Impact of synthesis conditions on optical and electrochemical properties of SnO_2 nanomaterials

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Introduction

- Study of structural, optical and electrochemical properties of SnO_2 nanoparticles synthesized by sol-gel method.
- SnO_2 nanoparticles were prepared using tin chloride hydrated (**SnO_2**).
- SnO_2 nanoparticles were coupled with carbon nanotube (**SnO_2:CNT**).

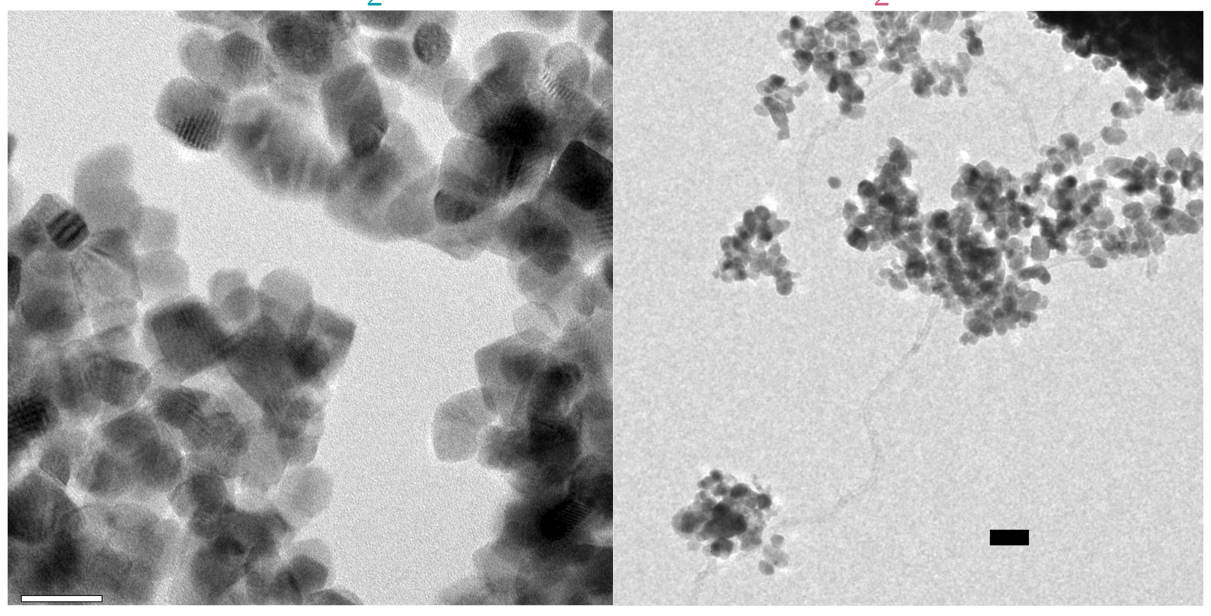
Synthesis

SnO_2 nanoparticles were synthesized using nonaqueous sol-gel method. $SnCl_4$ precursor was added to benzyl alcohol solvent in a sealed autoclave. The autoclave was heated up at 295 °C for 24 hours. Resulting powder is washing with dichloromethane. **SnO_2:CNT** sample was synthesized by adding CNT (functionalized with benzyl alcohol) prior to the synthesis.

Structural properties

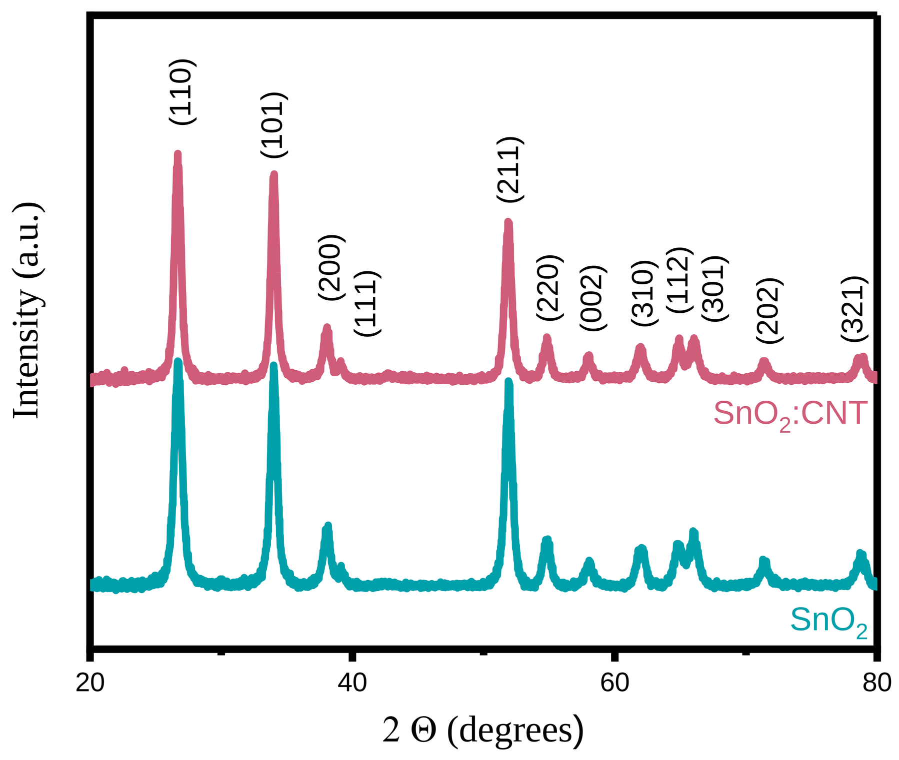
Transmission electron microscopy (TEM)

SnO_2 SnO_2:CNT



Nanomaterials are mostly spherical and cubic-like shape. Nanoparticles have an average size between 10 and 20 nm for SnO_2 and SnO_2:CNT.

X-ray diffraction (XRD)

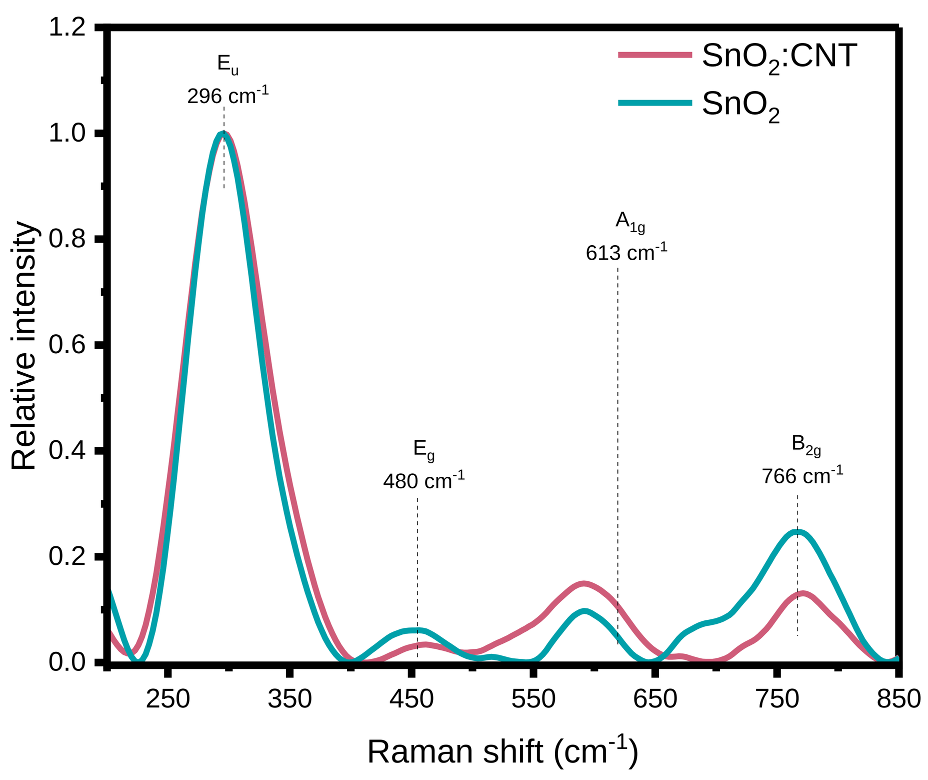


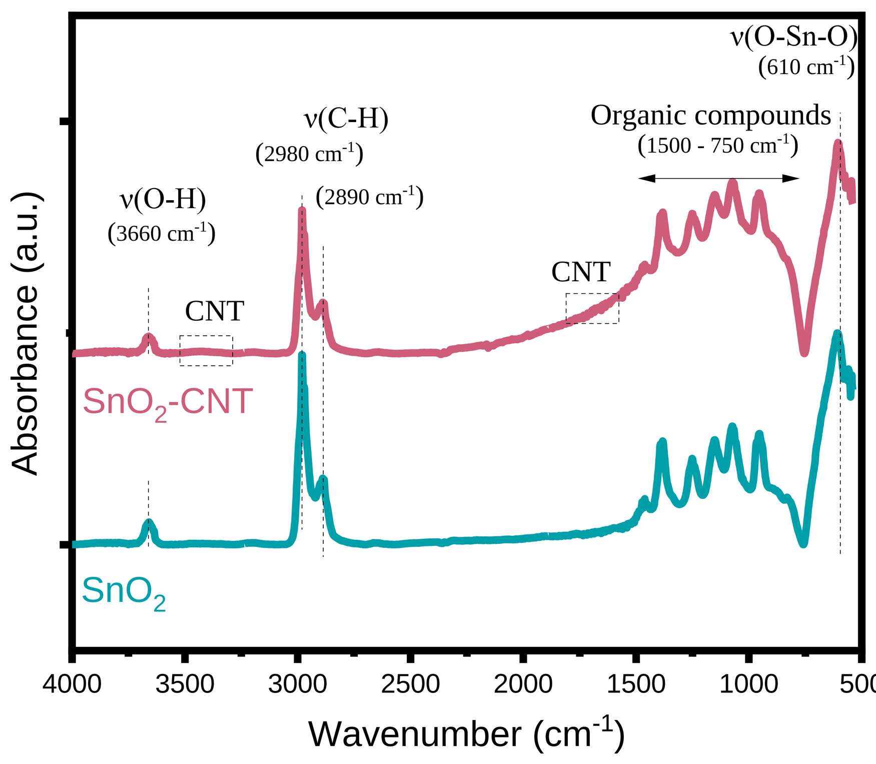
$$d_{hkl} = \frac{K\lambda}{\beta\cos(\Theta)}$$

Scherrer-Bragg equation. d_{hkl} is the crystallite size, K the Scherrer constant, β the full width at half maximum and θ the angle.

SnO_2 nanoparticles were obtained with a single tetragonal rutile phase. Scherrer-Bragg formula give crystallite size of 12.8 and 14.5 nm for SnO_2 and SnO_2:CNT, respectively.

Raman and FTIR spectroscopies





- New Raman active peaks due to nanosized SnO_2 materials and defects (E_u inactive mode at ~300 cm^{-1}).
- FTIR shows the presence of organics (alcohol and aliphatic hydrocarbon compounds from degradation of benzyl alcohol) coated at the surface of SnO_2 nanomaterials.
- Low intensity peak of CNT around 3400 and 1600 cm^{-1}.

Acknowledgement

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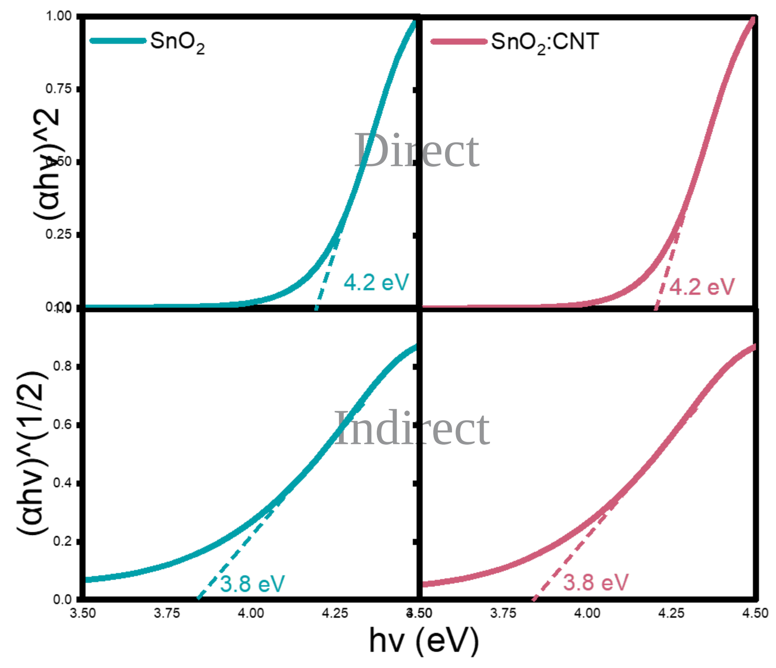
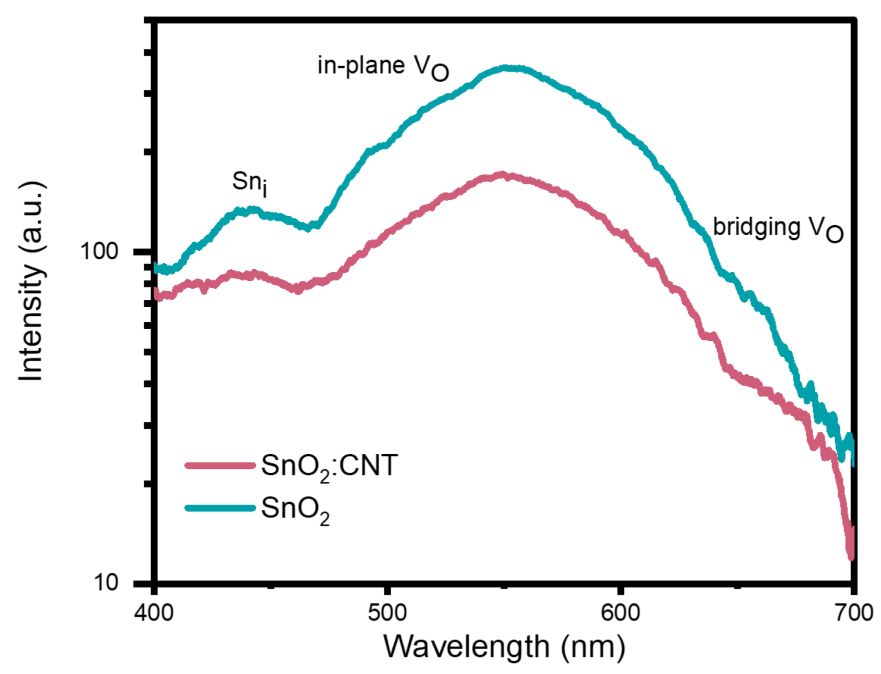
Optical properties

UV-Visible spectroscopy

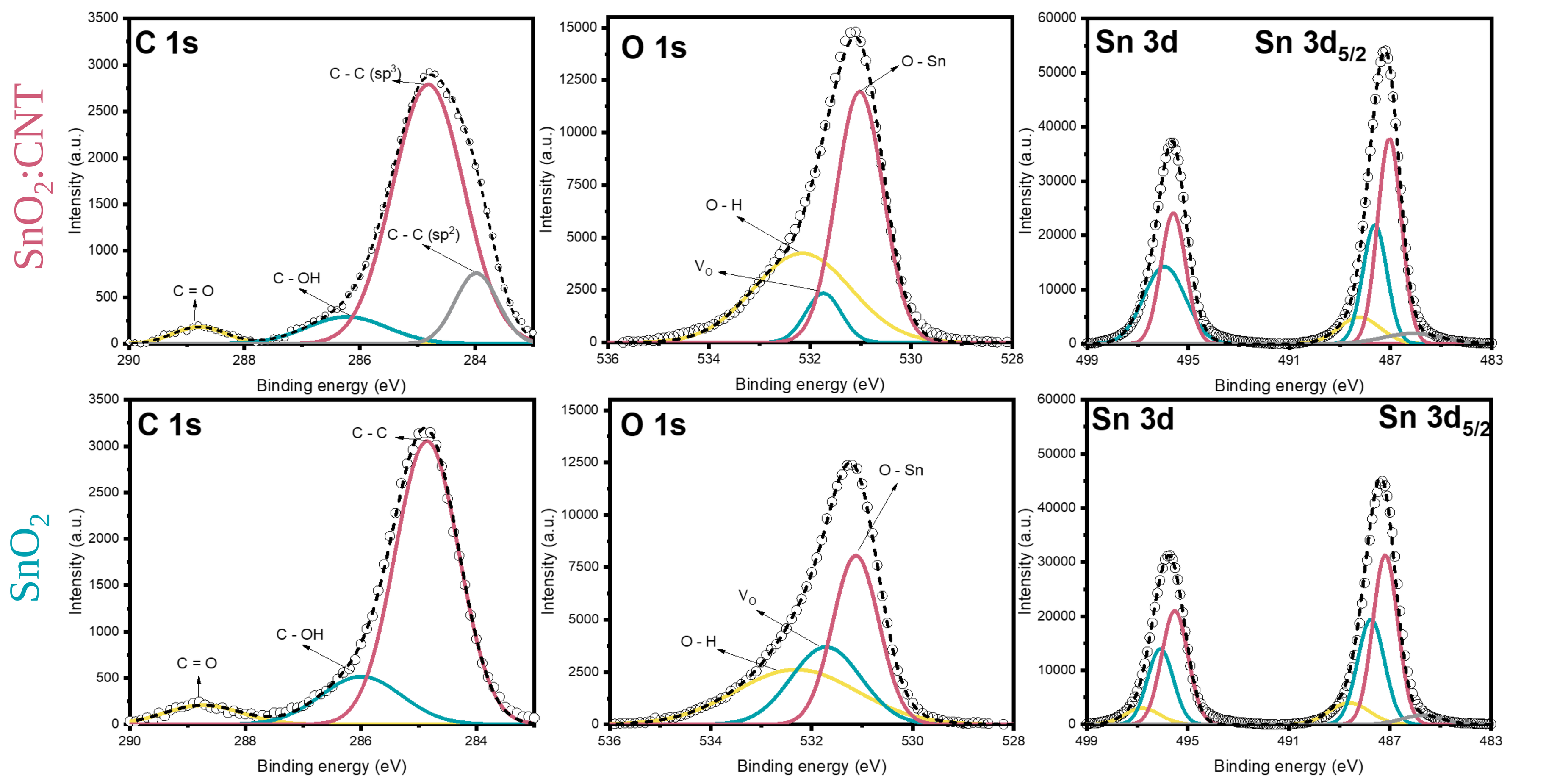


Photoluminescence



- Optical direct and indirect bandgap of 4.2 and 3.8 eV respectively for all SnO_2 samples.
- CNT passivate surface defects (decrease of oxygen vacancy intensities).

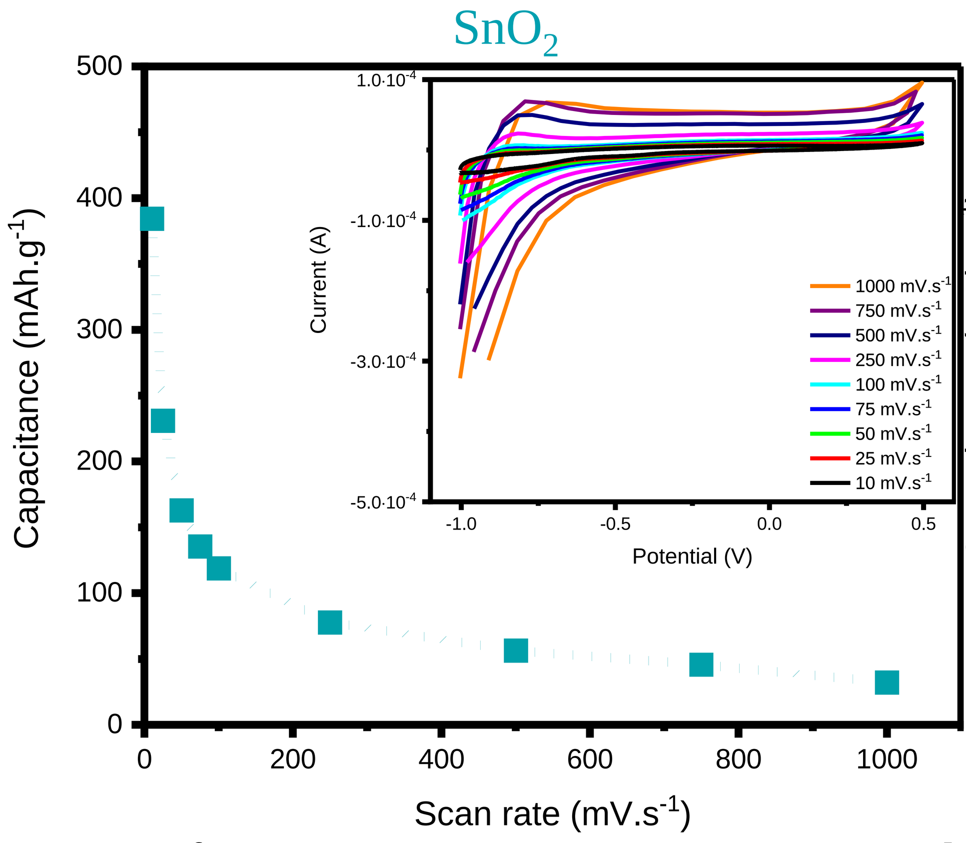
X-ray photoelectron spectroscopy



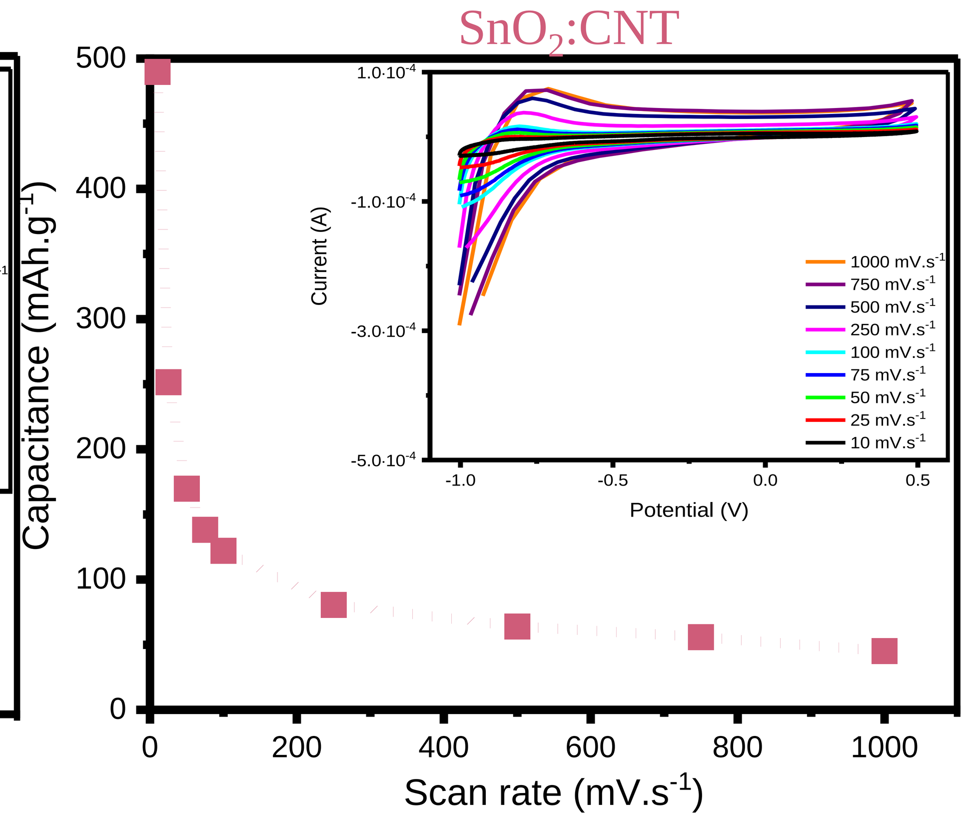
- Additional C-C (sp^2) peak at 283.98 eV belonging to CNT.
- Presence of CNT passivate V_O (decrease of V_O peak at 281.7 eV).

Cyclic voltammetry (CV)

SnO_2



SnO_2:CNT



Specific capacitance versus scan rate. Voltammograms using glassy carbon working electrode, Ag/AgCl reference electrode and Pt counter electrode in 0.5 M LiOH..

Capacitance Formula

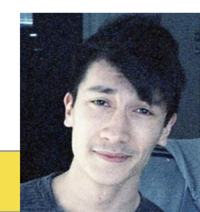
$$C = \frac{1}{m\Delta V}\int IdV$$

Capacitance formula. m is the mass of active materials, ΔV the potential window, I the current and V the potential.

- Similar nearly-rectangular shape highlighting pseudo-capacitor behavior.
- Higher capacitance (~500 $mAh.g^{-1}$) is achieved with CNT due to passivation or surface defects (against ~400 $mAh.g^{-1}$). Oxygen vacancies may act as screening center hindering Li^+ diffusion pathway.

Conclusion

- Rutile SnO_2 nanoparticles with sizes of 10 - 20 nm have been synthesized.
- Nanosized SnO_2 are synthesized and display oxygen vacancies.
- Pristine SnO_2 nanomaterials demonstrate high energy capacity (~ 400 $mAh.g^{-1}$).
- Carbon nanotubes passivate surface defects that hinder Li^+ ions diffusion and decrease ionic conductivity of Li^+ which result into higher energy capacity (~ 500 $mAh.g^{-1}$).



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