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Ph.D. thesis (2019-2022)  
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# Transparent Conductive Materials based on Silver Nanowires and Nanocelluloses : Physics and Applications

*Matériaux transparents et conducteurs à base de nanofils d'argent et de nanocelluloses : de la physique fondamentale aux applications*

## Context

### Transparent Conductive Materials

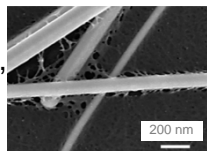
- Indium tin oxide most efficient and widely used but brittle and scarce
- Emerging materials : graphene, carbon nanotubes, metallic nanowire networks, conductive polymers...

### Silver nanowires, a good alternative to indium tin oxide

- Excellent opto-electrical properties and high flexibility,
- Electrical, thermal and mechanical stability issues

### Nanocellulose, an efficient renewable material for electronics

- Use in formulation with conductive particles,
- Use as substrate



Hoeng et al., *Nanoscale*, 2016, 8, 13131

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Auvergne-Rhône-Alpes

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## Objectives

### Development of a Transparent Conductive Materials based on ZnO/AgNW/CNF nanocomposites

*Efficient*

High transmittance (90%) and low sheet resistance (10  $\Omega$ /sq)

*Stable*

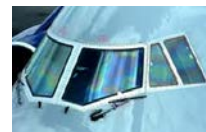
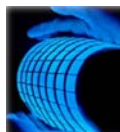
Thermal and electrical stability

*Low-cost and integrable within devices*

### Applications

Transparent conductive materials are the key components of :

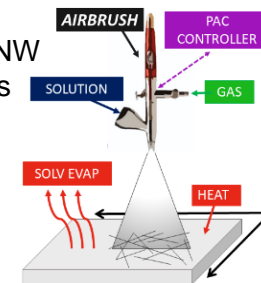
- Solar cells,
- Flexible light-emitting devices,
- Touch screens,
- Transparent heaters



## Methods

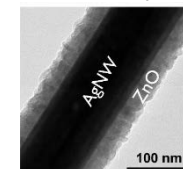
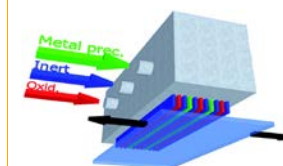
### Spray-coating

- Deposition of AgNW and CNF coatings
- Substrate (glass, PET, PEN)



### Atmospheric Pressure Spatial Atomic Layer Deposition

Coating of a thin conformal ZnO layer



Muñoz-Rojas et al., *Mat. Horizons*, 2014, 1, 314

Khan et al., *ACS Appl. Mat. & Interf.*, 2018, 10, 19208

### Characterizations

- Morphological and optical characterizations (Spectrophotometer, SEM, TEM, EDS, XPS),
- Thermal and electrical stability studies,
- Bending test

