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NanoSen-AQM: Nanostructured resistive sensors for the detection of atmospheric pollutants

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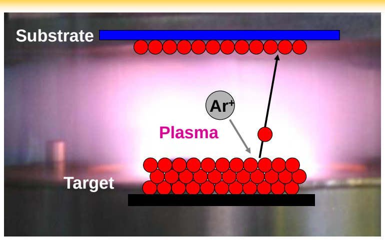
Abstract

The main objective of the NanoSen-AQM project (Interreg-Sudoe program from European Union) is to assess the air quality and to inform citizens in real time in distributed and sustainable way. In the project a new generation of nanosensors for external air quality management (mainly detection of NO2, CO and O3 pollutants) will be developed by the groups of CSIC (Madrid), CNRS-CIRIMAT (Toulouse) and CNRS-LAAS (Toulouse) and UEX (Badajoz). These partners will develop low cost resistive nanosensors based on nanostructured metal oxide semiconductors (SnO2, ZnO, ZnO:Ga, Co3O4, CuO,...). Sensitive materials nanostructures improve the gas sensing properties such as sensitivity, selectivity and response speed. These nanostructures will be deposited in various forms: nanowires, nanofibers, nanobelts, nanoparticles, thin films … and will be doped with functional materials (graphene, metal nanoparticles) or in the form of nanocomposites. The nanotechnologies that will be used for the fabrication of the sensing materials are low pressure chemical vapour deposition (LPCVD) aerosol assisted chemical vapour deposition (CVD), electrospinning (ES), atomic layer deposition (ALD) and RF-sputtering (RFS). The nanomaterials will be deposited onto silicon micromachined and polymeric substrates. The interest of polymeric substrates is their low cost, however they remain dedicated to measurements at low or moderate temperature. The micromachined heating platform can generate very rapid temperature variations, which is suitable for operating the sensor in a pulsed mode in order to improve the sensitivity/selectivity.

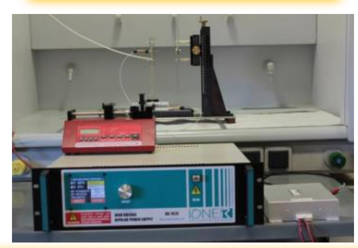
Elaboration and characterization of sensitive materials

RF sputtering deposition from ceramic target



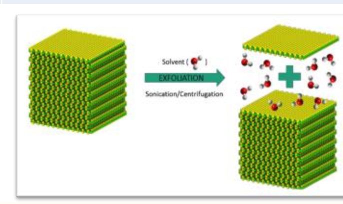
Different sputtered oxides :
- ZnO:Ga (2%)
- Co_3O_4, $Co_{1.7}Fe_{1.3}O_4$, and other spinel oxydes
- CuO, NiO, ...

Electrospinning

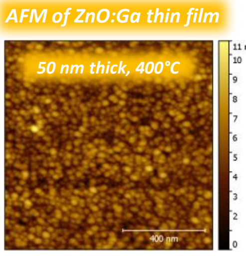


Graphene based sensitive materials

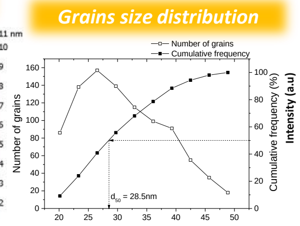
Sensor	Precursor
Gr	Graphite chemical exfoliation
GrSnO2	GrSnO2 (3:1) (100uL) + 500 uL GAV H20+IPA
GrTiO2	GrTiO2 (3:1) (100uL) + 500 uL GAV H20+IPA
GrZnO	GrZnO (3:1) (100uL) + 500 uL GAV H20+IPA



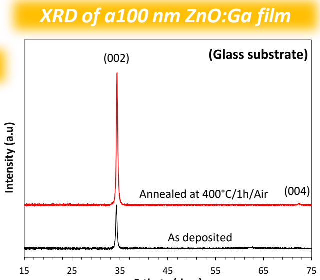
AFM of ZnO:Ga thin film



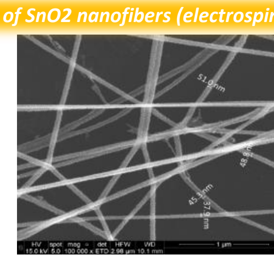
Grains size distribution



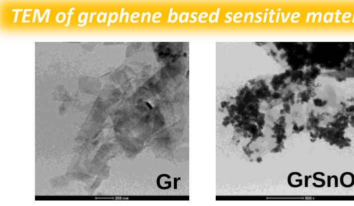
XRD of a100 nm ZnO:Ga film



SEM of SnO2 nanofibers (electrospinning)

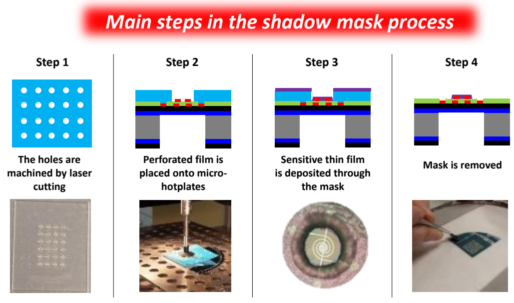


TEM of graphene based sensitive materials

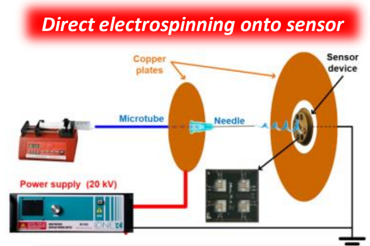


Integration

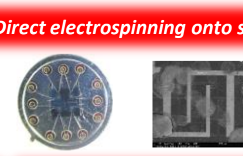
Main steps in the shadow mask process



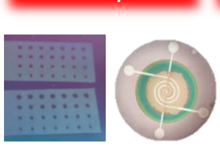
Direct electrospinning onto sensor



Direct electrospinning onto sensor



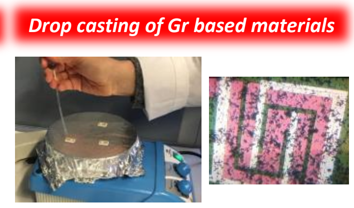
ZnO:Ga deposited



Multi-sensor (4 chips)

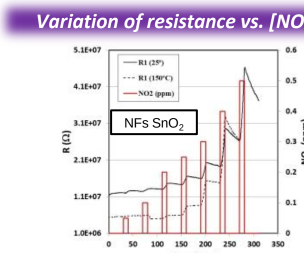
Polymer substrates

Drop casting of Gr based materials

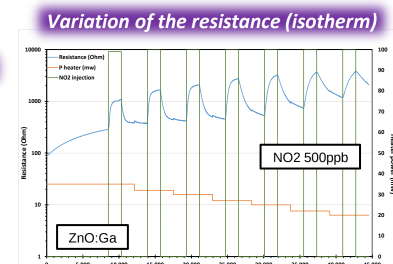


Sensing tests

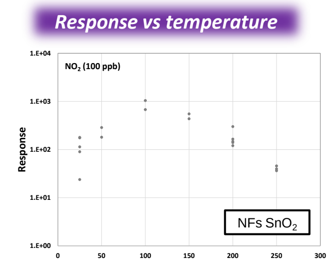
Variation of resistance vs. [NO2]



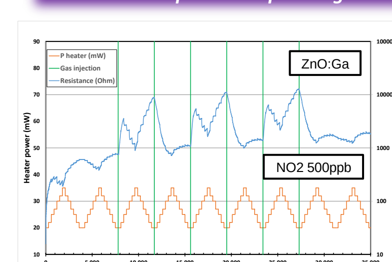
Variation of the resistance (isotherm)



Response vs temperature



Variable temperature operating mode



Conclusion

Multi-sensors will be prepared for operation in complex atmospheres containing various interfering gases to improve the selectivity. Due to the high number of materials studied and the large number of possible combinations between sensitive oxides and dopants (metals or oxides), it will thus be possible to deposit the best combinations on these multi-chip sensors to have efficient and selective sensors for outdoor air quality monitoring.

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