Selective contacts for undoped photovoltaic cells fabricated by high pressure sputtering

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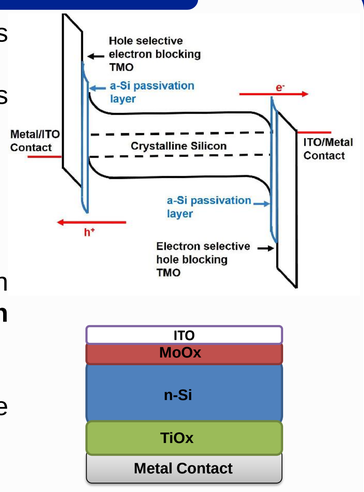
MOTIVATION

- To overcome intrinsic problems of homojunctions and HIT cells:
  - Use of toxic/dangerous chemicals.
  - High temperature process.
  - Parasitic absorption.
  - Interlayer damage.
- Research the selectivity behavior of Transition Metal Oxides (TMO) deposited by **High Pressure Sputtering (HPS)**
- Final objective: Fabrication of Dopant Free Asymmetric Heterocontact (DASH) solar cells.



EXPERIMENTAL

Fabrication process

Deposition of TMO thin films by the uncommon technique **HPS**. Ar and Ar-O2 atmosphere. Pressure greater than 0,5mbar

Higher pressure means a reduction of interlayer damage.

Mean free path between collisions

$$\lambda = \frac{kT}{\sqrt{2}\pi d^2 p}$$

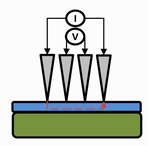
Our system:
- 3 different targets
- 3 different gases
- Temperature control

Characterization: Electrical and Structural

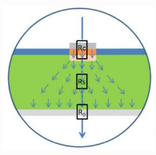
Four-point probe

To measure sheet resistance of deposited thin films

$$R_{sh} = \frac{\rho}{t} = \frac{\pi}{ln(2)}\frac{V}{I}$$



Cox & Strack method



Specific contact resistivity measurement ρ_c

$$R_T - R_S = \frac{\rho_c}{\frac{1}{4}\pi d^2} + R_O$$

X-ray Photoelectron Spectra (XPS)

To analyze chemical composition, i.e oxidation states

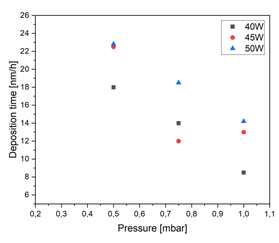
Fourier Transform Infrared Spectroscopy (FTIR)

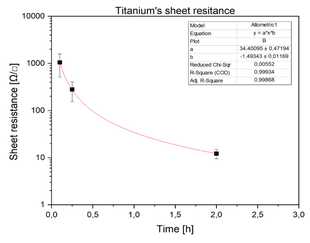
Absorption due to chemical bond vibrations

RESULTS

Electron Selective Contact (ESC) -TiOX

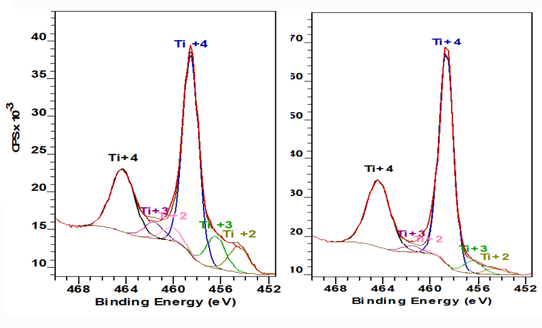
Different conditions to deposit TiOx. Process reproducibility is assured by target conditioning. Sheet resistance measurements to obtain information about film oxidation





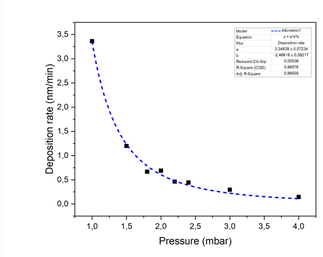
Plasma of Ar + O2 to oxidize Ti thin film. We used Glow Discharge Optical Emission Spectroscopy (GDOES) to ensure the oxidation of the metal and track the process.

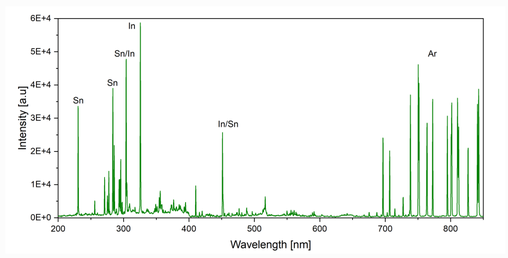
Different samples were measured with XPS. We could see the increment of the oxidation state relate to TiOx. A reduction of sub-stoichiometric states when we applied temperature.



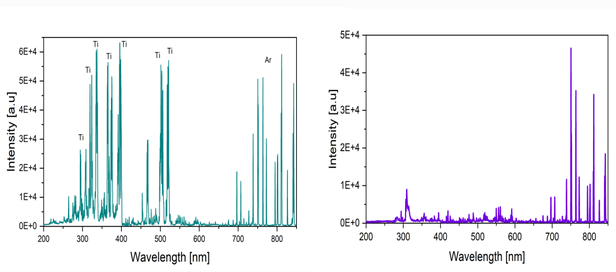
Transparent Conducting Oxides (TCO) - ITO

Characterization of deposition rate of ITO with different pressure to find the best condition to deposit. GDOES to track the emitted atoms/molecules and to detect possible contaminants in the chamber.



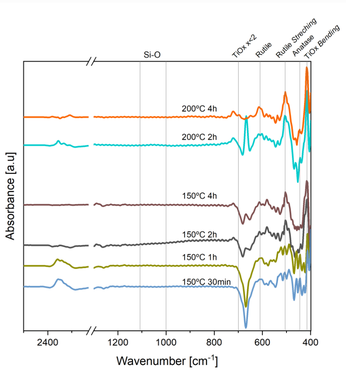


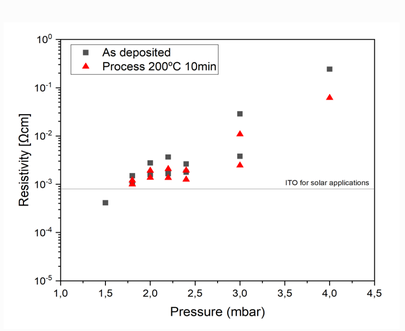
The sheet resistance of samples were measured with the four-point probe to compere the quality of our material with those of commercial PV applications. Furthermore, measurement of transmittance and reflectance was carried out to determine the absorptance of our material.

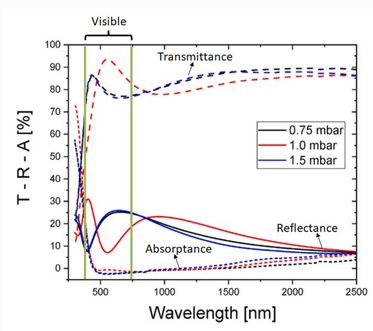


To measure the ρ_c (TiOx[5nm]-Si interlayer), photolithography to define the Cox & Strack circle structure. After the first measurement an annealing process was carried out.

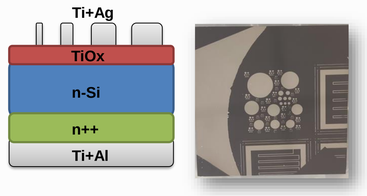
There are signs of molecular vibrations related to TiO2. We could see a slight relationship between the duration of oxidation process and the vibration modes intensity at 415 cm^{-1} and 506 cm^{-1}

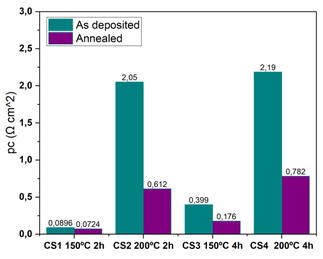


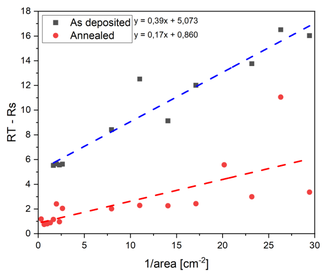


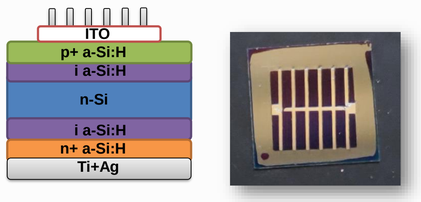


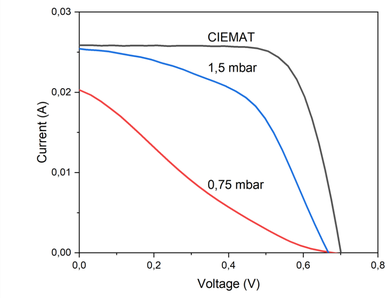
With the best condition, we deposited ITO on top of Heterojunction with Intrinsic Thin Layer (HIT) structures made by CIEMAT. Subsequently, we measured the IV curve of the cell [AM1.5G 25ºC].











CONCLUSIONS

- We have characterized the **conditions to deposit TiOx** thin films with the uncommon technique of HPS, **45W at 0,5mbar** appears to be the best condition. The **conditioning of the plasma is extremely important** to ensure the reproducibility of the process, around 3h of conditioning appears to be the sweet point.
- XPS and FTIR results reveal the correct oxidation of our film. **Process between 150 – 200ºC** shown almost stoichiometric TiOx (x=2)
- We did the Cox & Strack structure to measure the **specific contact resistivity (ρ_c) between n-Si and our TiOx**. After an annealing (200ºC 10min) all the samples portrayed lower ρ_c. Process with **150ºC and 2h of oxidation** is the best condition up to now. We obtained ρ_c similar to the bibliography.
- We deposited ITO with different high-pressure conditions, the **resistivity** presented with the best condition (1,5mbar) **is lower than 10^{-3} Ω cm**. Besides, the films present **high transmittance in the visible region**, around 70-90%.
- The behavior of our ITO in a HIT cell structure is promising. **Our best condition (1,5mbar) present FF 50% and efficiency (η) 9%.**

References

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