



**HAL**  
open science

## Silver-nanowires networks as transparent electrodes for electrochromic films

Ambreen Ambreen, Antoine Mazel, Brandon Faceira, Suraj Nayak, Daniel Bellet, Aline Rougier

► **To cite this version:**

Ambreen Ambreen, Antoine Mazel, Brandon Faceira, Suraj Nayak, Daniel Bellet, et al.. Silver-nanowires networks as transparent electrodes for electrochromic films. 21st International Symposium on Intercalation Compounds - ISICXXI, Jun 2023, Nancy, France. hal-04726383

**HAL Id: hal-04726383**

**<https://hal.science/hal-04726383v1>**

Submitted on 28 Oct 2024

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# Silver-Nanowires Networks as Transparent Electrodes for Electrochromic Films



A. Ambreen<sup>1,2\*</sup>, A. Mazel<sup>1</sup>, B. Faceira<sup>1</sup>, C. Sanchez<sup>2</sup>, S. Nayak<sup>1</sup>, D. Muñoz-Rojas<sup>2</sup>, D. Bellet<sup>2</sup>, A. Rougier<sup>1</sup>

<sup>1</sup>Univ. Bordeaux, CNRS, Bordeaux INP, ICMCB, UMR 5026, F-33600 Pessac, France

<sup>2</sup>Univ. Grenoble Alpes, CNRS, Grenoble INP, LMGP, 38000 Grenoble, France



## 1. CONTEXT & OBJECTIVES

➤ Electrochromic smart windows minimize energy consumption in buildings and improve indoor comfort.

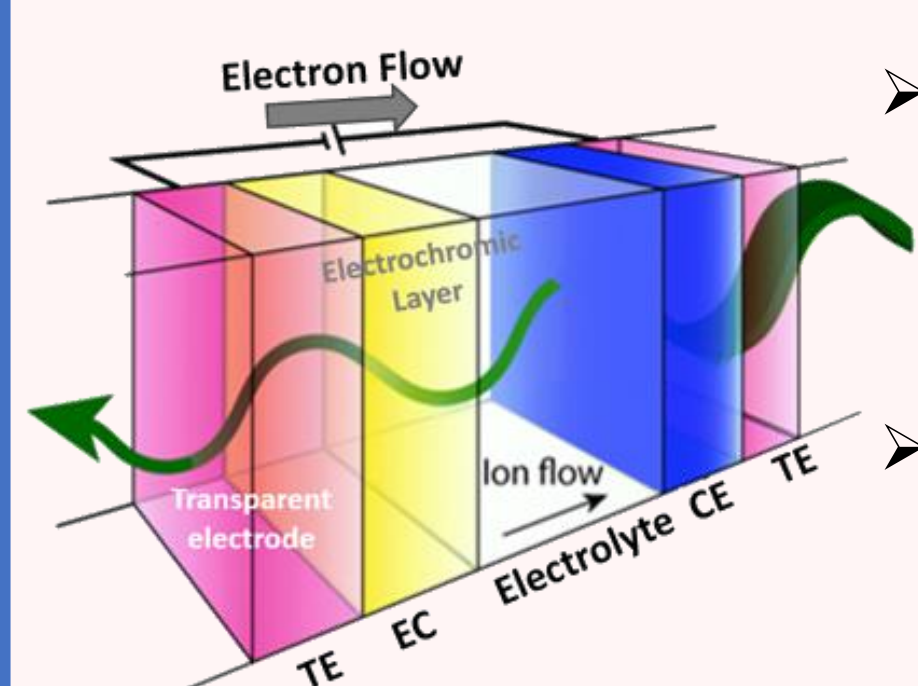


➤ Indium tin oxide (ITO) is used extensively as a transparent electrode for electrochromic devices.

➤ Limitations of ITO: high cost, scarcity, and brittleness.

➤ Silver nanowire (AgNW) networks as an alternative; high optical transparency, excellent electrical properties, and mechanical flexibility.

➤ Instability of AgNWs under electrical & thermal stress.

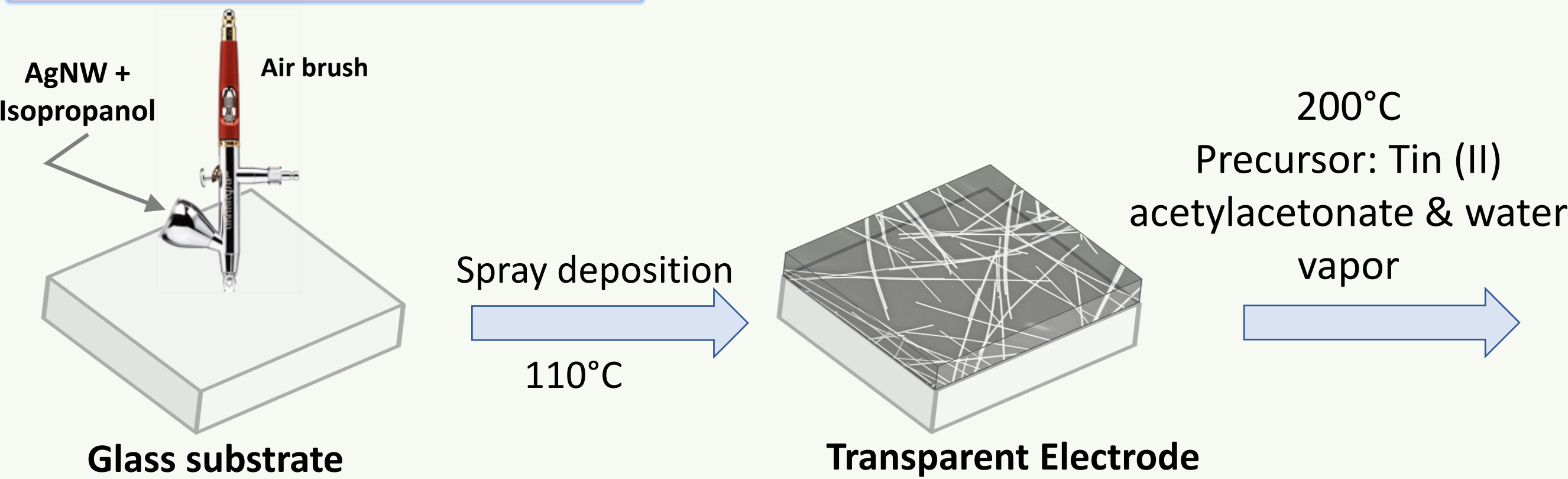


➤ To prepare ITO-free electrochromic films using AgNW networks as transparent electrodes (TE).

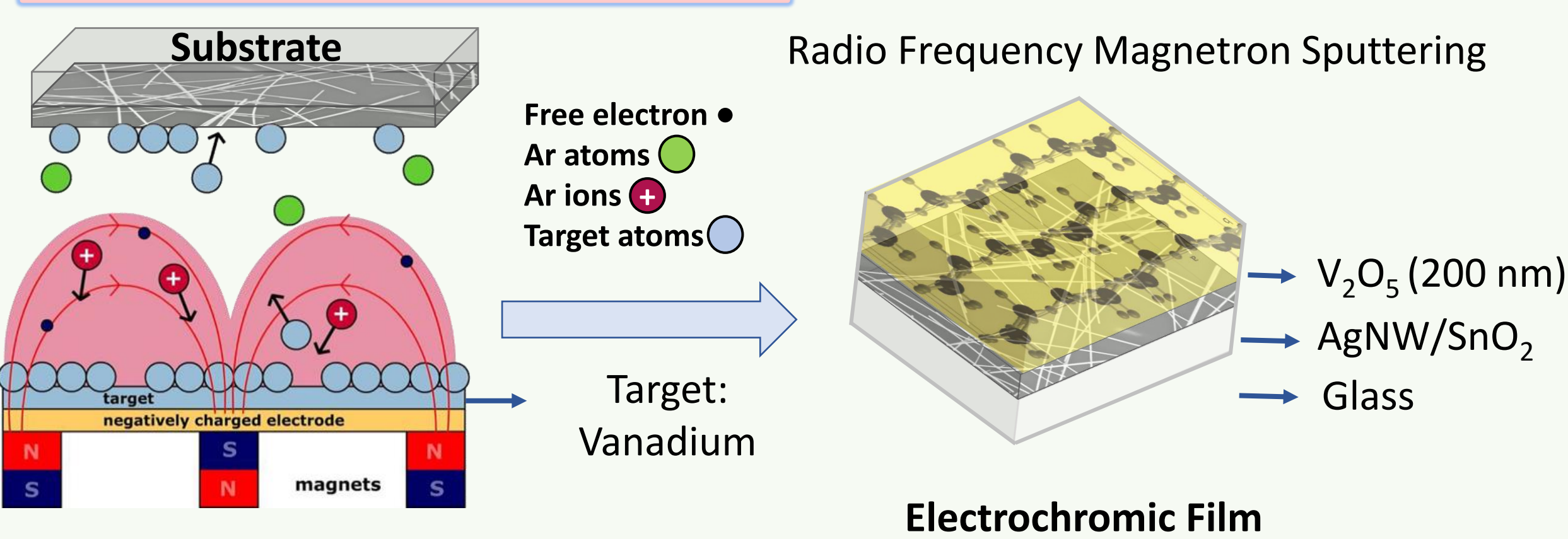
➤ Investigate the performance of V<sub>2</sub>O<sub>5</sub> as an electrochromic layer on AgNW TE.

## 2. Experimental

### a. Deposition of AgNW networks

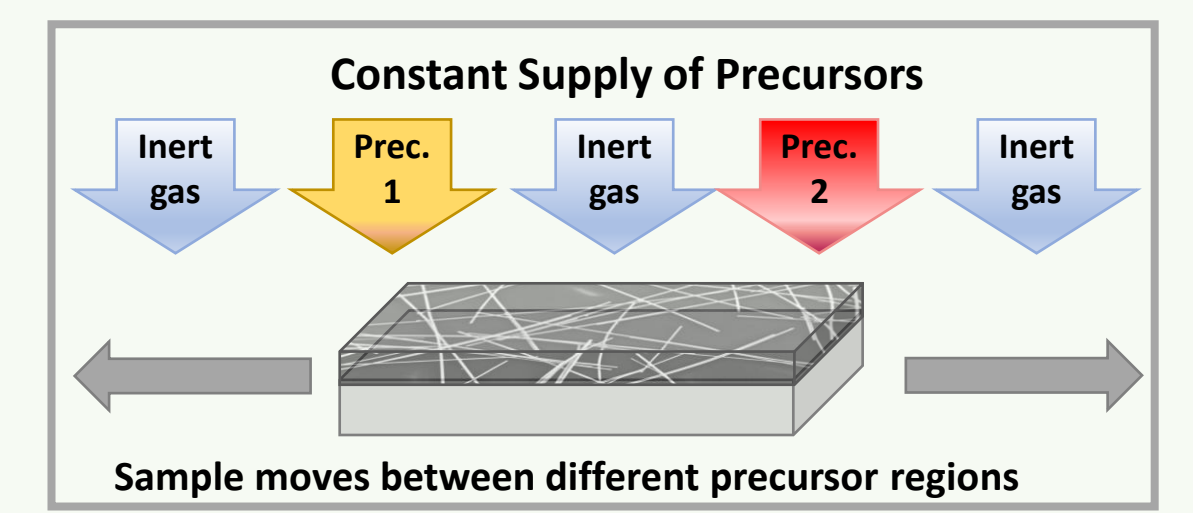


### c. Deposition of Electrochromic Oxide



### b. Deposition of Protected Oxide Layer

Spatial Atomic Layer Deposition  
30 nm thick SnO<sub>2</sub> coating on AgNW networks



#### Deposition Conditions

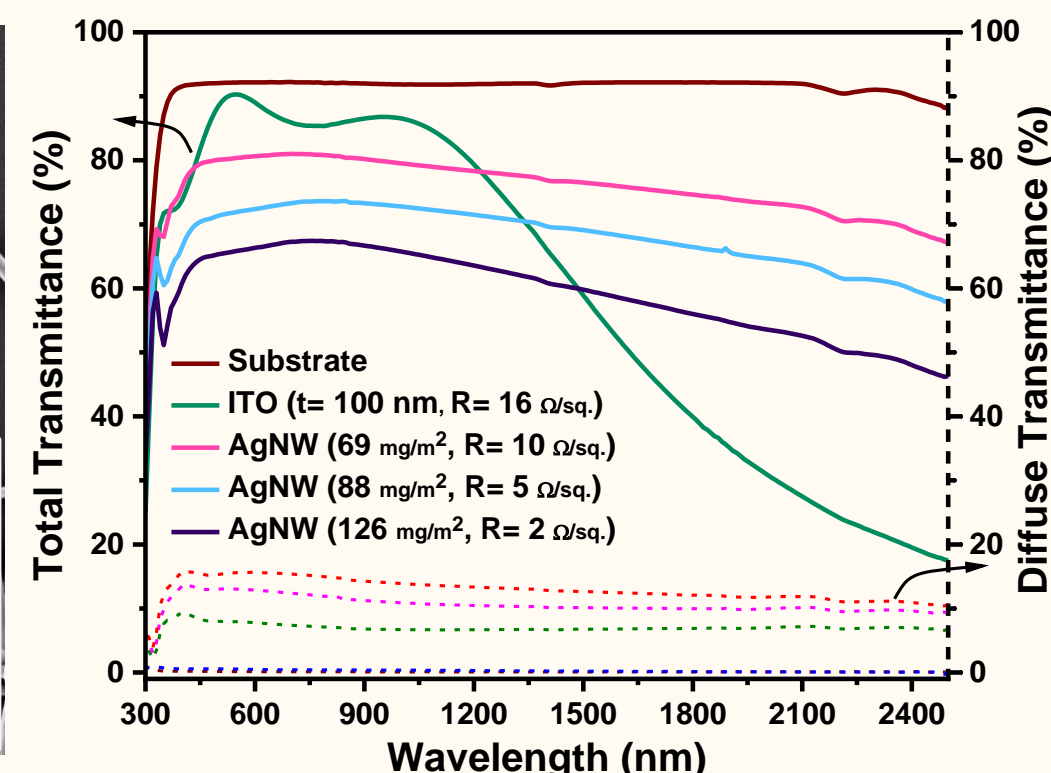
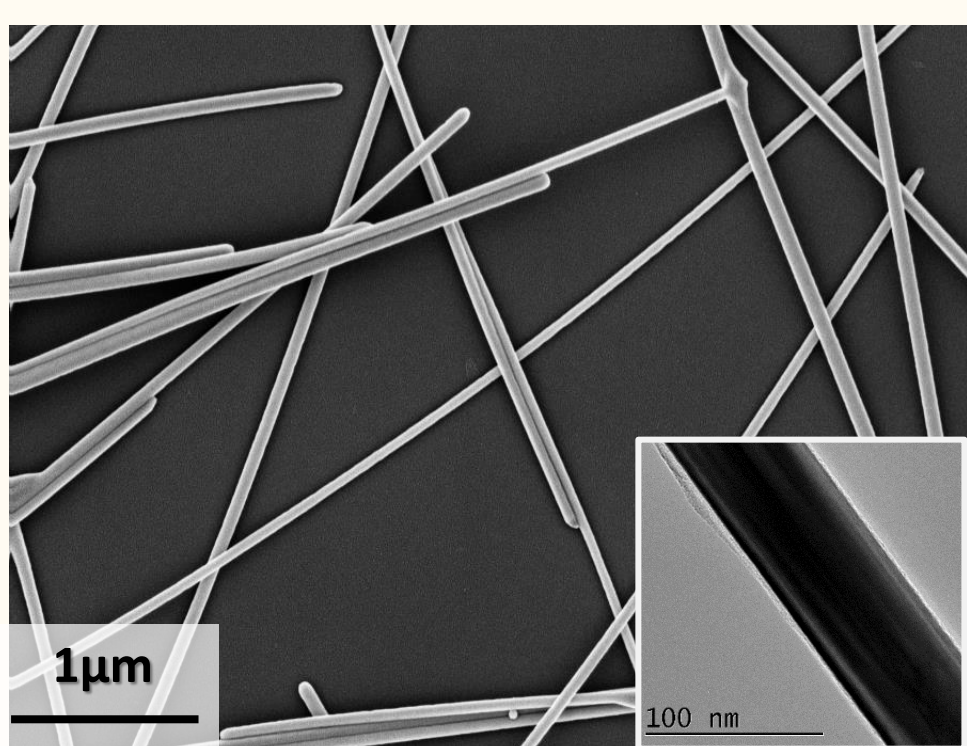
Condition	V <sub>2</sub> O <sub>5</sub>
Power W	200
Total Pressure Pa	2
Ar+O <sub>2</sub> Plasma sccm	90: 10

## 3. Results & Discussions

### 3.1 AgNWs Transparent Electrode

#### Bare AgNW Networks

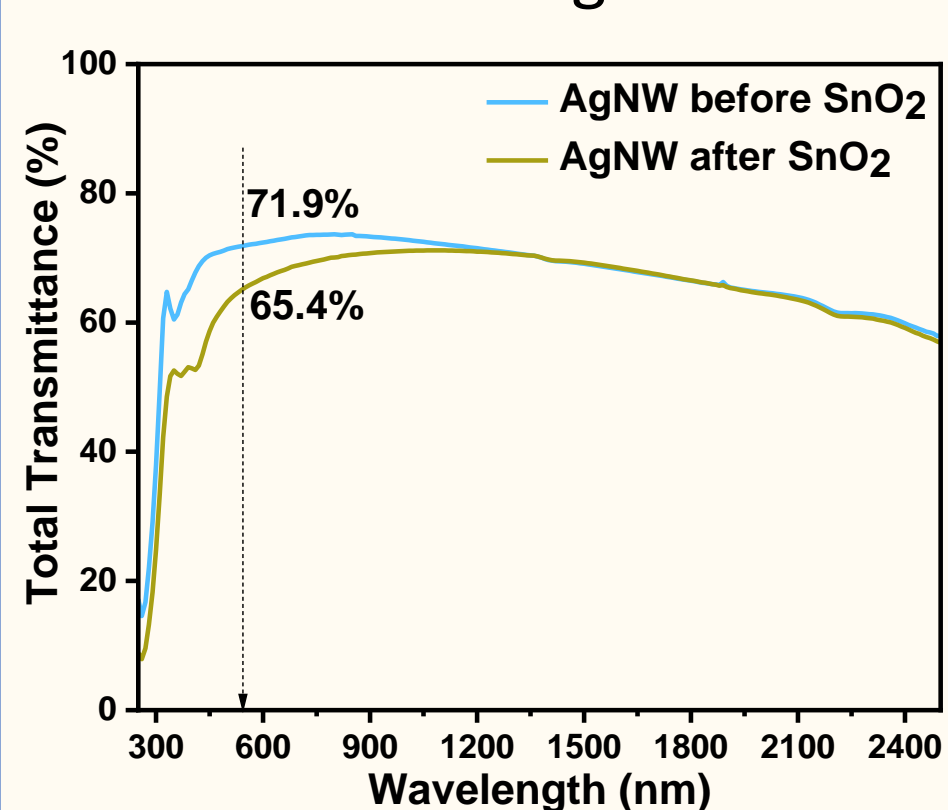
#### Film Morphology & Optical



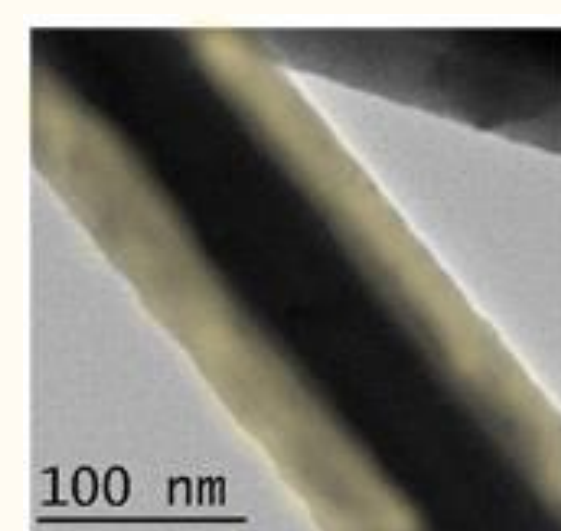
Effect of areal mass density of network on transmittance

#### Oxide Protected AgNWs

Optical transmittance of AgNWs before and after SnO<sub>2</sub> coating

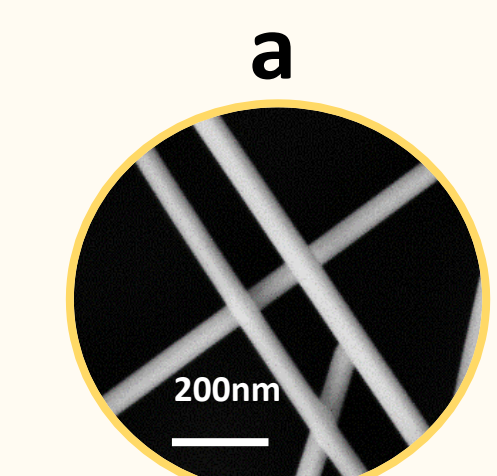
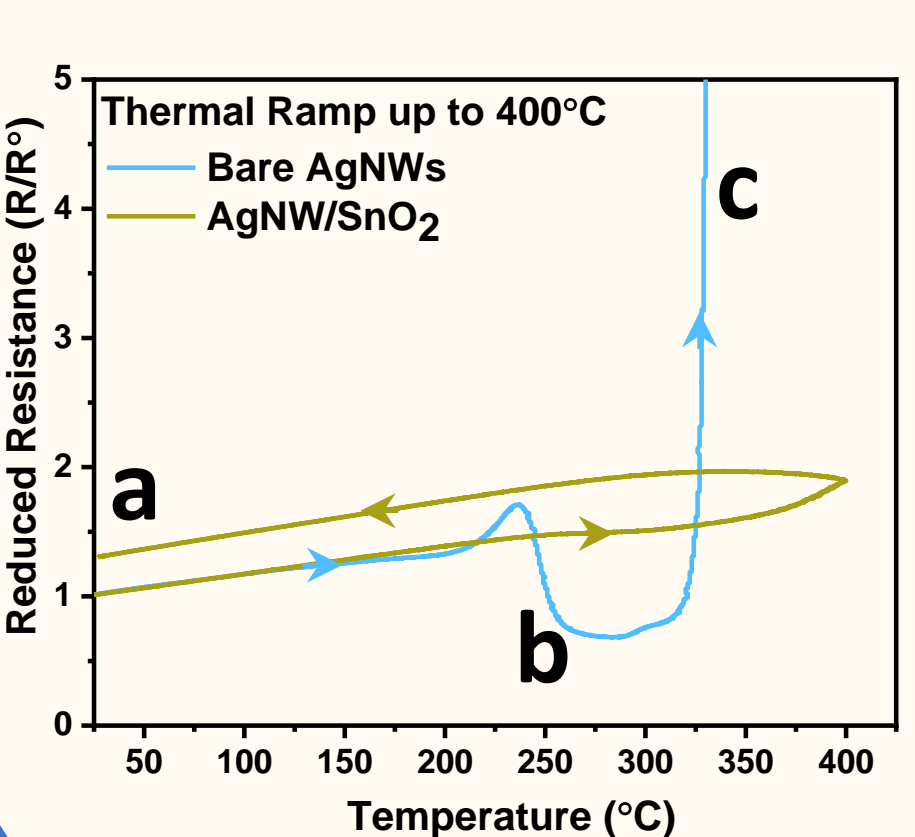


TEM image 30 nm thick SnO<sub>2</sub> around AgNW

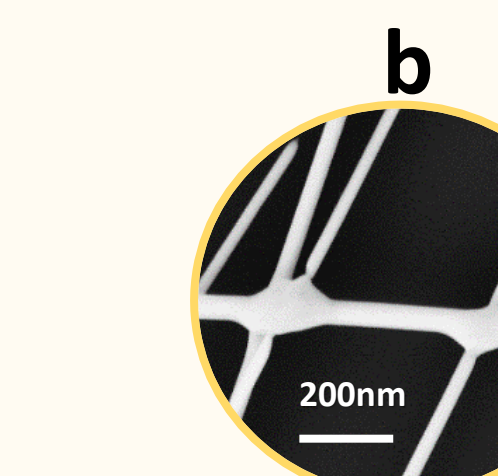


#### Thermal Stability

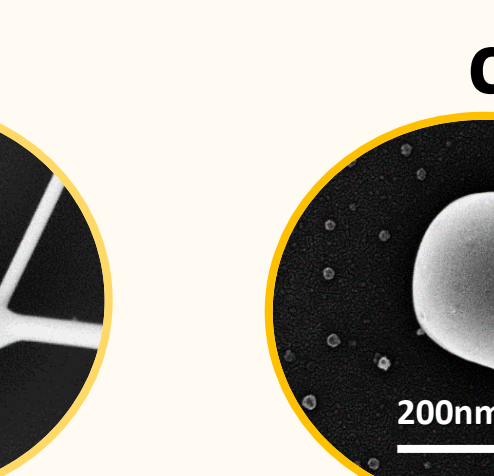
Bare AgNW degrades above 300°C, while SnO<sub>2</sub> coated AgNW are stable even at 400°C



AgNW junctions before a thermal ramp 25°C



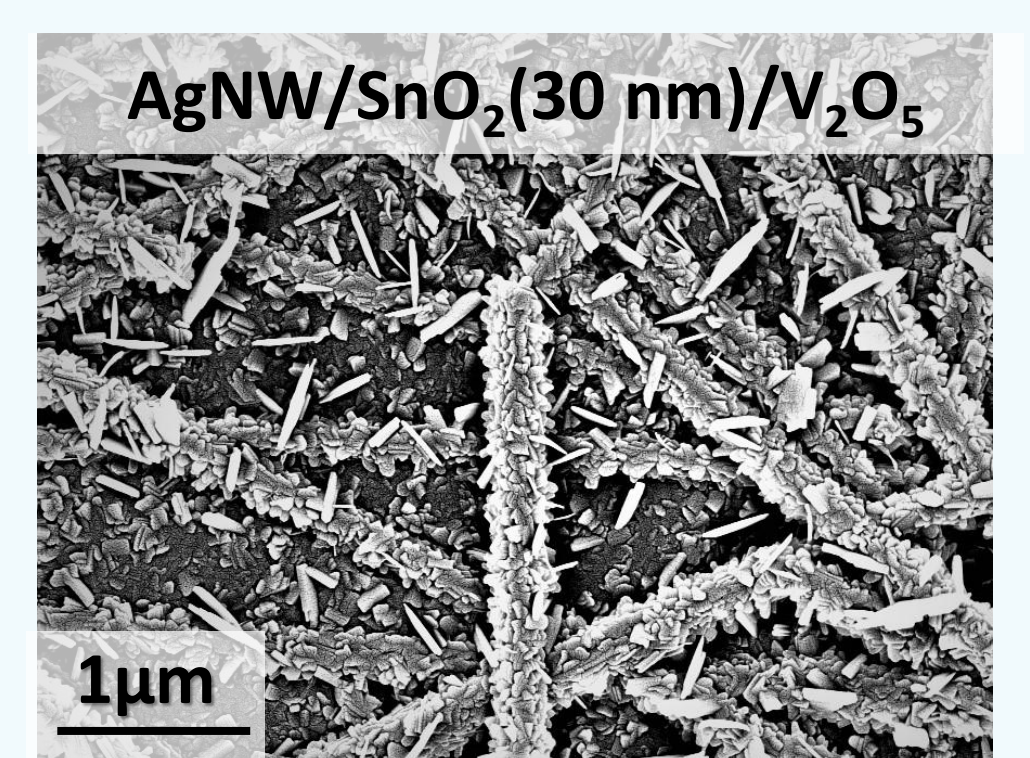
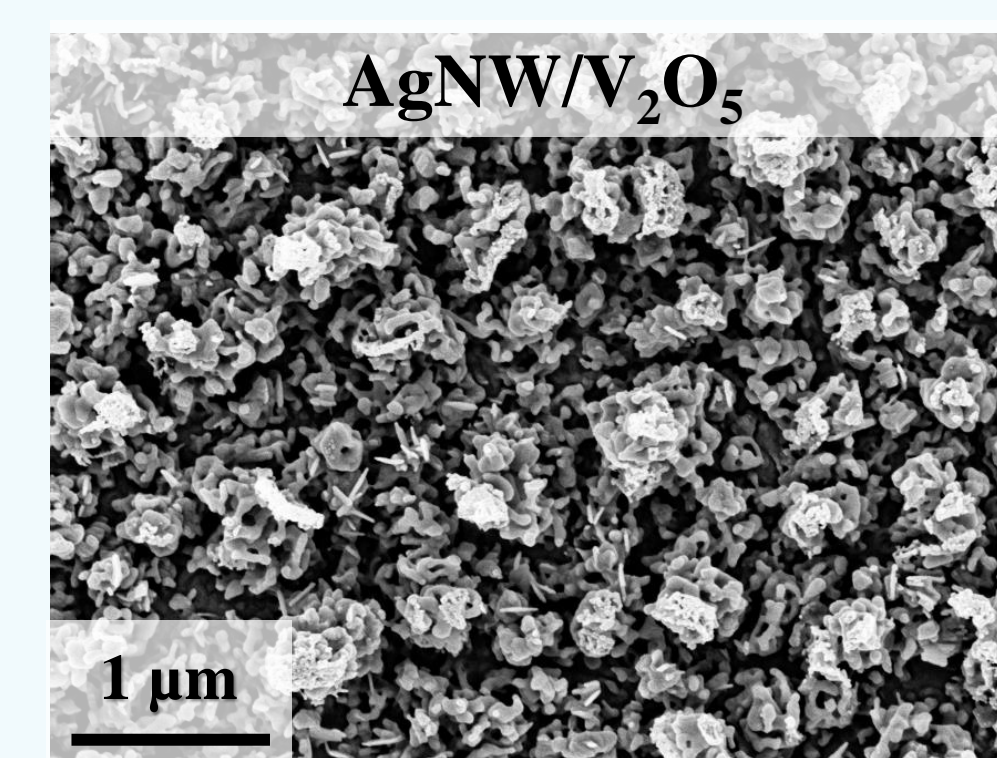
Sintering of junctions upon a thermal ramp up to 265°C



Spheroidization of AgNW upon a thermal ramp up to 400°C

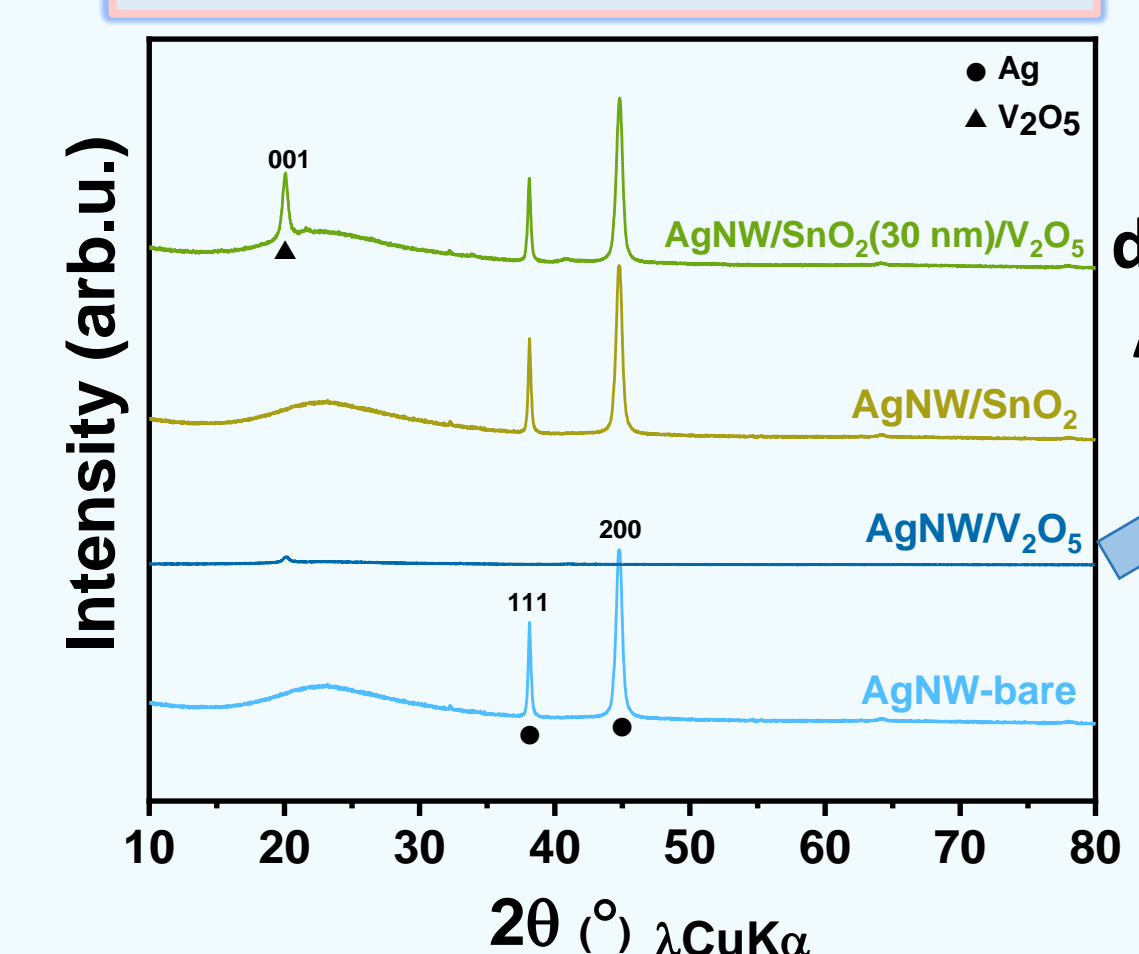
### 3.2 Electrochromic Layer V<sub>2</sub>O<sub>5</sub>

#### Film Morphology



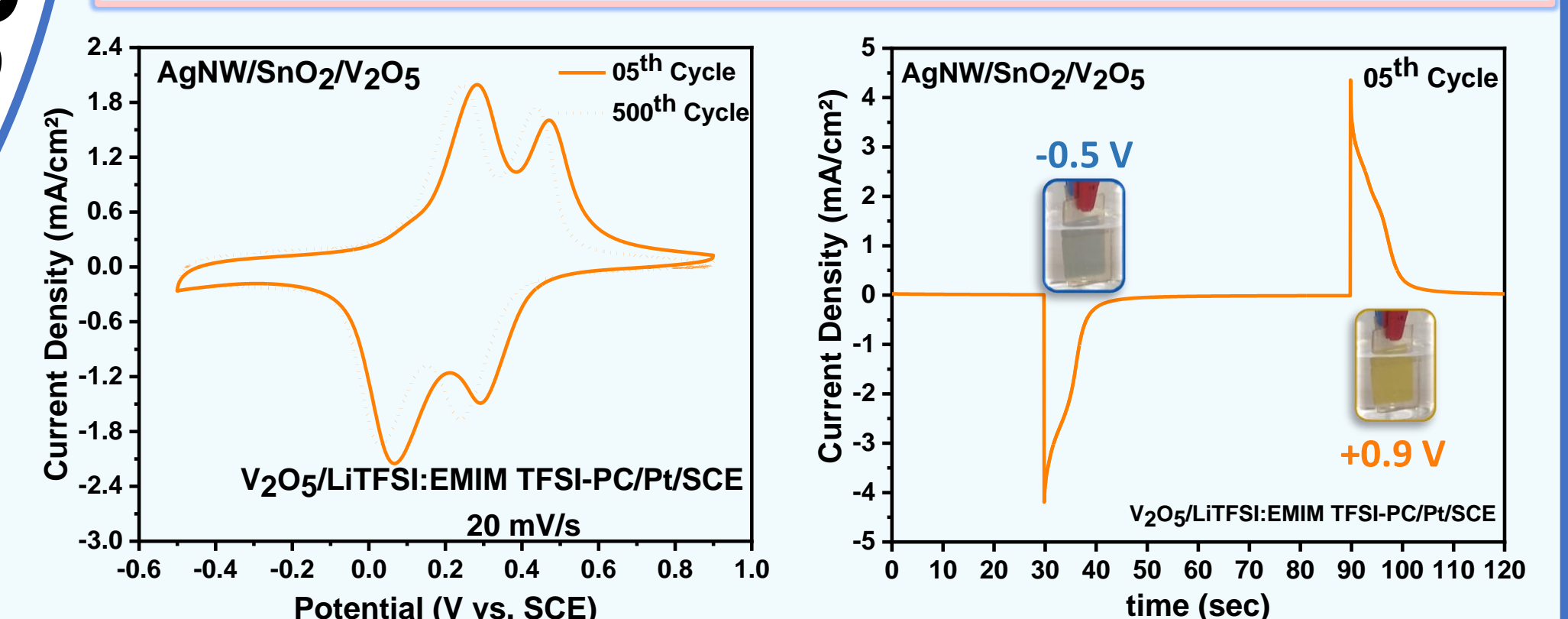
Bare AgNW degraded in the sputtering conditions. While coated AgNWs remain stable after V<sub>2</sub>O<sub>5</sub> deposition

#### XRD Analysis

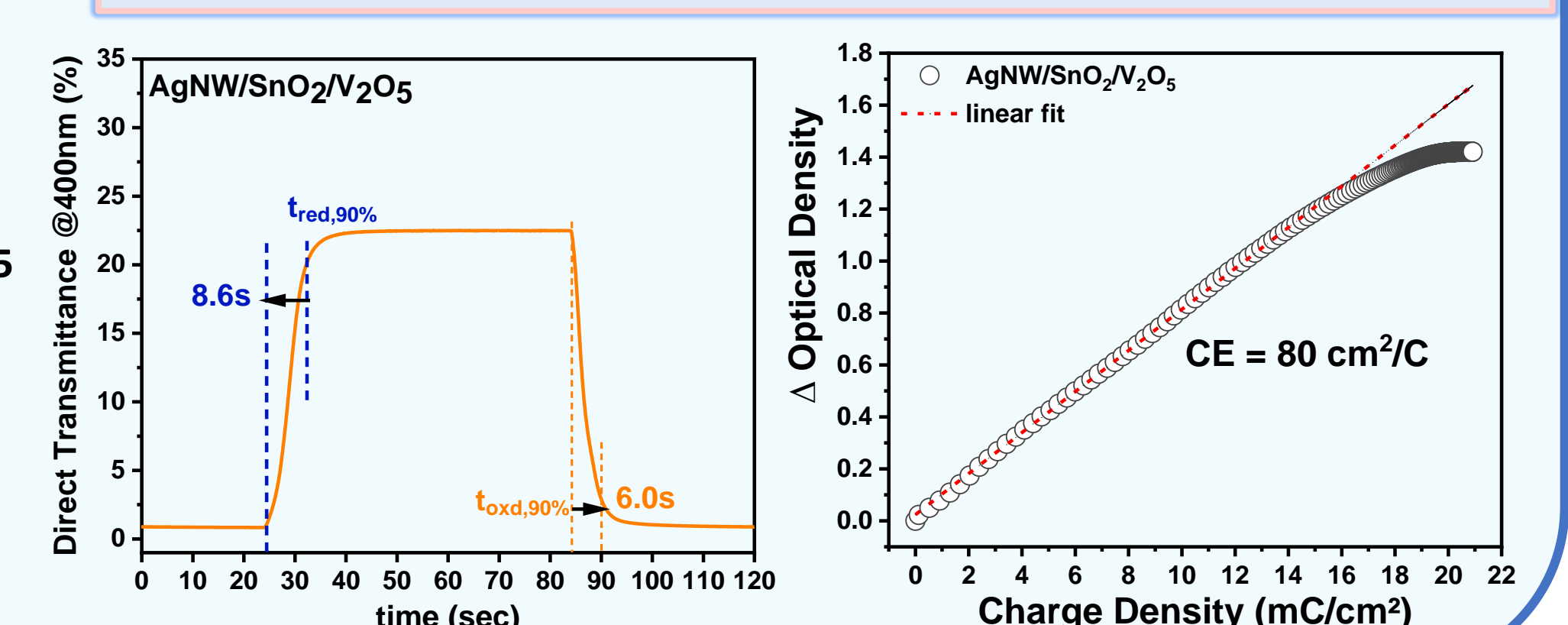


Silver peaks disappear for bare AgNW after V<sub>2</sub>O<sub>5</sub> deposition

#### Cyclic Voltammetry & Chronoamperometry



#### Switching time & Coloration Efficiency



## 4. Conclusion & Perspectives

- ✓ Successfully deposited V<sub>2</sub>O<sub>5</sub> on AgNW networks.
- ✓ The conformal coating of SnO<sub>2</sub> protected the AgNW networks against reactive plasma during the sputtering deposition of electrochromic oxide.
- ✓ Good electrochromic response, switching time, and coloration efficiency.
- ✓ Integration of AgNW networks based TE into EC device & Investigation of other electrochromic materials like SurMOF and PEDOT.

## References

1. Klaus Ellmer, *Nature Photonics* 6 (2012) 809
2. Muñoz-Rojas et al. *C. R. Physique* 18 (2017) 391
3. Bardet et al. *Nanomaterials* 11 (2021) 2785
4. Mjehri et al. *ACS Applied Energy Materials* 1 (2018) 2721

## Acknowledgment

The authors acknowledge the financial support by the Agence Nationale de Recherche (ANR) for Partner Grenoble INP/LMGP & ICMCB Bordeaux via the Project M-Era-Net INSTEAD  
Contact info: \*[ambreen.ambreen@grenoble-inp.fr](mailto:ambreen.ambreen@grenoble-inp.fr), [antoine.mazel@icmcb.cnrs.fr](mailto:antoine.mazel@icmcb.cnrs.fr)