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

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Nanotechnology Laboratory: Facilities in Portici

Clean room for photolithographic process

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

Surface area and pore analyzer

Dynamic Light Scattering

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

Glass substrate

500 nm gap

Pt electrodes

Gap milling by FIB

500 nm

8 μm gap

8 μm

100 μm

100 μm

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

ELECTROLYTE SOLUTIONS

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

\[
\left\langle \vec{F}_{DEP} \right\rangle = 2\pi \varepsilon_m \text{Re}\left| K(\omega) \right| R^3 \mid \vec{E} \mid^2
\]

**Clausius-Mossotti Factor**

\[
\text{Re}\left| K(\omega) \right| = \frac{\varepsilon_p - \varepsilon_m}{\varepsilon_p + 2\varepsilon_m} + \frac{3(\varepsilon_m \sigma_p - \varepsilon_p \sigma_m)}{\tau_{MW} \left( \sigma_p + 2\sigma_m \right)^2 \left( 1 + \omega^2 \tau_{MW}^2 \right)}
\]
**Preliminary Results**

**Graphene-based devices**

- Pt electrodes
- FIB milling
- Gap 500 nm

**ZnO-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.
 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

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Vera La Ferrara, Brigitte Altare, Etienne Mussera, and Girolamo Di Francia
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

• 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

PROEDURE
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

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