Micro-structural evaluation of RF sputtered TNTs on functional substrates for perovskite solar cell applications

Simcelile Zinya

(201210029)

Supervisor: *Dr. Raymond T. Taziwa*
Co-supervisor: *Prof. Edson L. Meyer*
Co-supervisor: *Dr. David M. Katwire*

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Introduction

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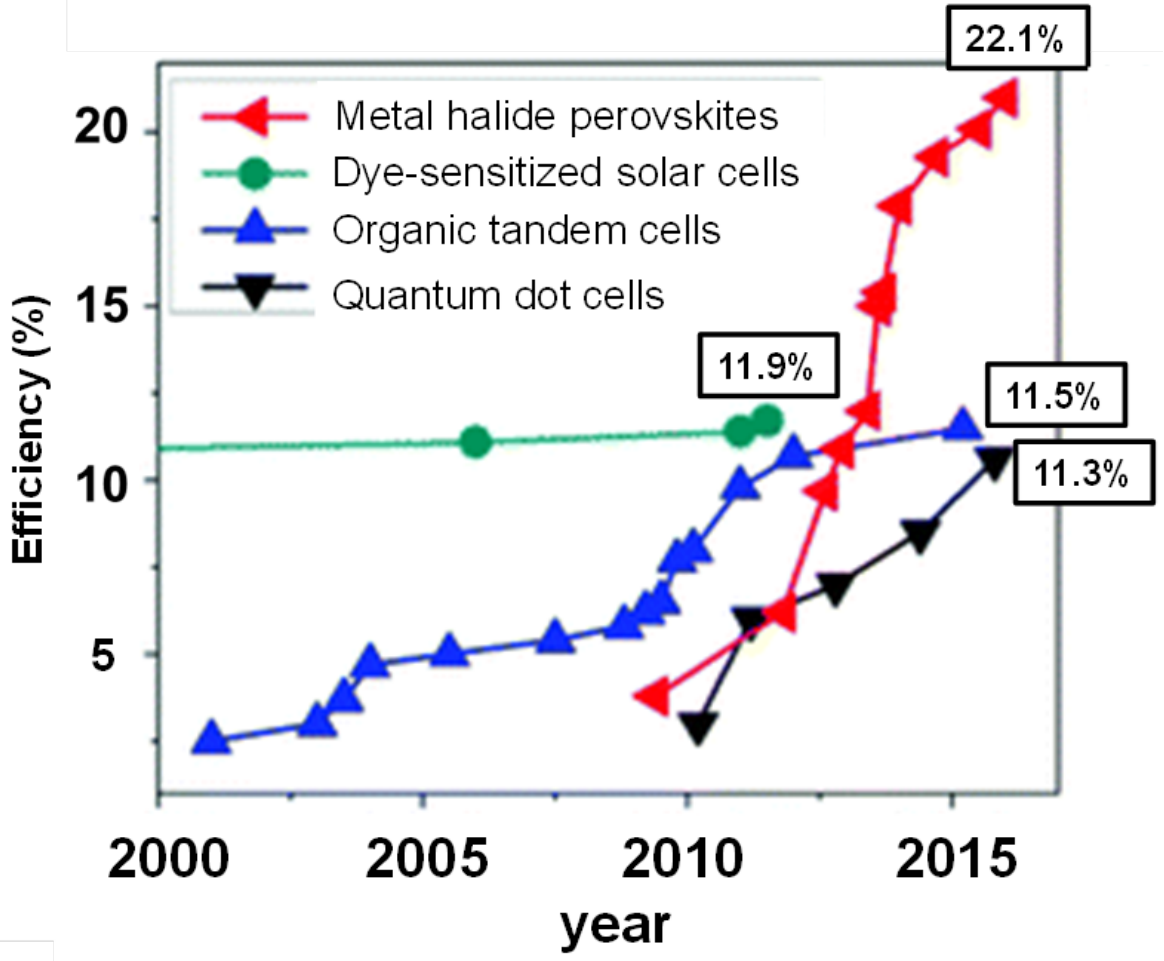
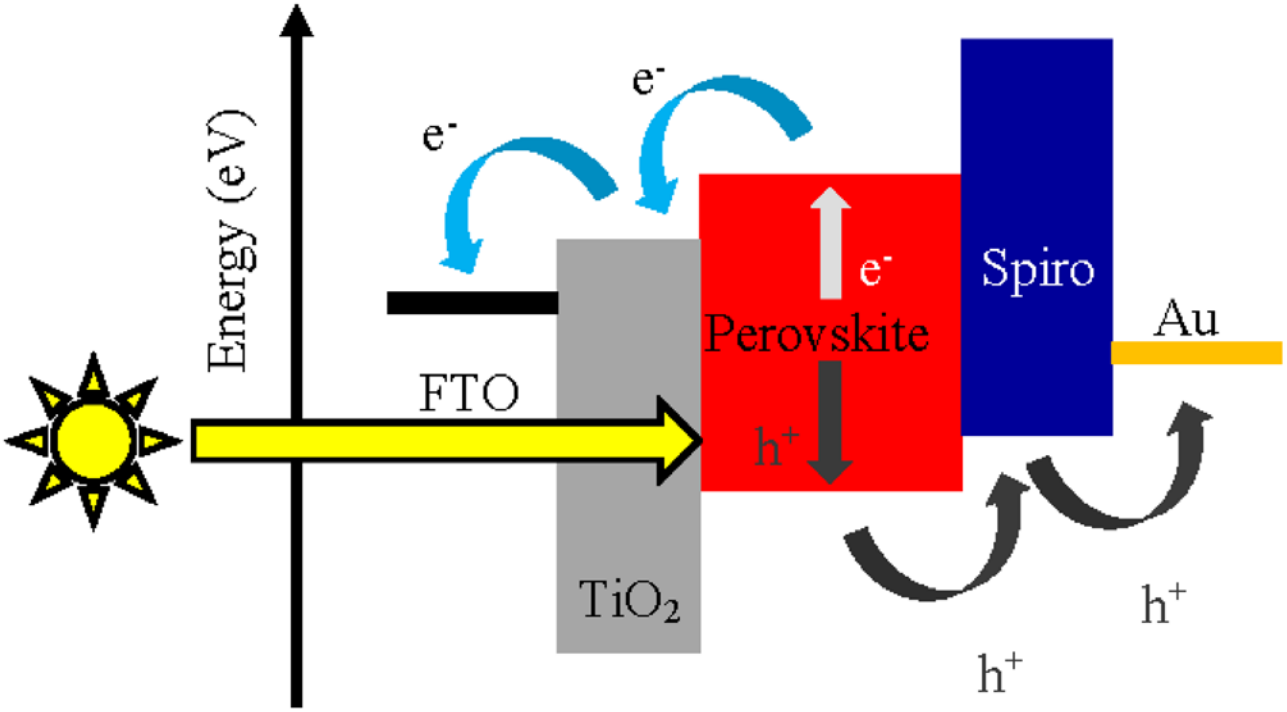


- Energy demand has intensified research on renewable energy sources.
- Perovskite solar cells (PSCs) are deemed as the most promising candidates efficient energy generation.

Background



- Despite rapid progress in the PSC efficiency, there have been concerns about the choice of electron transport layer (ETL) in the solar cell architecture.
- ETL can be either planar, mesoscopic or nanostructure layers.

Background

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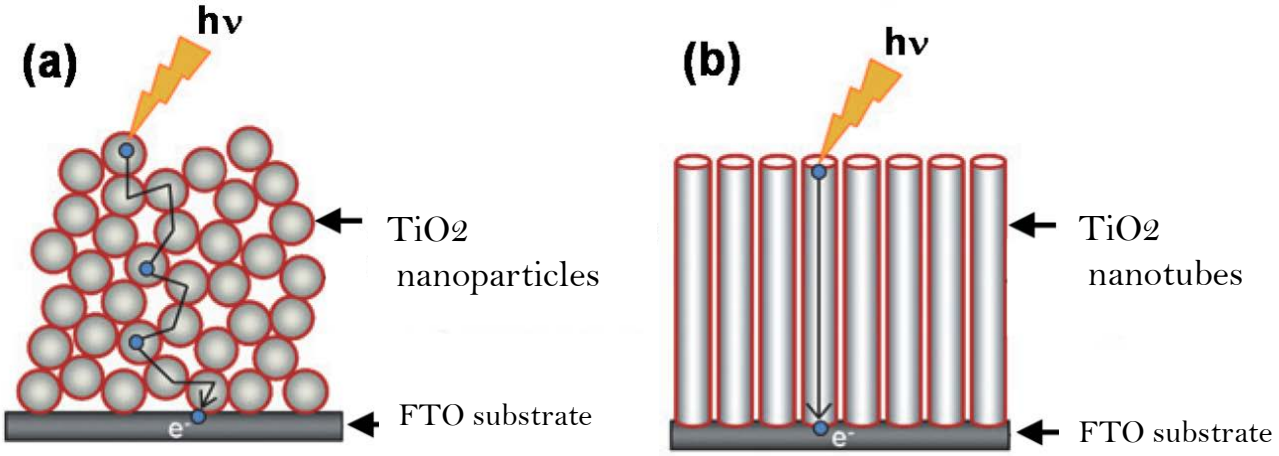

- TiO_2 nanostructures such as nanotubes can allow for complete infiltration of perovskite material and provide vectorial charge transport for charge collection efficiencies.

- Hence, this study focuses on synthesis and structural evaluation of TiO_2 nanotubes on functional substrates (TNTs-FS) with change in annealing temperature.

- This will allow a more qualitative study and understanding of TNTs structural properties.

Methodology

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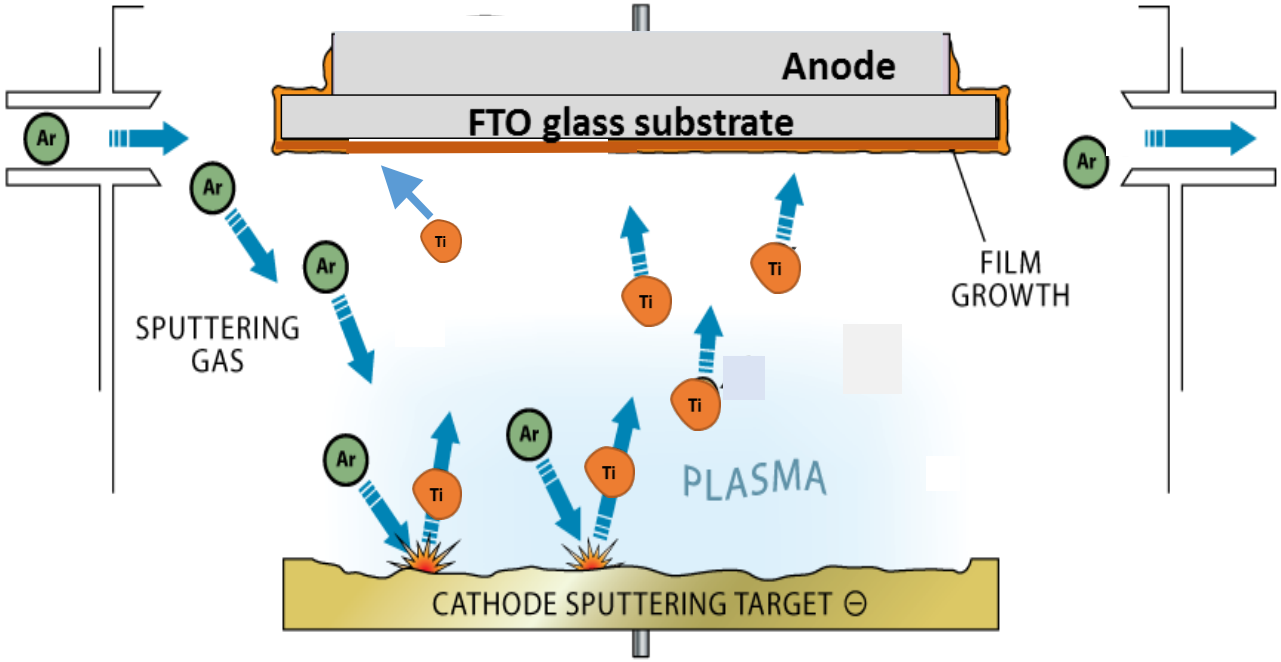
RF SPUTTERING PROCESS



SPUTTERING CONDITIONS

- Ar Pressure – 1.5 Pa
- RF power – 1 kW
- Input Voltage – 440 V

Experimental setup

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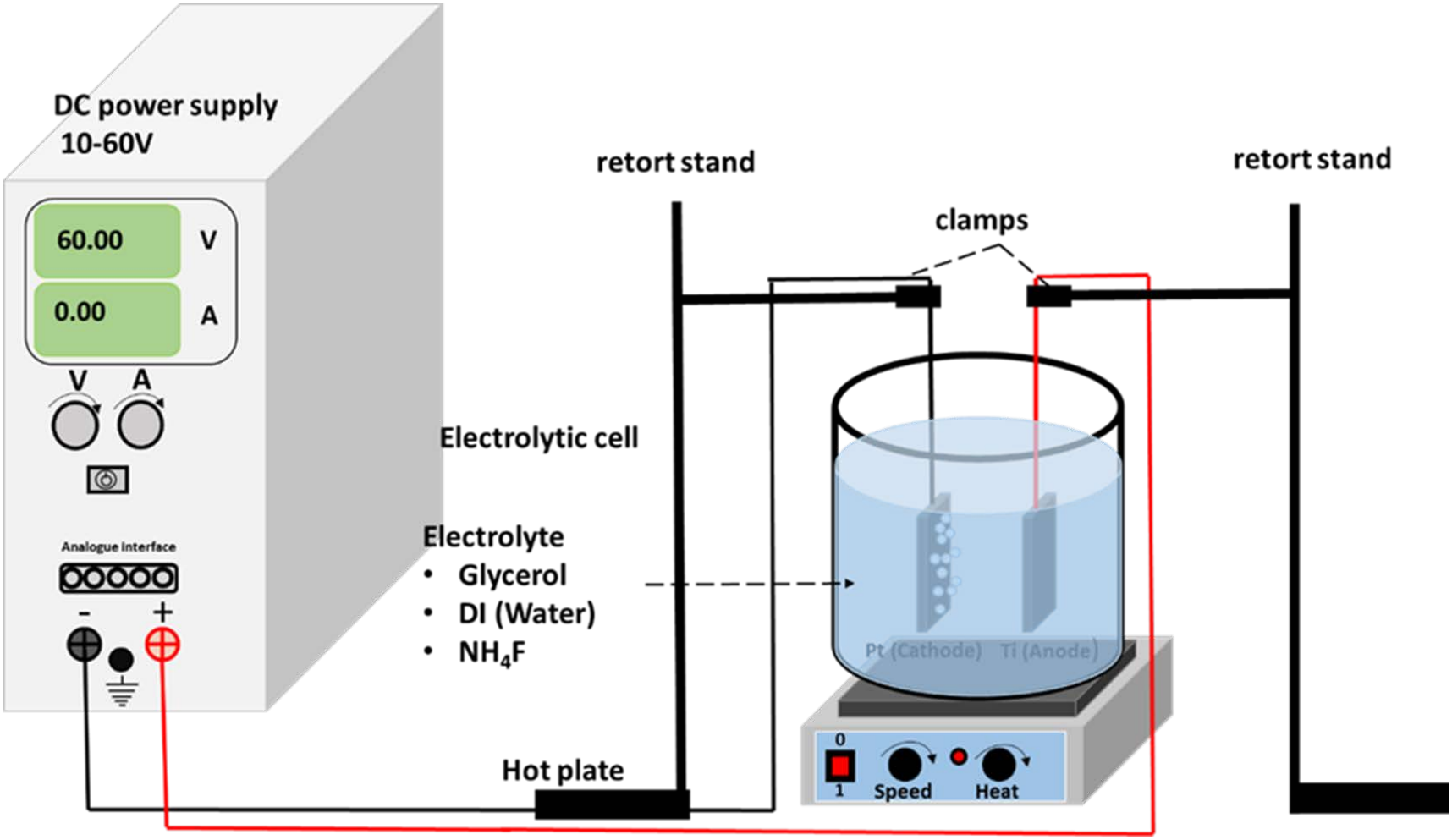

Electro-anodization

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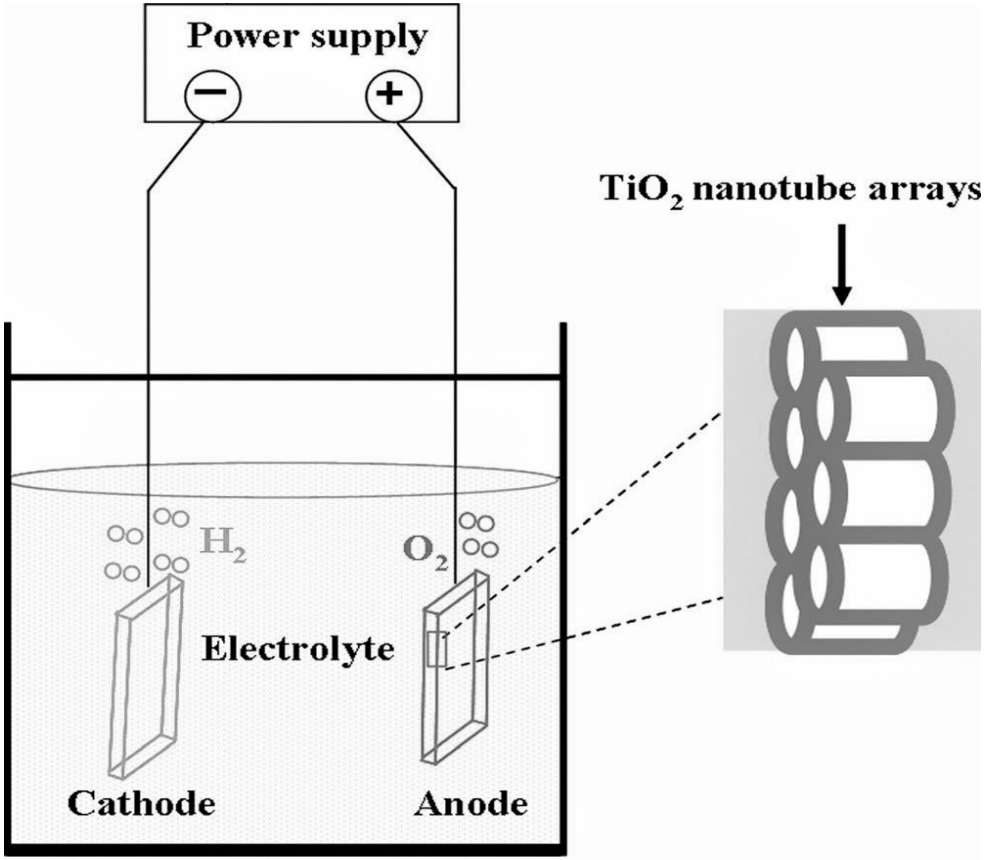

Reactions at anode:

1. $Ti \rightarrow Ti^{+4} + 4e^-$
2. $Ti^{+4} + 2H_2O \rightarrow TiO_2 + 4H^+$
3. $TiO_2 + 4H^+ + 6F^- \rightarrow [TiF_6]^{-2} + 2H_2O$

- Anodization of Ti occurs as a result of the competition between oxide formation and chemical dissolution of the oxide by F^-.

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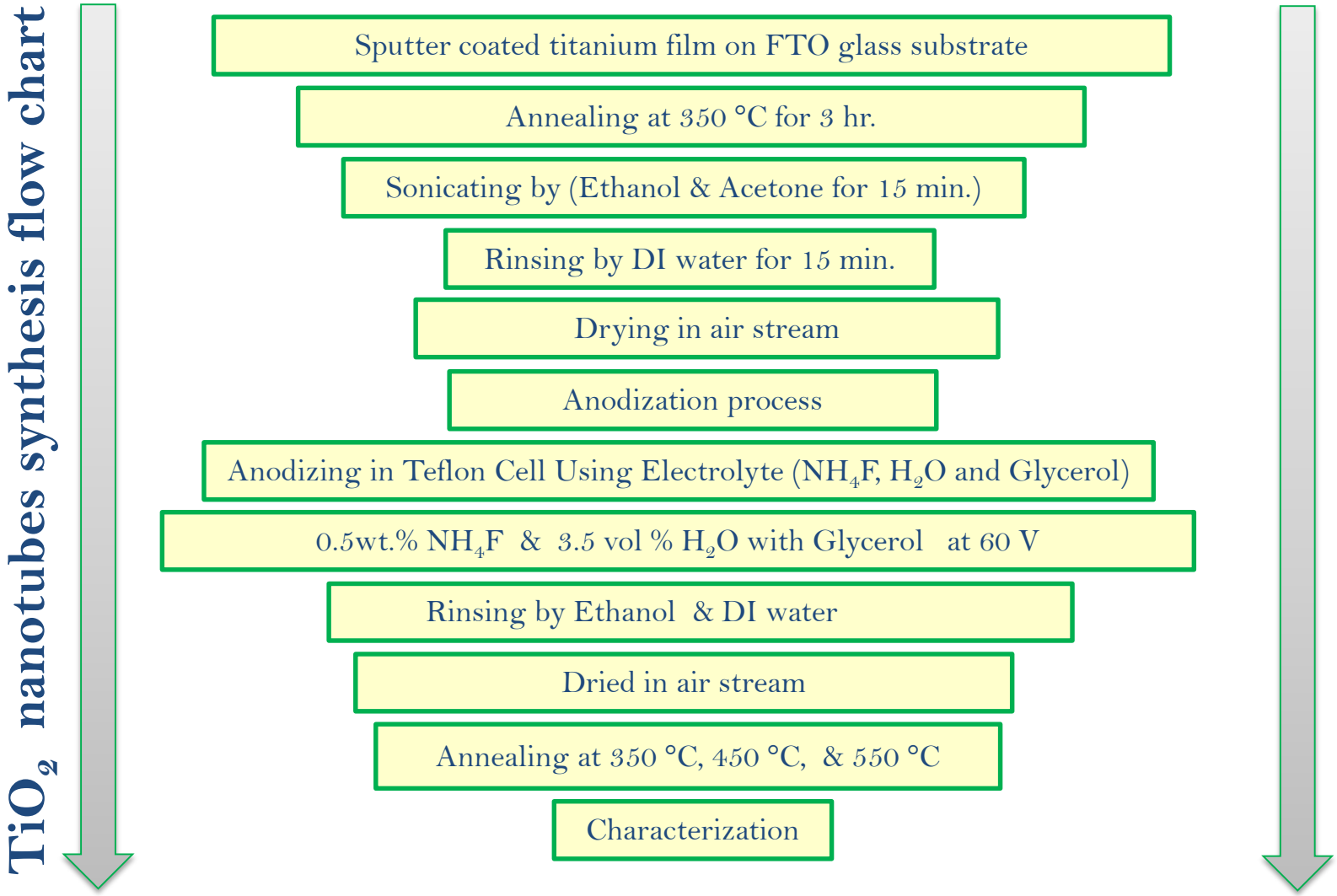

Characterization techniques

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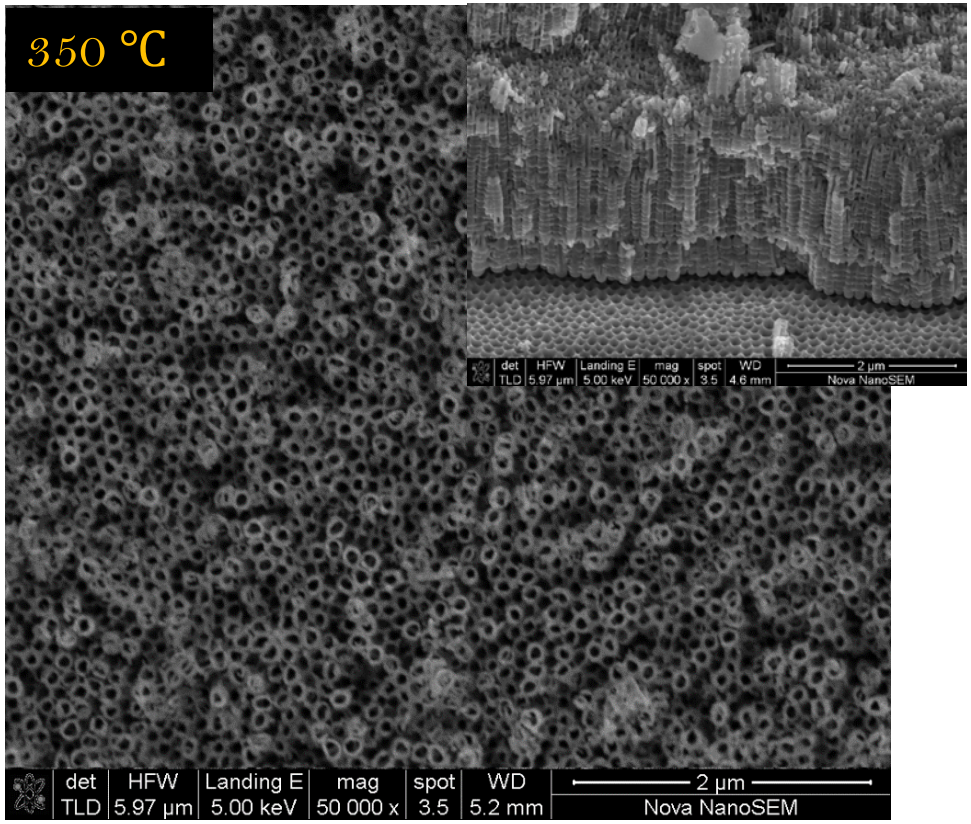
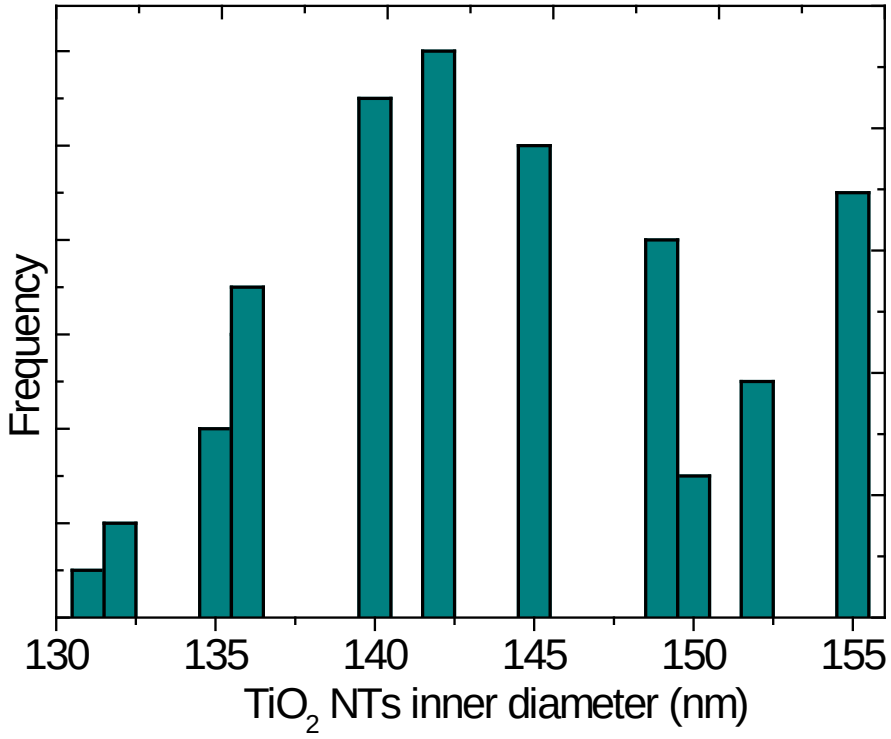
- The following techniques were used to determine the structural and morphological properties TNTs grown on FTO glass substrate.

  - Scanning Electron Microscopy
  - X-ray Diffraction
  - Confocal Raman Spectroscopy
    - Large area scan
    - Depth profiling

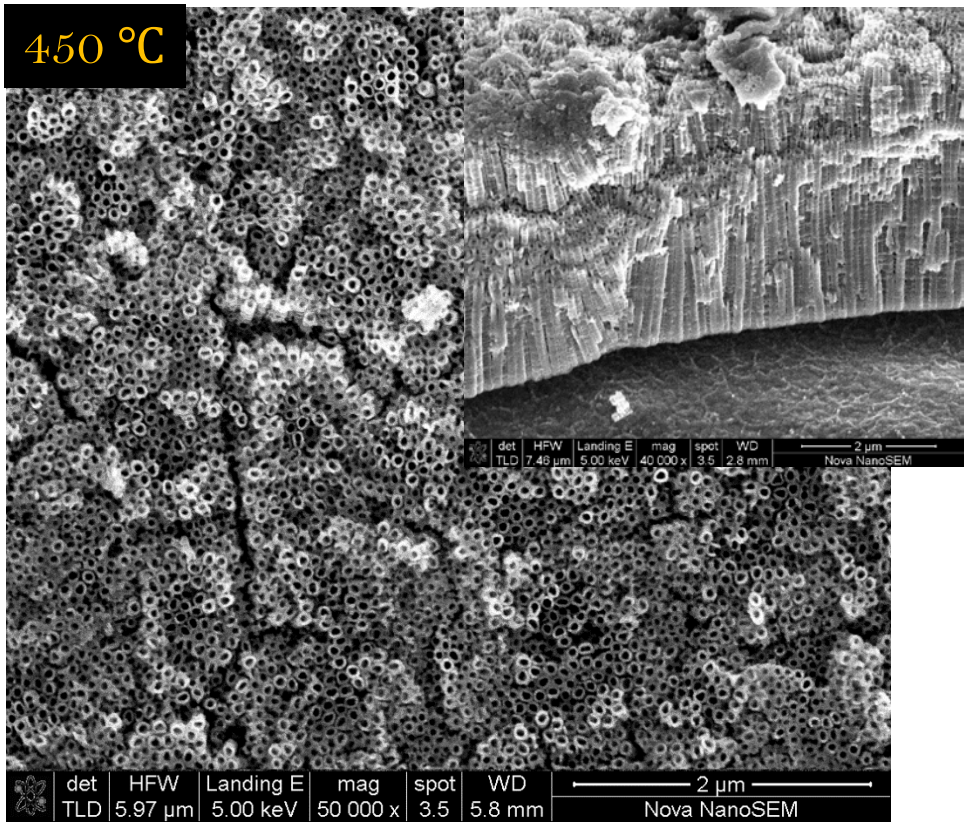
Results : SEM

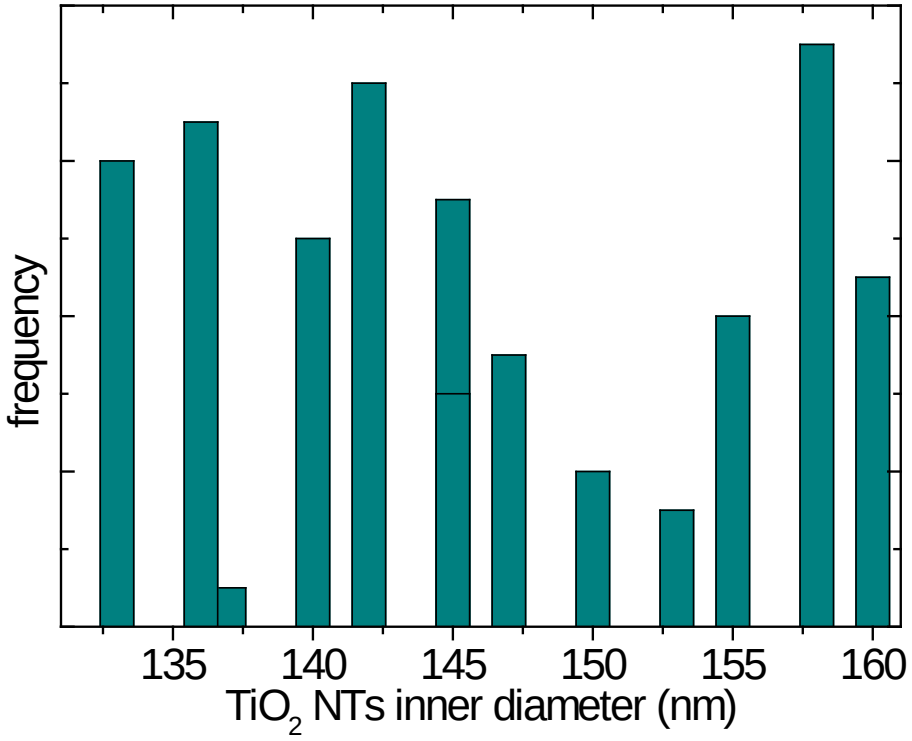




- SEM micrographs have revealed regular TNTs.
- Pore diameter of TNTs are in the range of 130- 155 nm.

Results : SEM





- Well orientated surface morphology of TNTs on FTO glass substrate.
- Increased TNT inner diameter size (130- 160 nm).

Results : SEM

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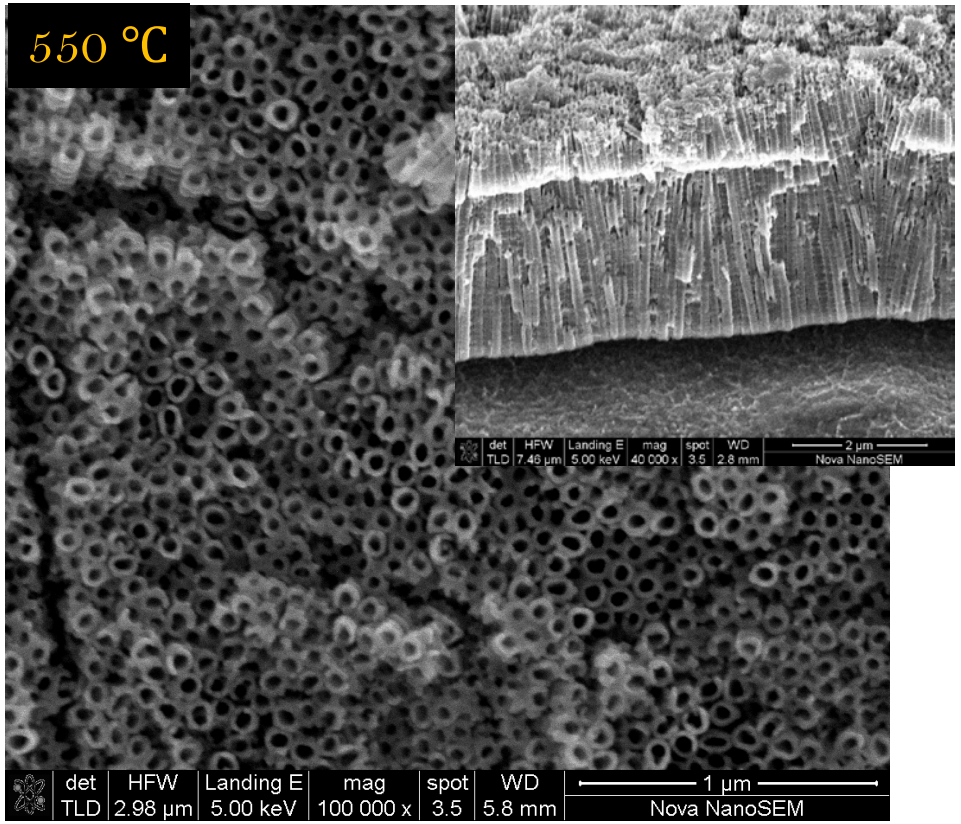

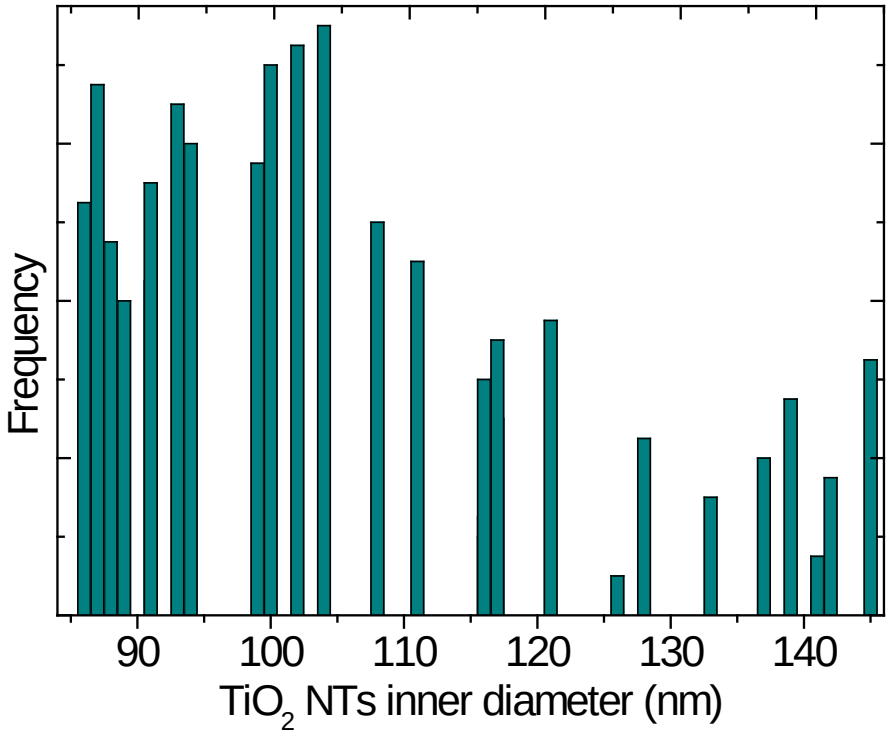

- Cross sectional view shows smooth & well aligned TNTs.
- Increase in temperature results in greatly enhanced morphology of TNTs.

Results : XRD

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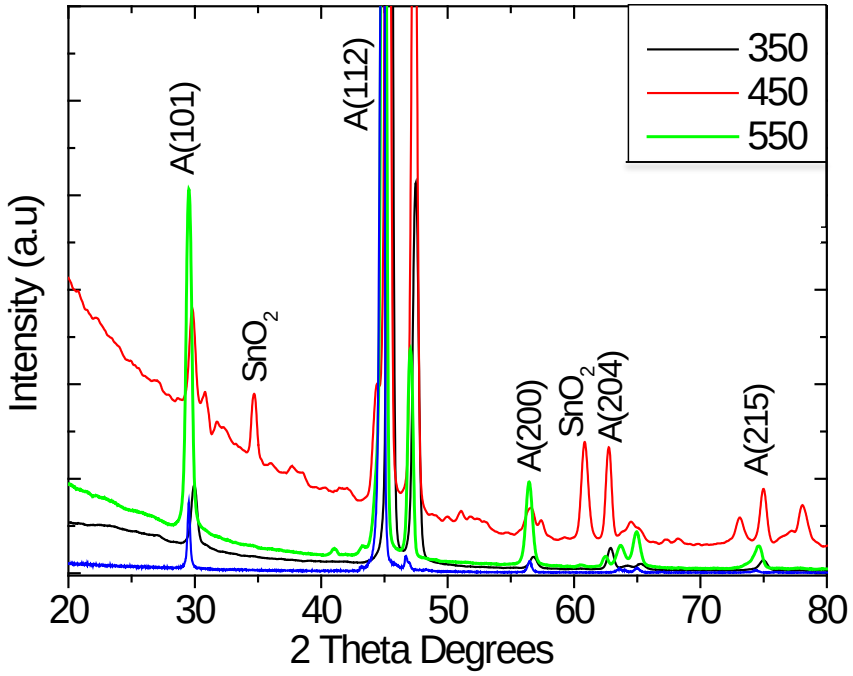
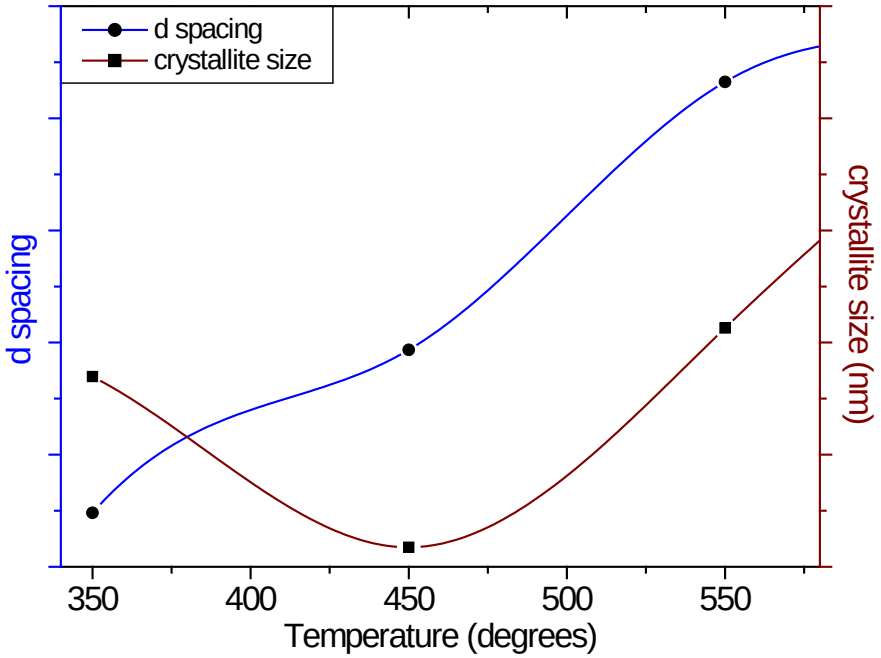
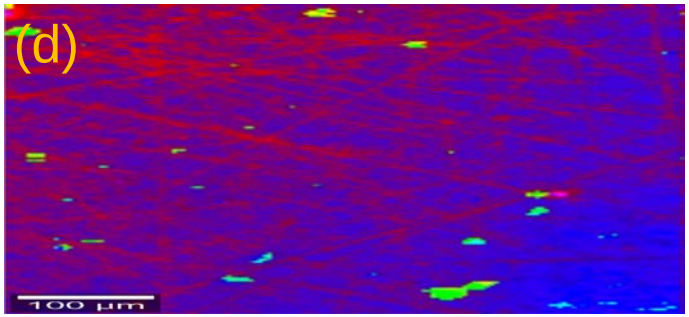


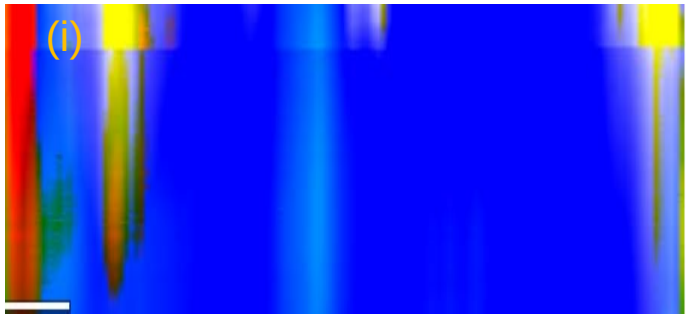


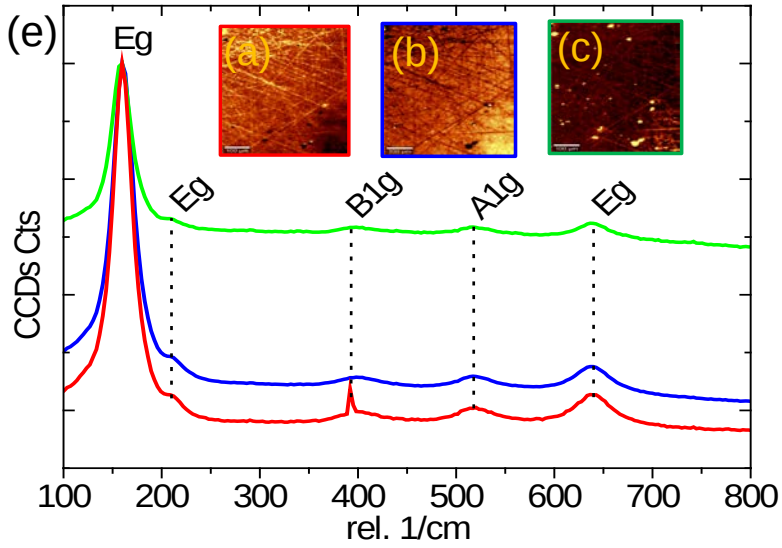
XRD spectra of the anodized TNTs-FS and annealed at 350 ℃, 450 ℃, & 550 ℃

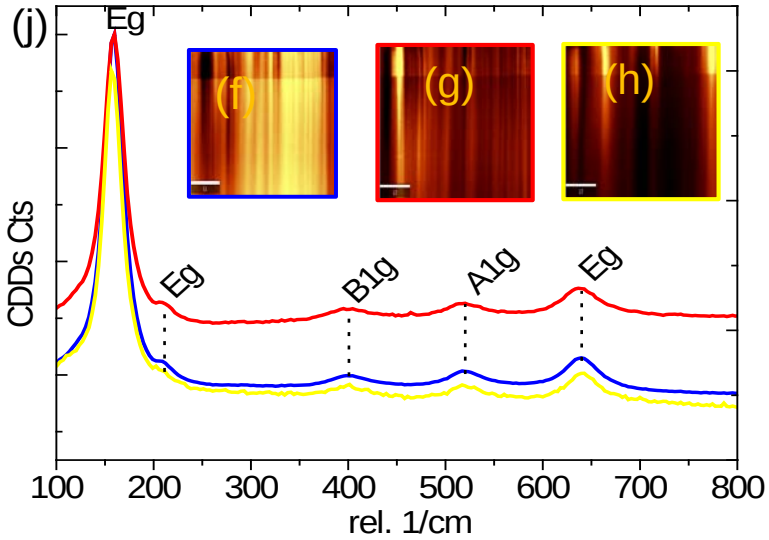
d spacing & crystallite size calculated from the XRD spectra of the anodized TNTs-FS

Results : CRS









LAS (XY) TNT 350 °C

Depth (XZ) TNT 350 °C

Results : CRS

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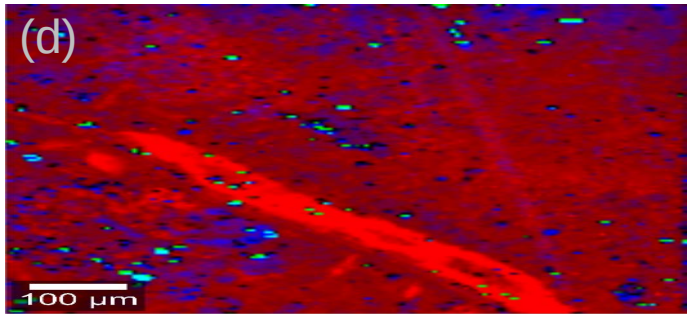

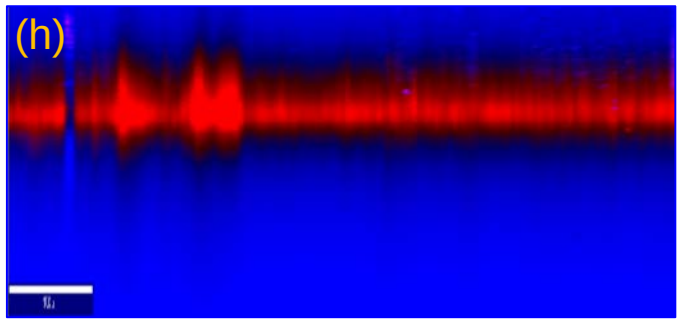

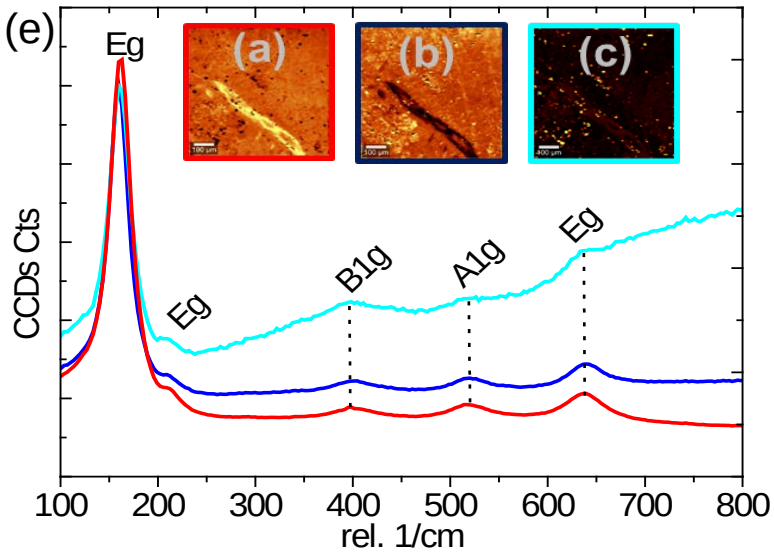

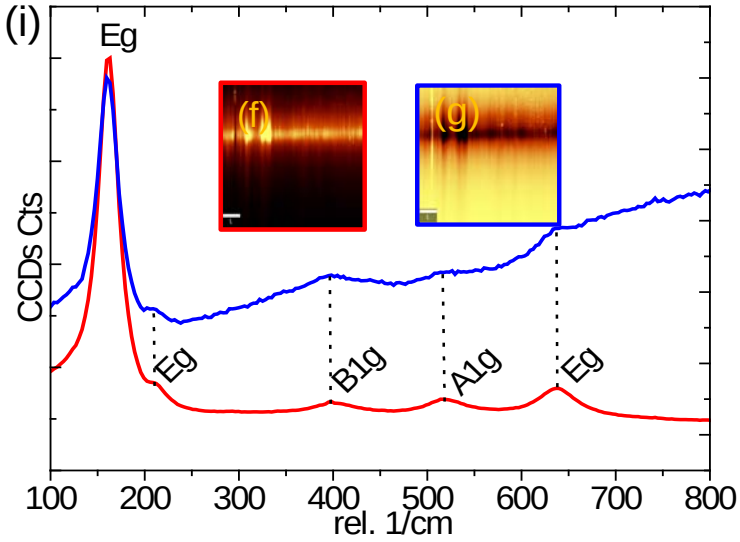

LAS (XY) TNT 450 °C

Depth (XZ) TNT 450 °C

Results : CRS

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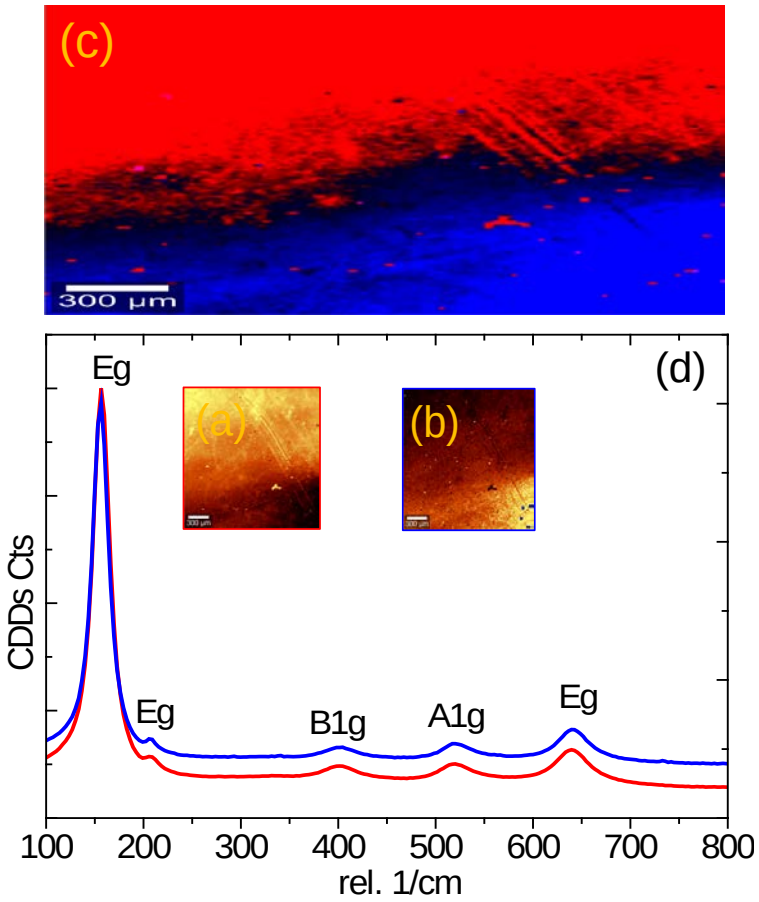

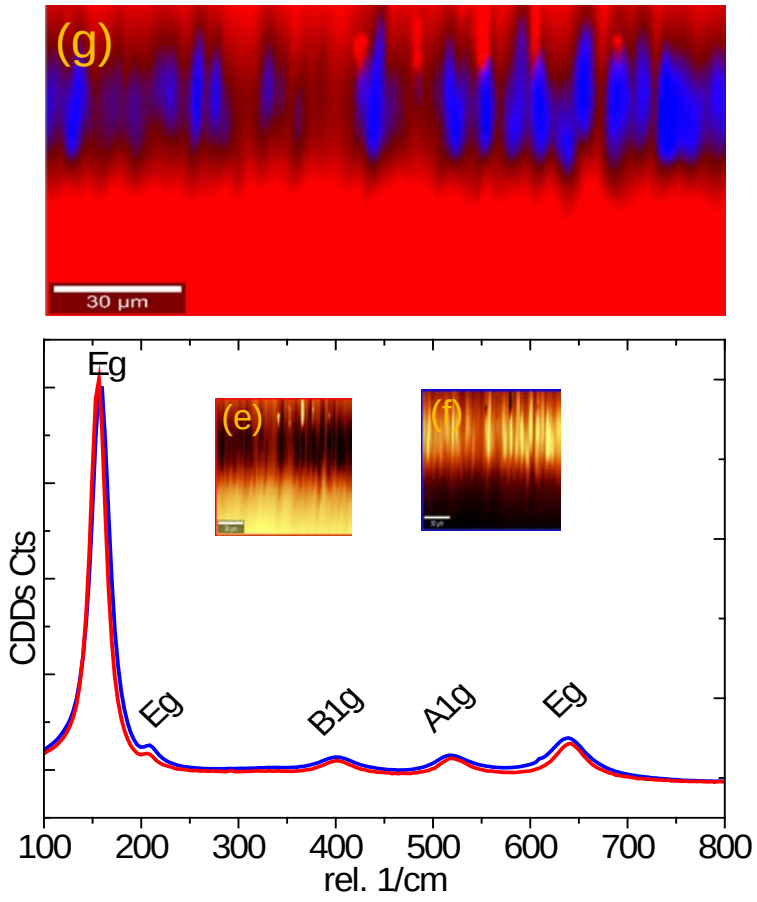

LAS (XY) TNT 550 °C

Depth (XZ) TNT 550 °C

Conclusions

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- TNT arrays with a pore diameter size range of 85 – 160 nm were successfully grown on transparent conductive FTO substrates by anodizing the sputtered Ti films.
- SEM micrographs show the regular morphology with no disruption or deformation of TNTs on FTO substrate even at elevated temperature (550 °C).
- CRS analysis (LAS & Depth) & XRD confirmed the presence of anatase TNTs on FTO glass substrate with increase in temperature resulting in high peaks intensities, thus high structural phase maturity.
- The enhanced morphology & presence of only anatase phase TNTs make these substrates suitable for PSCs.

Acknowledgements

- I would like to thank God almighty for the gift of life and wisdom.
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