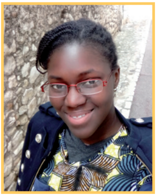

Highly conductive PEDOT materials for all-polymeric flexible transparent heaters and thermoelectricity

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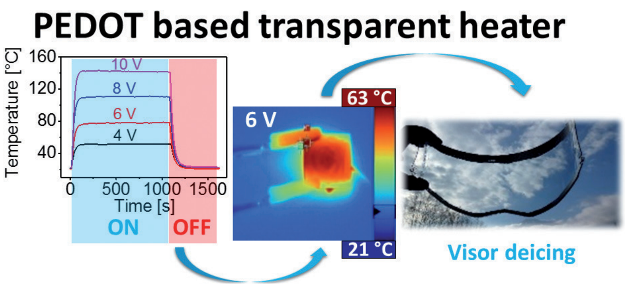
PHD GRANT

LABORATORIES : INAC, LITEN

During this thesis we developed one of the most conductive PEDOT-based material for future optoelectronic and thermoelectric applications. First our materials were fully characterized and the interesting properties for the targeted applications were investigated using techniques available in different laboratories in Grenoble (ESRF, INAC, Liten, PTA nanocharacterisation facilities of CEA). In particular, not alone are our materials very conductive, but they also are highly transparent. Finally they were investigated as thermoelectric materials, transparent electrodes in solar cells and we also demonstrated a novel application of PEDOT as transparent heater. Noteworthy, our PEDOT materials can heat above 120 °C under a bias of 12 V, a result that opens the route for future applications of de-icing or defogging windshields or other surfaces during winter.

These experimental results are comforted by a theoretical physical model; and a prototype of a visor de-icer has also been demonstrated to highlight this new application .



Left: temperature response time under different bias, middle: Thermal image showing the uniform heating, right: visor de-icer prototype.

OUTCOMES

[1] Structure and dopant engineering in PEDOT thin films: practical tools for a dramatic conductivity enhancement, Chem. Mater. 28, 3462 (2016).

[2] All polymeric flexible transparent heaters, ACS Appl. Mater. Interfaces 9, 27250 (2017).

Patent: Liten patent "Utilisation à titre d'élément chauffant d'un films polymérique conducteur et transparent à base de polymères poly(thio-séléno-)phéniques" (n° WO2018069286A1)

Oral presentations: EMRS-Fall, Warsaw, Poland, 2016; Orzel, Scztzyrk, Poland, 2017; Synohe, Annecy, France, 2017.

Semiconducting Nanowires for Thermoelectrics

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LABORATORIES : INAC, NEEL

For high thermoelectric efficiency, materials with high electrical conductivity and low thermal conductivity are needed. The thermal conductivity of semiconductors is dominated by phonon transport, implying that the electrical and thermal conductivities can be decoupled. For instance, the mean free path of phonons in a silicon nanowire is strongly reduced by surface scattering if the diameter of the nanowire is reduced.

We grow forests of doped silicon nanowires using Chemical Vapor Deposition with gold droplets to induce the Vapor-Liquid-Solid mechanism. The nanowires undergo guided growth in alumina templates with pores formed by anodizing aluminum.

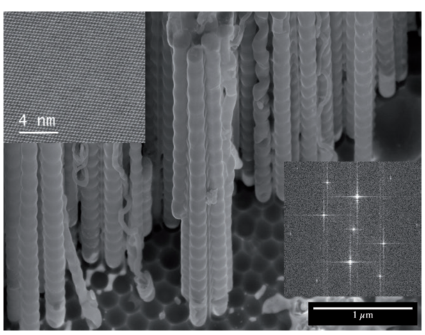

Fig. 1 : SEM image of the diameter-modulated silicon nanowires. (Insets) High-resolution TEM image and its FFT showing the crystal structure of the nanowires.

The nanowire profile follows the internal geometry of the pores, which is tuned by changing the parameters of the anodization (Fig. 1). We measure the thermal conductivity of the forest of nanowires embedded in the template (using the 3ω method and Raman thermometry) and the electrical conductivity of single nanowire; we use SEM and TEM for structural characterization. The thermal conductivity of silicon nanowires of diameter equal to 65 nm was measured to be 10 $Wm^{-1}K^{-1}$ at 300K, an order of magnitude below that of bulk silicon. Optimizing the thermal conductivity through the nanowire morphology and the electrical conductivity through doping should allow us to obtain large values of the power factor and realize a cost-effective thermoelectric device.

OUTCOMES

[1] Anisotropic thermal conductivity of a dense forest of nanowires with 3 ω method, accepted Rev. Sci. Instrum.

Communications: EMRS, Strasbourg, 2017; GDRe Thermal NanoScience, Lille, 2017

Collaboration: Institut Català de Nanociència i Nanotecnologia, Barcelona

Others: Selected for the InnoEnergy PhD School.

Semiconducting Nanowires for Thermoelectrics

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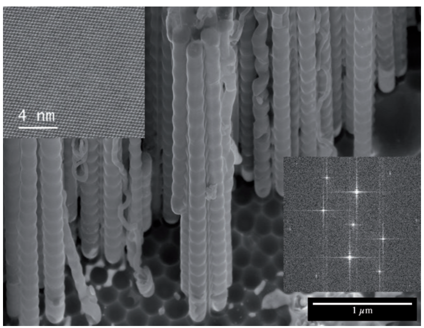

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