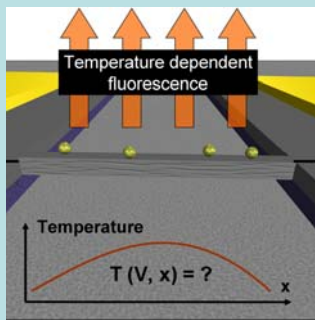


Principe et Objectifs



Il s'agit de caractériser thermiquement des nanofils métalliques et semi-conducteurs en utilisant des nanosondes fluorescentes dont les propriétés d'émission sont dépendantes de la température. Les nanofils sont obtenus en utilisant plusieurs procédés de fabrication : lithographie électronique, croissance électrolytique sur membranes poreuses et croissance par épitaxie. Plusieurs types de sondes sont comparées (nanoparticules, nanocristaux, molécules organiques et inorganiques, etc.) afin d'accroître les résolutions spatiales et temporelles en milieux sec et liquide.

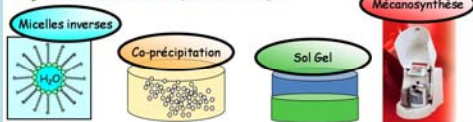
Outre la compréhension des phénomènes de transfert thermique dans des structures de faible dimensionnalité, ce projet vise à développer des capteurs chimiques et biologiques dont les propriétés de surface sont modulées thermiquement.

Fabrication of fluorescent particles

Choix des techniques expérimentales

- ➔ Critères à respecter :
- Taille nanométrique intermédiaire (40 nm - 500 nm)
 - Distribution monodisperse (taille)
 - Morphologie sphérique
 - Pureté chimique

Différentes voies de synthèse envisagées :

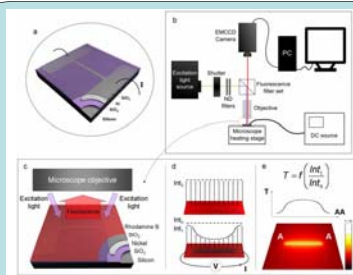


Techniques d'analyses utilisées :

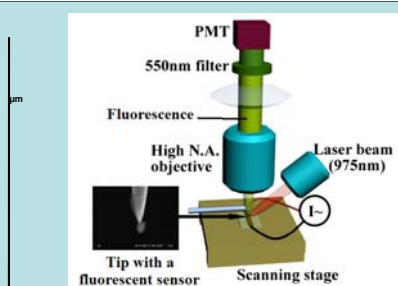
- FTIR
- DRX
- MET

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Fluorescence Thermometry : Two experimental configurations

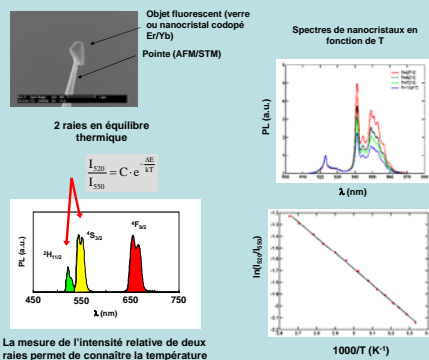


a) Resistive heating in a metal micro- or nanowire is used in our case to achieve locally confined temperature changes. b) Setup for fluorescence thermometry using an EMCCD camera to capture fluorescent images. c) The sample is covered by a thin and dense layer of Rhodamine B molecules. d) Local heating occurs when a current is applied to the sample. Depending on the local temperature change, the local emitted fluorescence intensity changes. e) With precise knowledge of the relation between intensity change and temperature change, a given change in intensity can be converted to temperature.

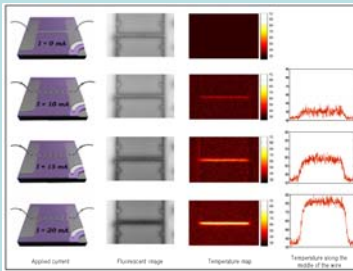


Description of the experimental set-up for Scanning Thermal Imaging. A small fluorescent particle (diameter < 500nm) is glued at the extremity of an atomic force microscope tip. The particle is excited with a laser beam. When it 'touches' a hot zone, the fluorescence is modified. The set-up works in a dc or ac mode. In the ac mode (see images below), the device is heated with an alternating current ($f \sim 1\text{kHz}$) which modulates the fluorescence emission of the particle.

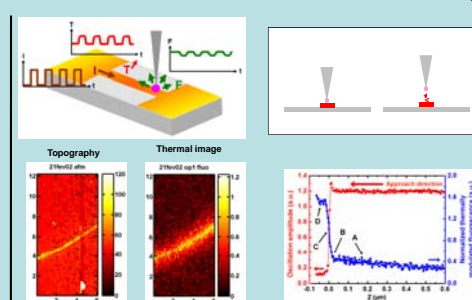
Photoluminescence spectra



Experimental results obtained for metallic nanowires

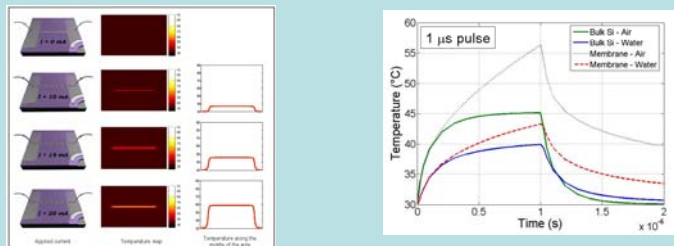


Resistive heating in an 80 μm long, 2 μm wide and 40 nm thick wire. When a current is applied through the wire, local resistive heating occurs due to the geometrical confinement that the wire represent. The top row shows the case where no current is applied. The next three rows show the cases for gradually increasing currents of 10 mA, 15 mA, and 20 mA. The first column shows the applied current value; the second column, the Rhodamine B fluorescence images; the third column, the temperature images after the conversion of the intensity changes; and the fourth column, the temperature along the middle of the respective wire.



Schematic cross-sections (a,d), topography (b,e) and thermally modulated fluorescence images (c,f) of two different 200nm-wide Ni stripes. The structures, which only differ by the presence of a 50nm-thick SiO₂ passivation layer, have been studied with two different tips. The values given in (a,d) indicate the thickness of the different layers.

3D Finite Element Simulations

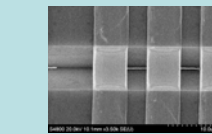


Using the FEM simulation software COMSOL, theoretical predictions, particularly those regarding the temperature distribution, can be made. From the top row to the bottom, simulated temperature maps of the four cases. As the current is increased, the temperature increases while the profile of the temperature distribution remains virtually the same.

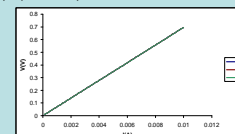
Temporal response of the temperature on top of the center of the nanowire and at the interface between the passivating oxide and the medium above (air or water). It is clearly observed that the use of a suspended membrane structure gives a slower response.

Perspectives

- Development of a Scanning thermal imaging apparatus that works in a liquid cell.
- Thermal characterization of nanowires in AC mode at higher frequencies (1 to 10kHz).
- Thermal characterization of segmented nanowires (membranes poreuses)
- Thermal simulation using molecular dynamics
- Thermal modulation of thermoresponsive polymers deposited on the nanowires



Gold nanowires prepared by electrodeposition in porous alumina membranes (250nm diameter, 6 μm thickness) aligned by a capillary method, then addressed by lift-off of gold electrodes.



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