ITALIAN NATIONAL AGENCY
FOR NEW TECHNOLOGIES, ENERGY AND
SUSTAINABLE ECONOMIC DEVELOPMENT

Focused Ion Beam electrode patterning for nanostructured material-based chemical gas sensor

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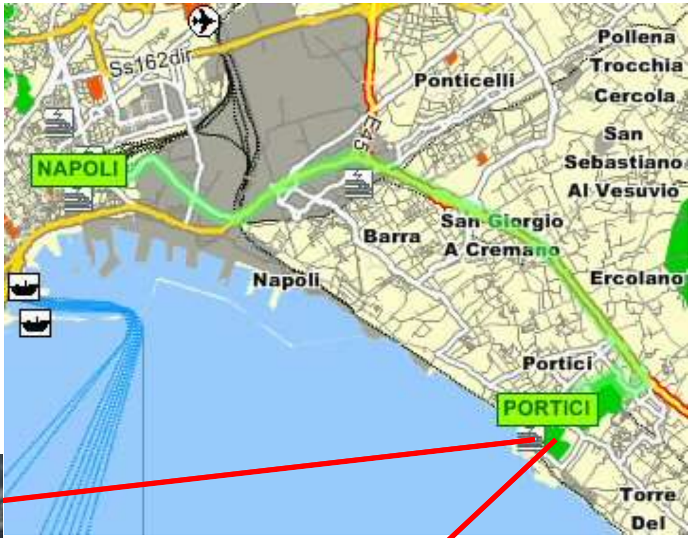
and B. Alfano, G. Fiorentino, M. Miglietta, E. Massera, T. Polichetti, G. Di Francia

EFUG MEETING 2010
Gaeta, October 11

ENEA Research Centre in Portici



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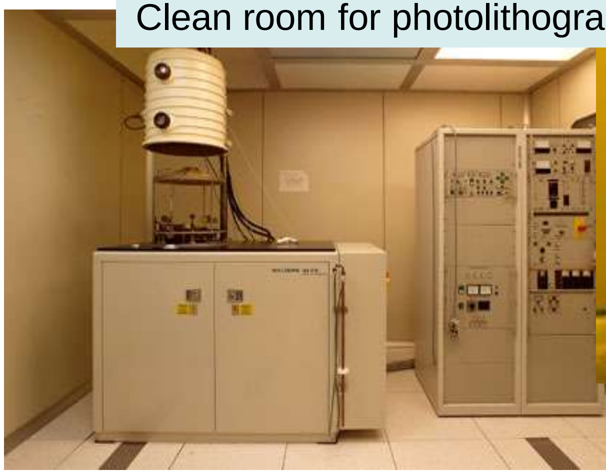
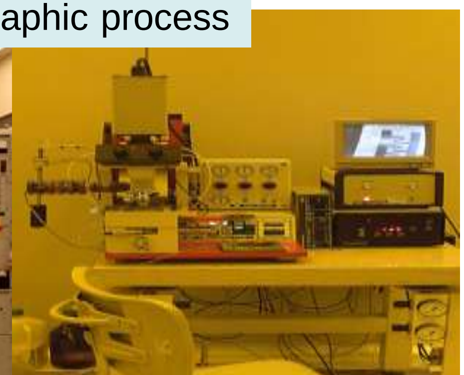
Nanotechnology Laboratory: Facilities in Portici

Clean room for photolithographic process

Surface area and pore analyzer

Dynamic Light Scattering





Dual Beam FEI QUANTA 200 3D
(SEM and Focused Ion Beam)

Optical and electrical apparatus for sensor testing

Grow-in-place approach for assembling nanowire-device

FOCUSED ION BEAM

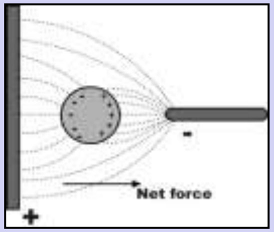
geometry of the electrodes plays a very important part

Finely focused beam of gallium ion interacts with metallorganic compounds and deposit metal nanoelectrodes

&

DIELECTROPHORESIS

non-uniform electric field polarizes small particles, in solution, moving to high electric field up to assemble nanowires

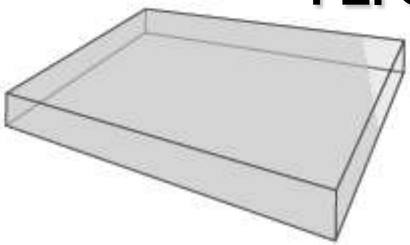


NO TEMPLATE

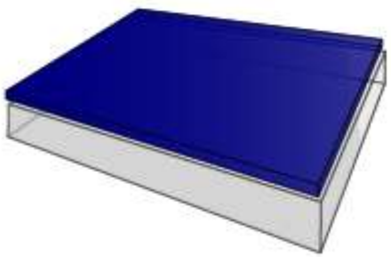
- **GROWTH**
- **POSITION**
- **ALIGN**
- **NO MANIPULATION**

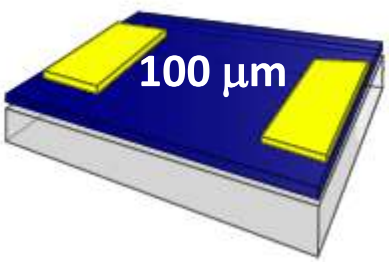
FIB-assisted platinum electrodes & Dielectrophoresis

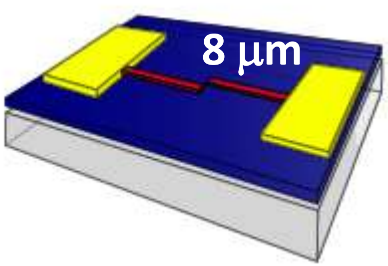
FEI QUANTA 200 3D



Silicon substrate

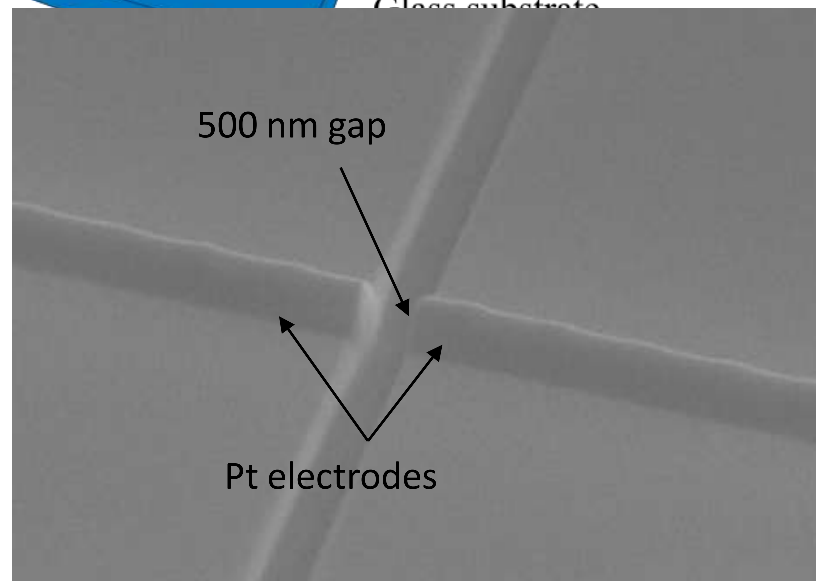


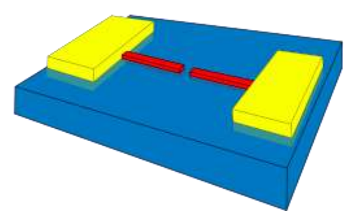




8 µm gap

Platinum microelectrodes
(300 nm in width, 500 nm in height)
deposited by
FOCUSED ION BEAM (FIB)





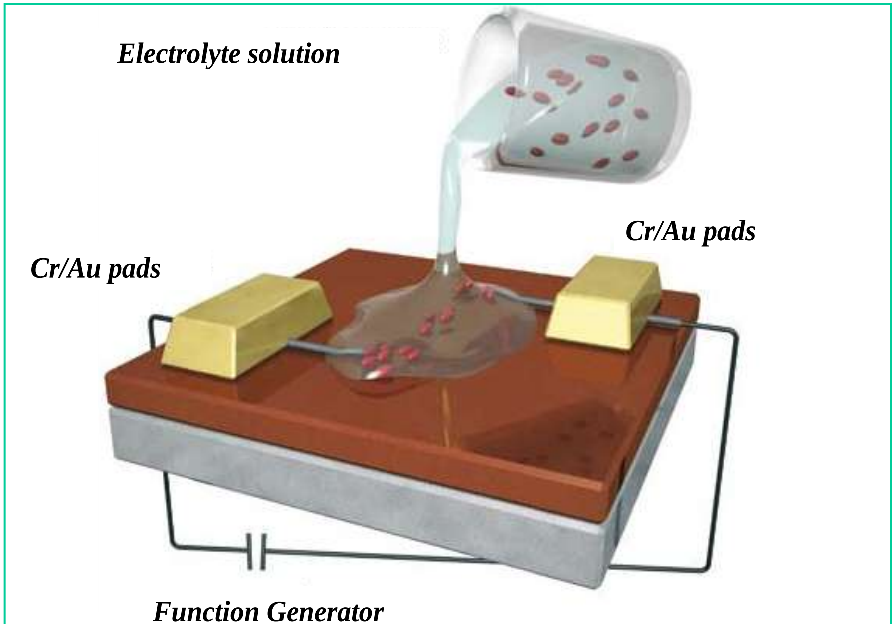
Gap milling by FIB

500 nm

DIELECTROPHORESIS

ELECTROLYTE SOLUTIONS

1. Palladium acetate solution
2. ZnO in DIW solution
3. graphite dispersion in N-Methyl Pyrrolidone and exfoliation in graphene

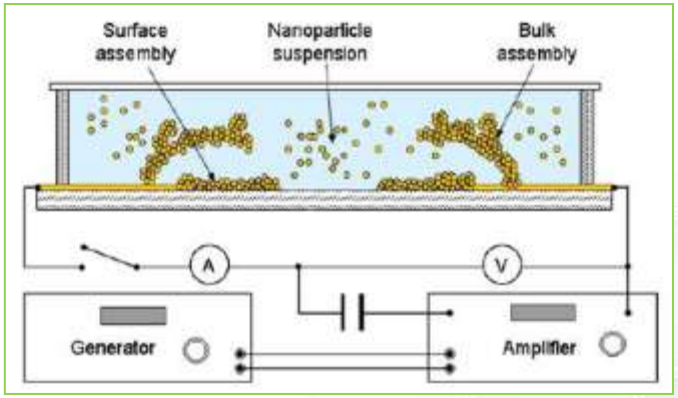


Di Francia, La Ferrara and Alfano "Le Scienze "2010

$$\left\langle \vec{F}_{DEP} \right\rangle = 2\pi\varepsilon_m \operatorname{Re}\left|K(\omega)\right| R^3 \nabla \left|\vec{E}\right|^2$$

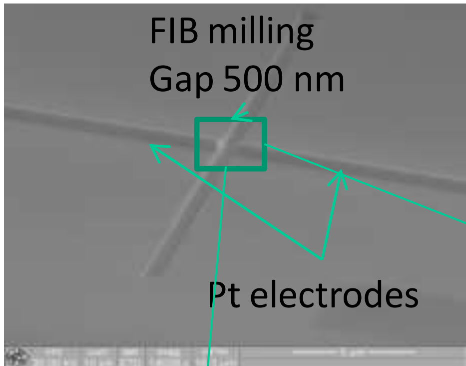
Clausius-Mossotti Factor

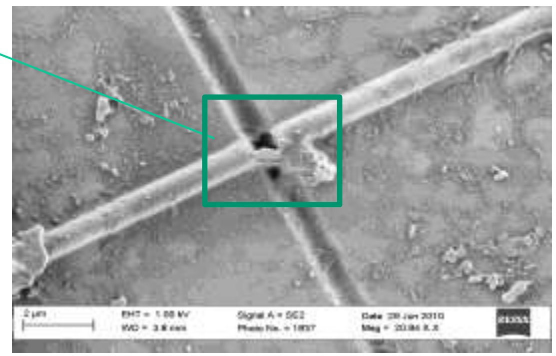
$$\operatorname{Re}\left|K(\omega)\right| = \frac{\varepsilon_p - \varepsilon_m}{\varepsilon_p + 2\varepsilon_m} + \frac{3(\varepsilon_m \sigma_p - \varepsilon_p \sigma_m)}{\tau_{MW}(\sigma_p + 2\sigma_m)^2 (1 + \omega^2 \tau_{MW}^2)}$$

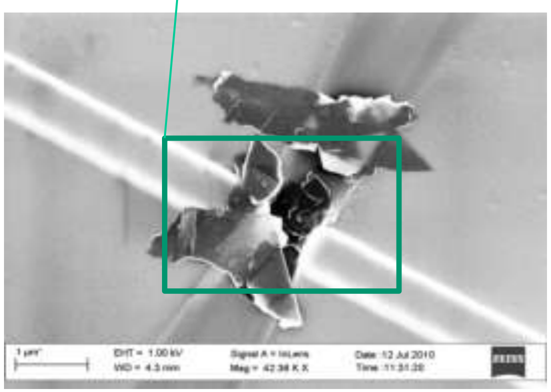


PRELIMINARY RESULTS

Graphene-based devices





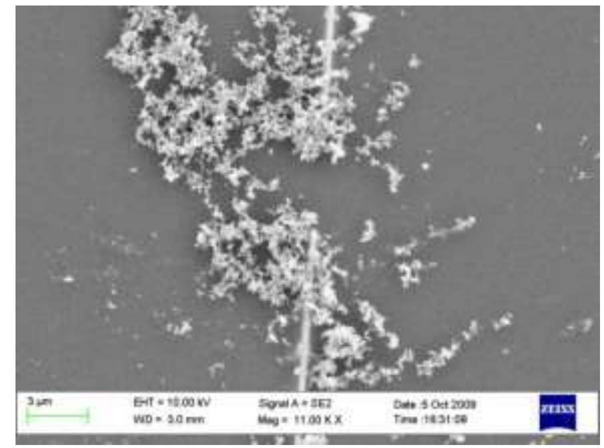


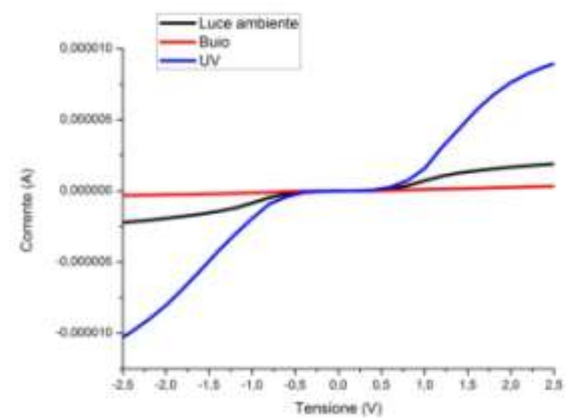
R =700 kΩ

Preliminary results: **capture of thick flakes and not of single-layer graphene.**

Results show that when dielectrophoresis is applied to an organic solvent graphene dispersion only thick flakes are driven towards the electrodes, because **single-layer graphene are present at low concentration** in the solution.

ZnO-based devices

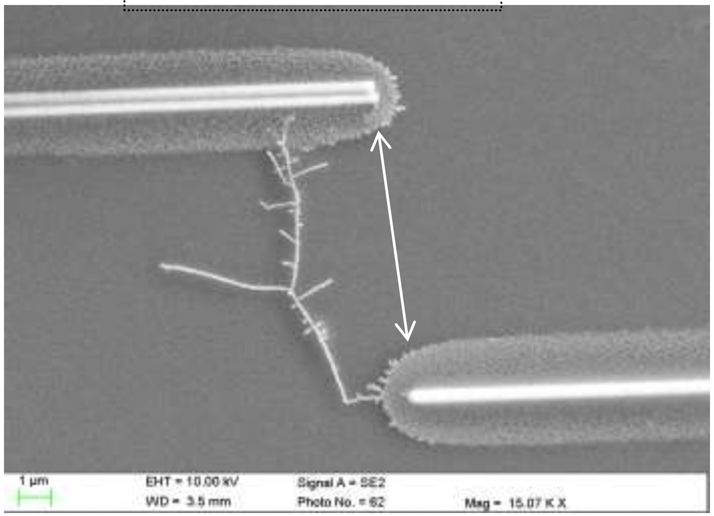




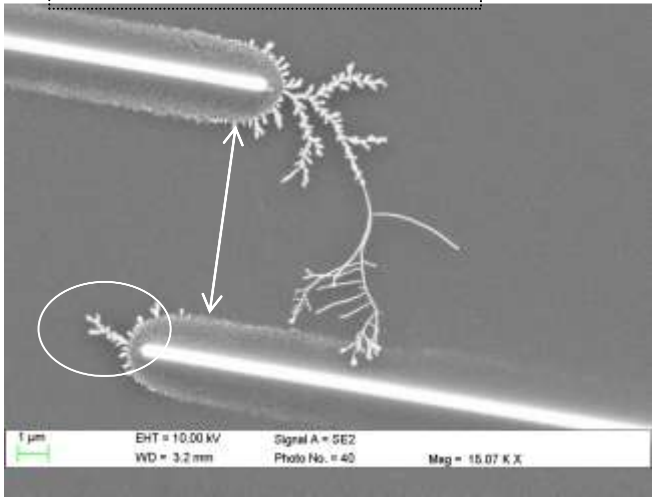
SENSOR DEVICE: SINGLE PALLADIUM NANOWIRE

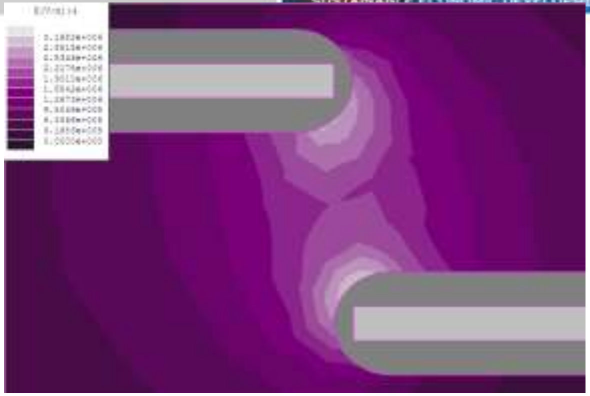
electrode geometry influences the nanowire growth: fixing the frequency at 300kHz

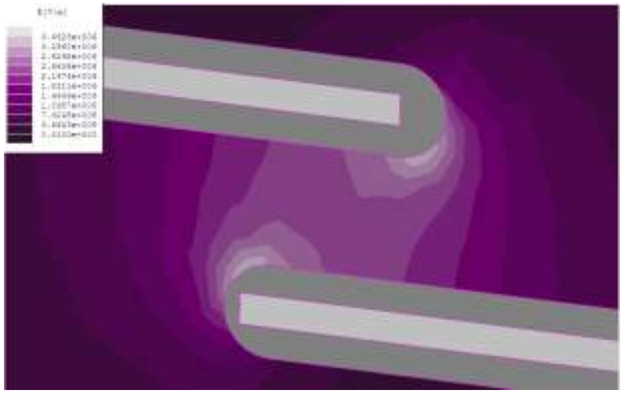
No overlapping
Gap 7 μm



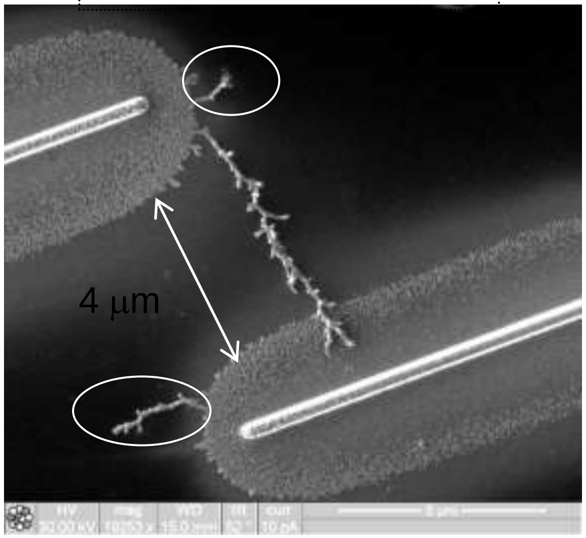
overlapping 3 μm
Gap 7 μm



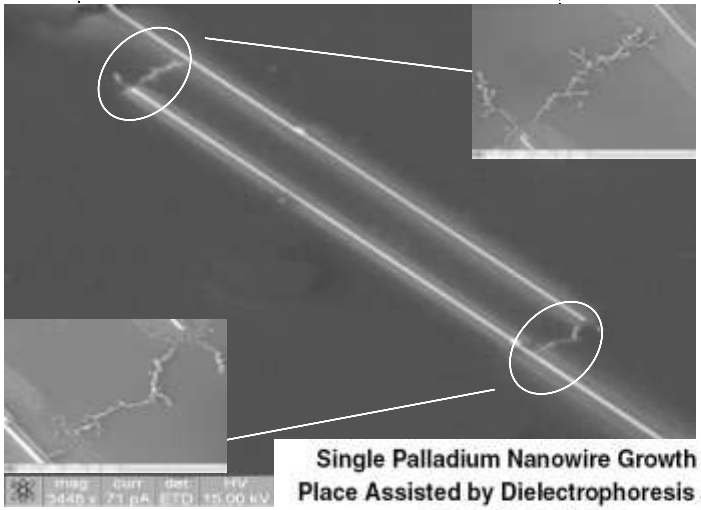


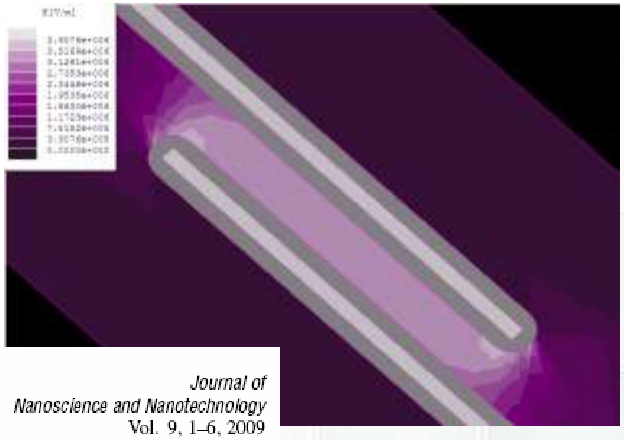


overlapping 2 μm
Gap 4 μm



overlapping 100 μm
Gap 6 μm





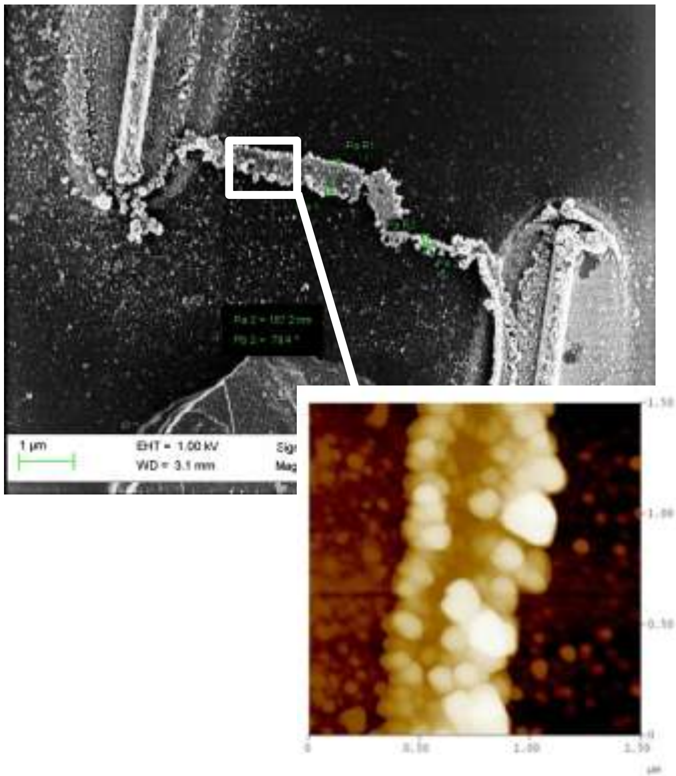
Single Palladium Nanowire Growth in Place Assisted by Dielectrophoresis and Focused Ion Beam

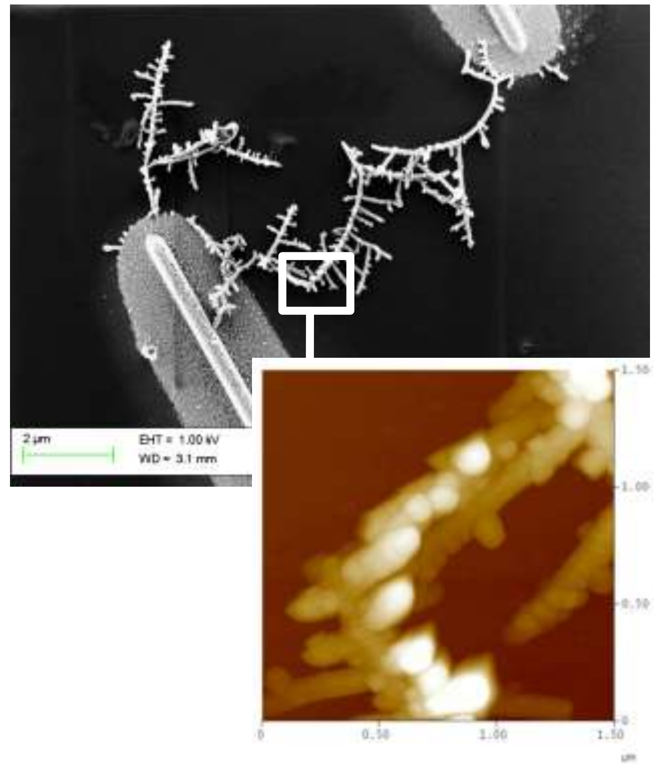
Vera La Ferrara[1,*], Brigida Alfano[2], Ettore Massera[1], and Girolamo Di Francia[1]

Journal of Nanoscience and Nanotechnology
Vol. 9, 1–6, 2009

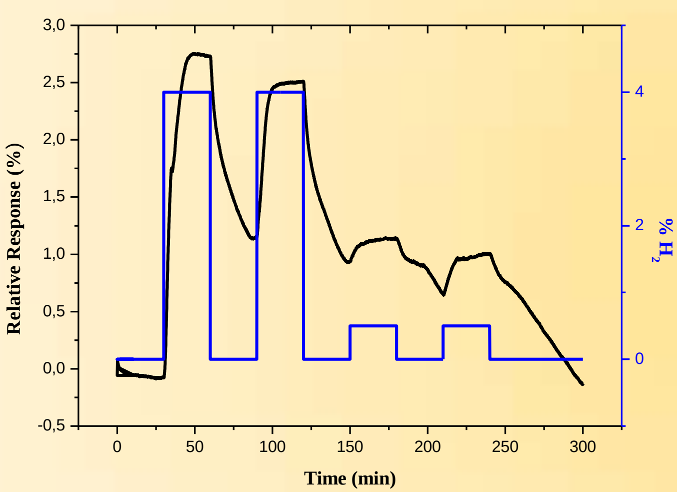
Single Pd Nanowire based HYDROGEN sensor

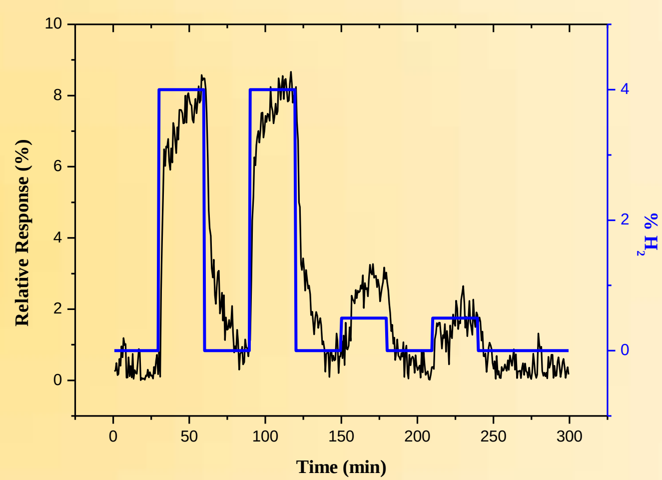
Frequency influences the nanowire growth: fixing the electrode pattern





- compact grain structure
- overlaid layers
- Grain diameter ranging from 30 to 100 nm.





CONCLUSIONS

PROCEDURE

i) One/two **platinum nanoelectrodes** have been deposited by **FIB and eventually milled for nanogap**

ii) nanoparticles solution is dropped between nanoelectrodes;

iii) an **alternating electric field (DEP)**, conducts to **single nanowire or nanostructures assembly**

- **DEP is versatile technique controlling nanowire length, diameter and position**
- **FIB process is a direct-write method to realize nanopatterned electrodes**
- **single palladium nanowire based device operating as Hydrogen sensor at RT**
- **Preliminary results on graphene and ZnO**

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