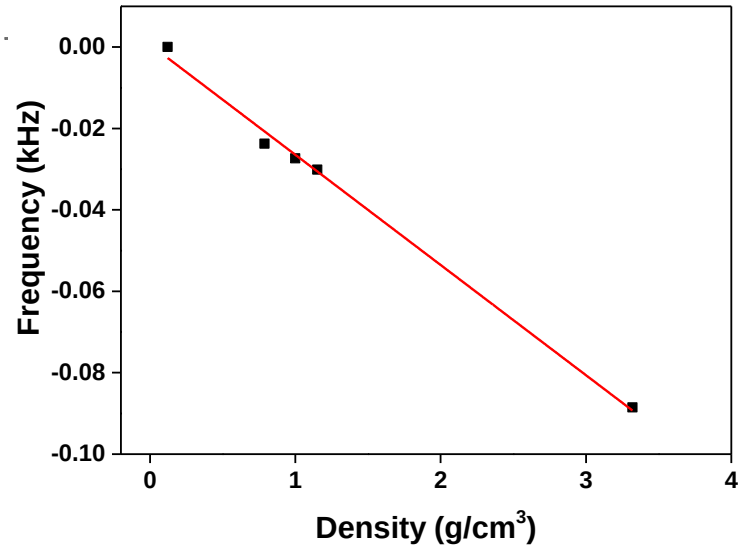


Test with liquid with different density

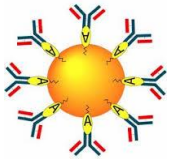
No liquid



With liquid



Coming soon: test on functionalized mesoporous silica beads



Conclusions and Acknowledgements

- **Future works:**
  - **Immunoassy on Acrilic Acid based 3D printed MC**
  - **Immunoassy with thiol groups on Ag 3D printed MC**
  - **Detection of microparticles flowing in 3D printed microchannel resonator**

- **Credits:**
  - **Roberta Calmo, Alessandro Chiadò, Davide Scalia, Erika Fantino, Carlo Ricciardi (DISAT, Politecnico di Torino)**
  - **Annalisa Chiappone, Ignazio Roppolo (CSF@Polito, IIT)**

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