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# **Contactos selectivos para células fotovoltaicas sin dopados fabricados mediante pulverización catódica de alta presión**

Francisco José Pérez Zenteno

Grupo de Láminas Delgadas y Microelectrónica

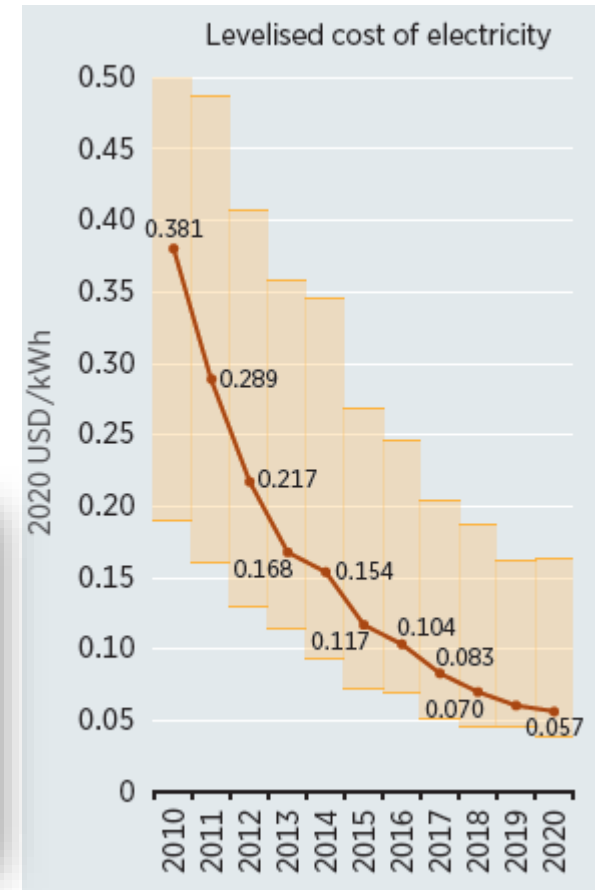
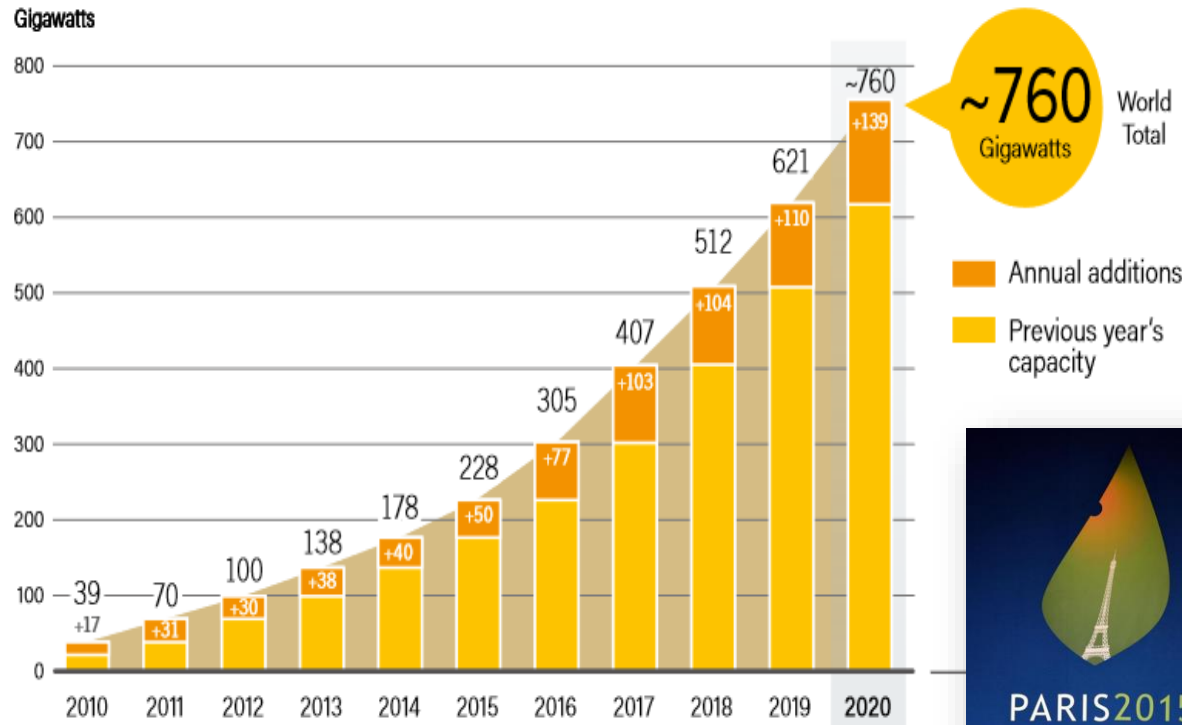
Dto. de Estructura de la Materia, Física Térmica y Electrónica

Directores: Enrique San Andrés Serrano Eric García Hemme

Jornadas de doctorando: 22 – 24 marzo 2022

- Introducción
  - Energía solar fotovoltaica
  - Células tradicionales
  - Contactos selectivos
  - *High Pressure Sputtering*
- Motivación y Objetivos
- Resultados
  - *ITO*
  - *TiO<sub>x</sub>*
  - *MoO<sub>x</sub>*
- Trabajos futuros





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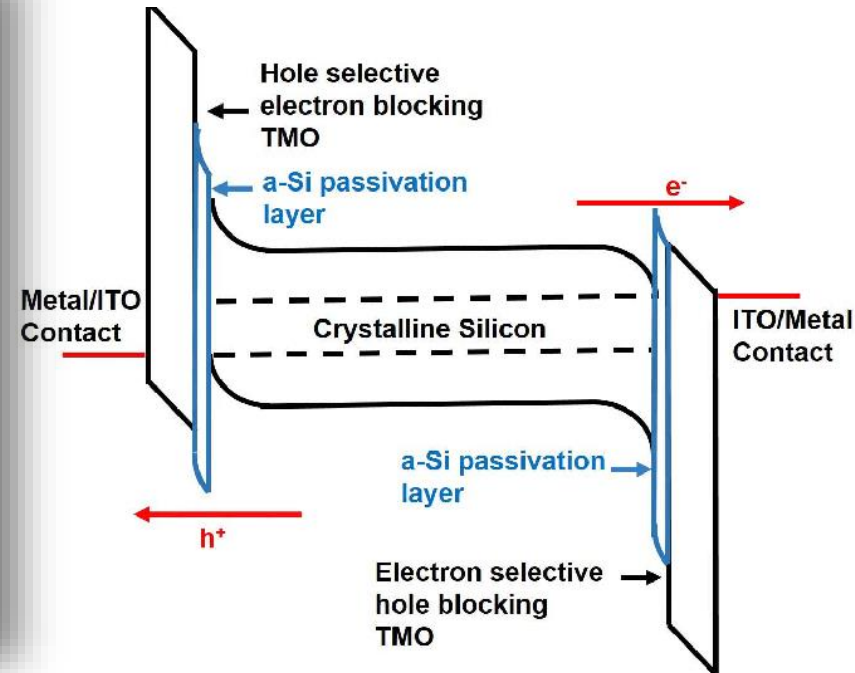
## Charge Carrier Separation in Solar Cells

Uli Würfel, Andres Cuevas, *Fellow, IEEE*, and Peter Würfel

**Abstract**—The selective transport of electrons and holes to the two terminals of a solar cell is often attributed to an electric field, although well-known physics states that they are driven by gradients of quasi-Fermi energies. However, in an illuminated semiconductor, these forces are not selective, and they drive both charge carriers toward both contacts. This paper shows that the necessary selectivity is achieved by differences in the conductivities of electrons and holes in two distinct regions of the device, which, for one charge carrier, allows transport to one contact and block transport to the other contact.

since it is a consequence of thermal equilibrium. Second, solar cell configurations exist, some of which will be discussed here, where there is no electric field at the operating point of the solar cell, or where the charge carriers even flow in a direction opposite to the electric field.

In this paper, we present an alternative explanation of solar cell operation that is straightforward and not in conflict with the laws of physics. It is based on the fact that the driving forces for



$$J_n = \mu_n n \frac{dE_{Fn}}{dx} = \frac{\sigma_n}{q} \frac{dE_{Fn}}{dx}$$

$$J_p = \mu_p p \frac{dE_{Fp}}{dx} = \frac{\sigma_p}{q} \frac{dE_{Fp}}{dx}$$

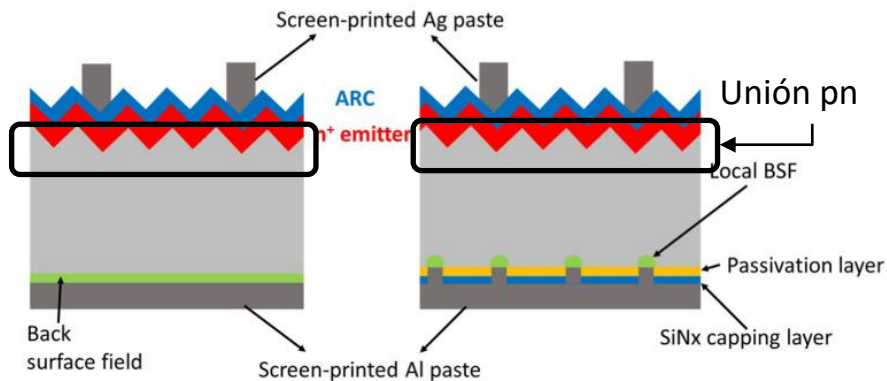
- Gradiente cuasi-niveles Fermi

- Conductividad

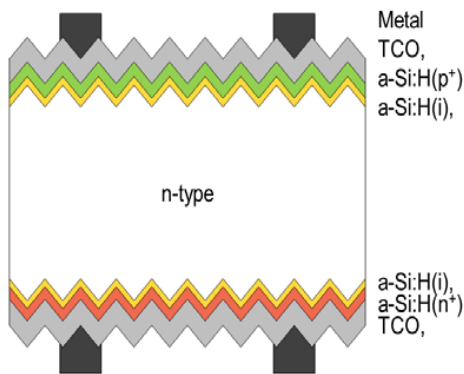
1. Dopado

2. **Doblamiento bandas**  
(*Materiales alto bandgap*)

Aprox. 90% del mercado Al-BSF y PERC

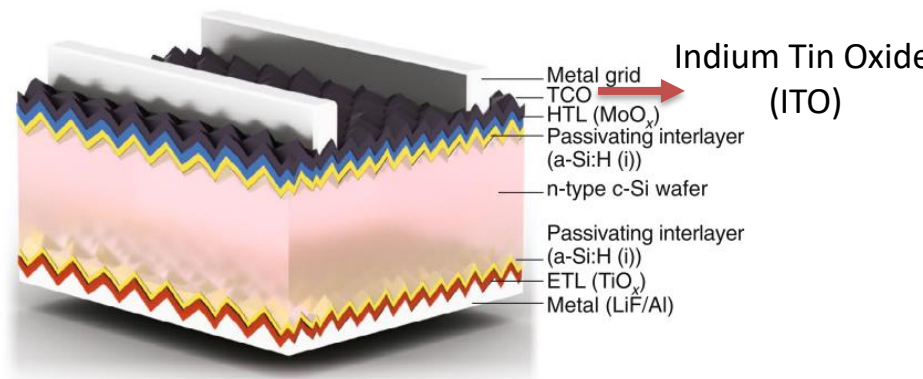


## Célula HIT



- Se está llegando al límite de eficiencia
- Problema: dopado a-Si:H

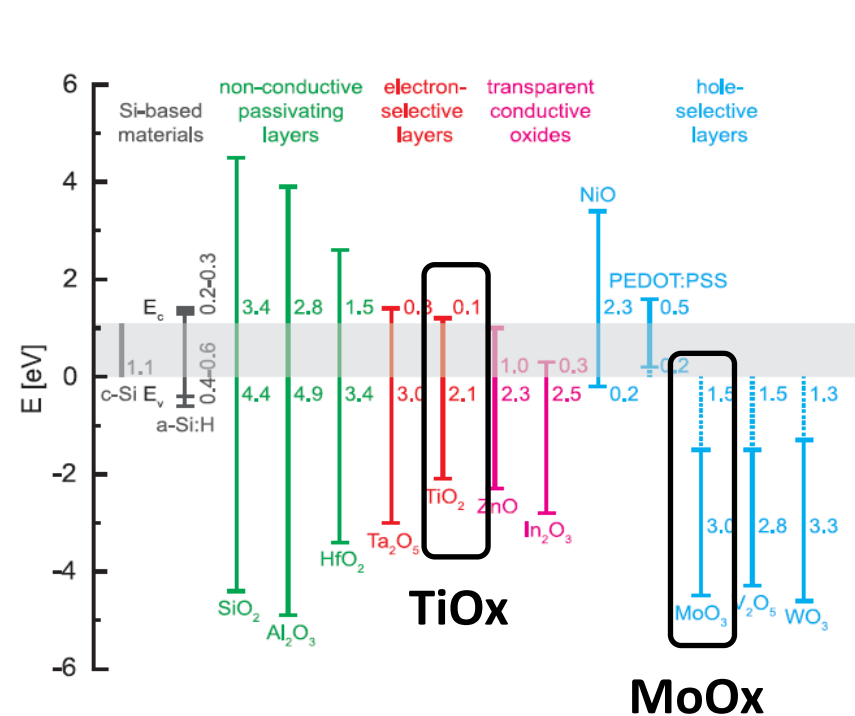
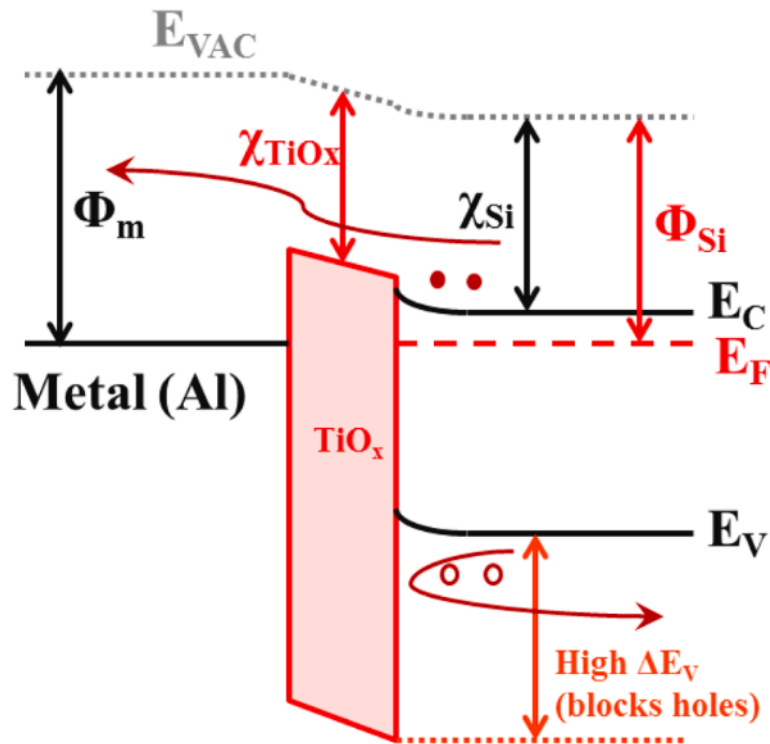
## Dopand Free Asymmetric Heterocontact (DASH)



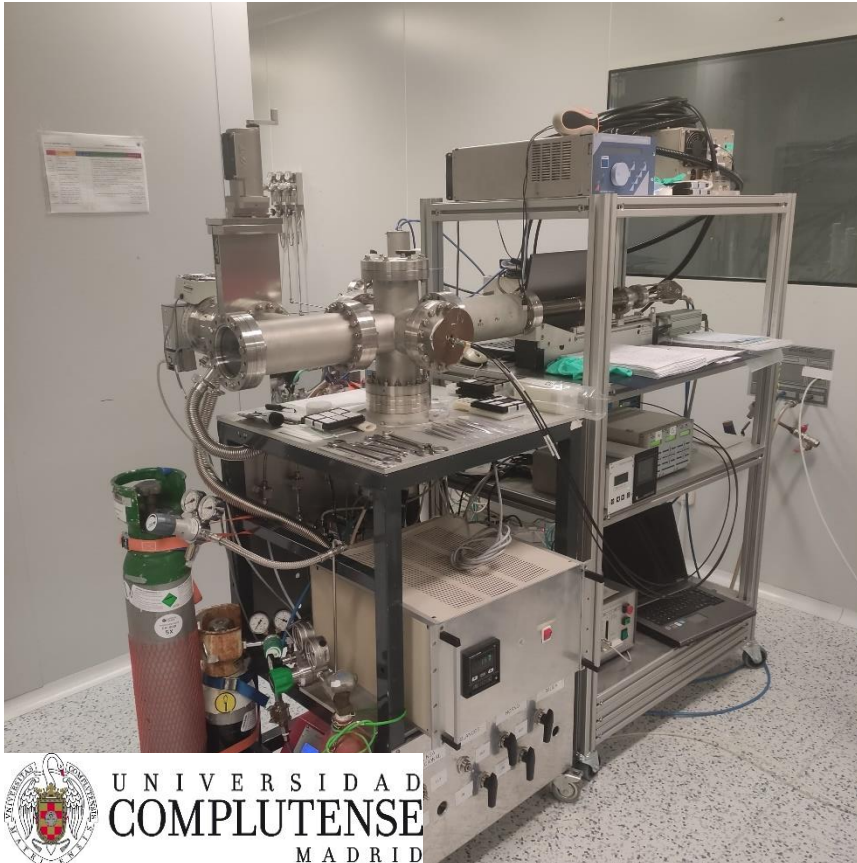
- **Producir selectividad**
  - Flujo asimétrico de los portadores
- **Bajar costos de producción**
  - < temperatura
  - Evitar materiales dopados



## Óxidos de metales de transición (TMO's)



- Técnica depositar láminas delgadas.



¿Alta presión?

Típicamente

$$10^{-4} \text{ a } 10^{-3} \text{ mbar}$$


HPS

1 mbar

Recorrido libre medio

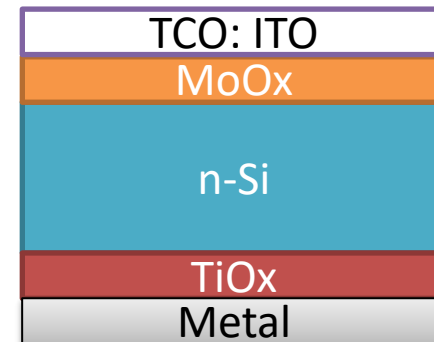
$$\lambda = \frac{kT}{\sqrt{2}\pi d^2 p}$$

Reduce daño

- 
- 3 blancos diferentes (brazo robótico)
  - **Procesos *in situ***

*La técnica de pulverización a alta presión (HPS) para el depósito de óxidos metálicos será capaz de depositar sobre Si estructuras que permitan la extracción selectiva de electrones y huecos en células fotovoltaicas. Que permitirán la construcción de células fotovoltaicas con SC sin dopado*

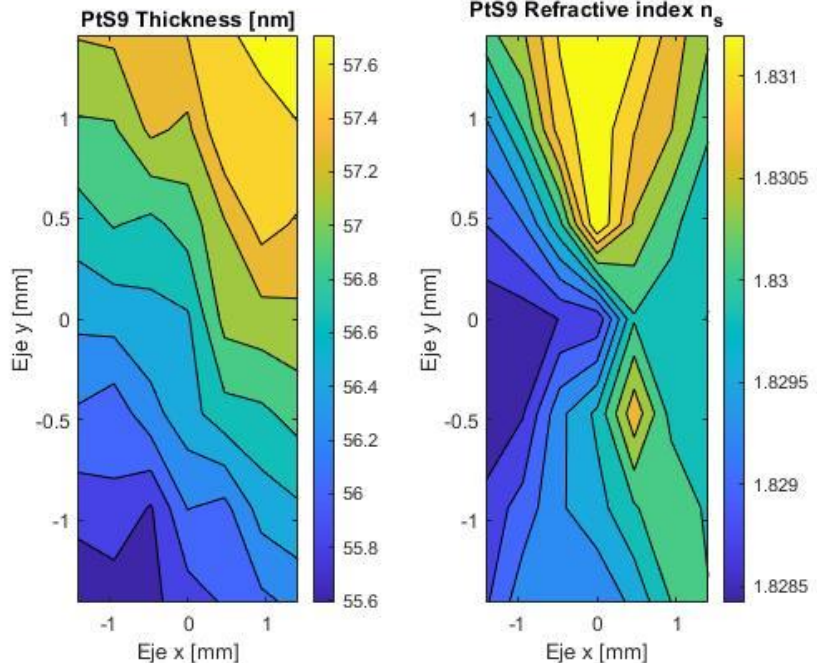
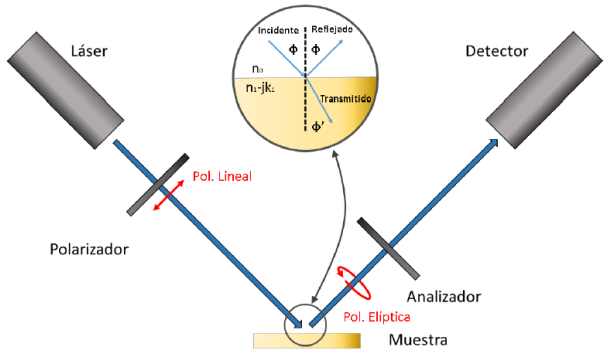
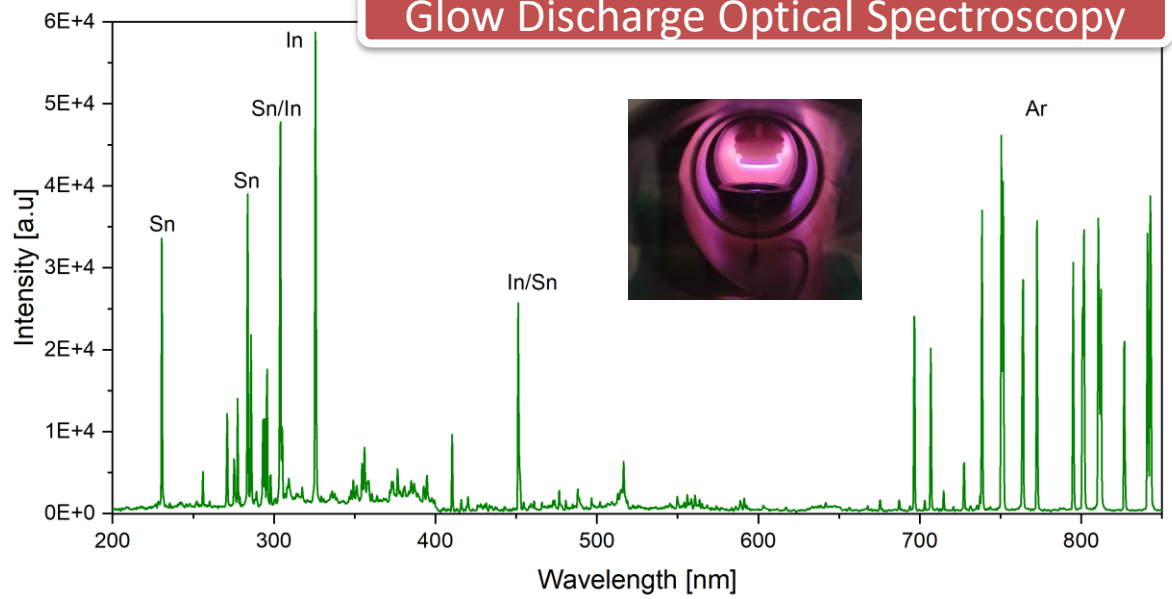
- ESC y HSC por medio de HPS
- ITO por medio de HPS
- SC - PVcell



Elipsómetro

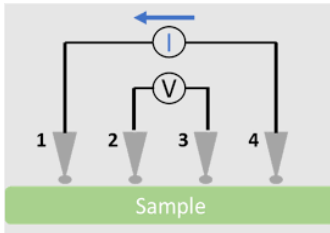


Glow Discharge Optical Spectroscopy

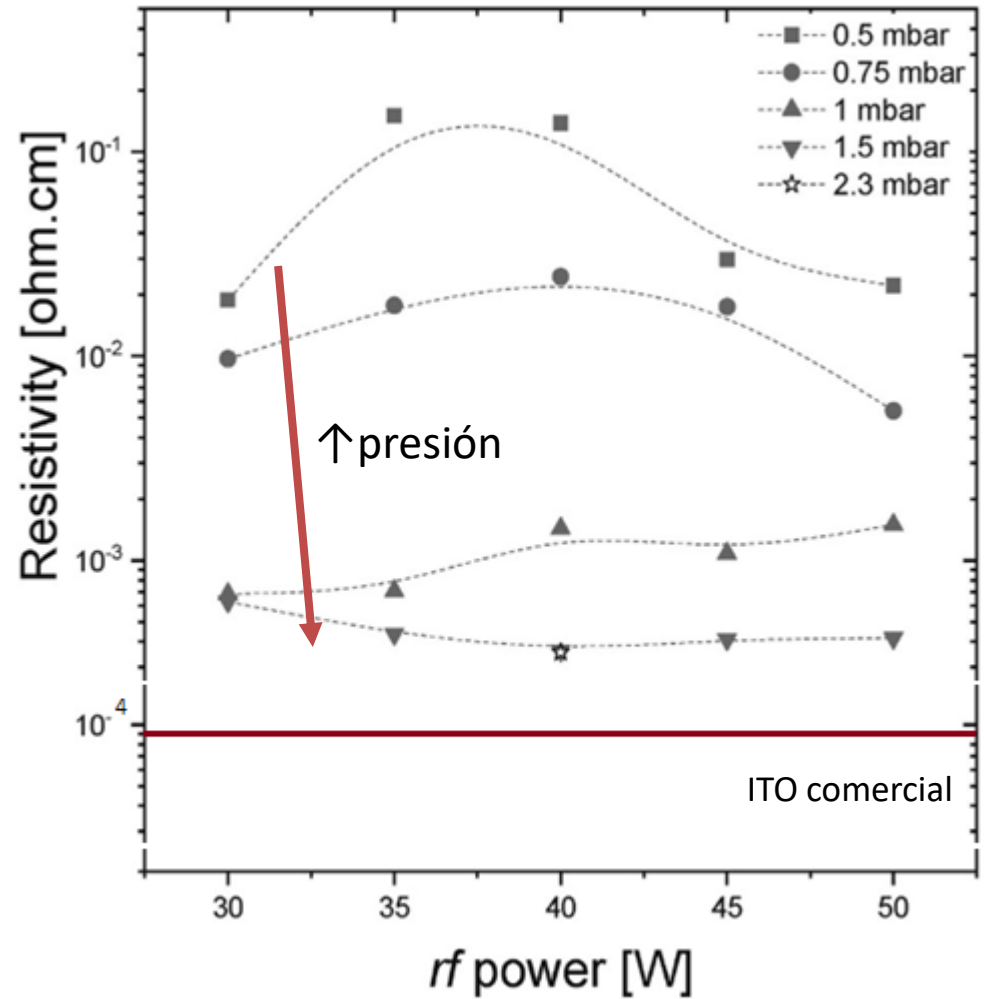
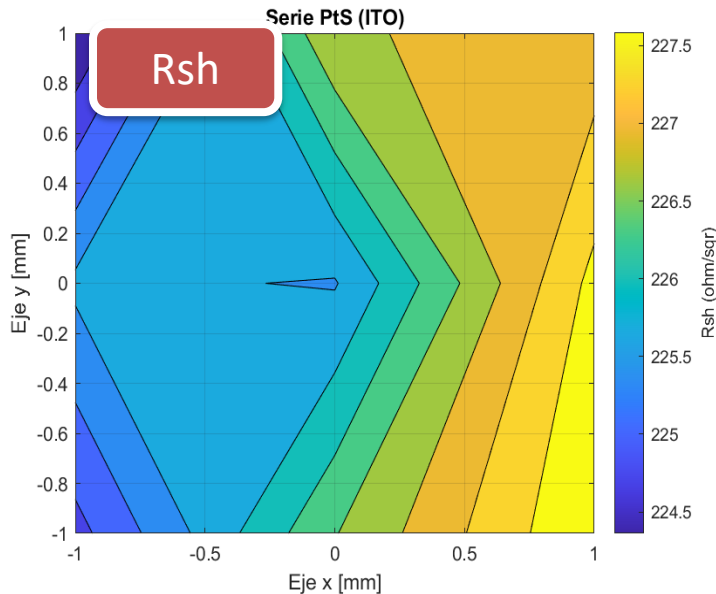


Espesor

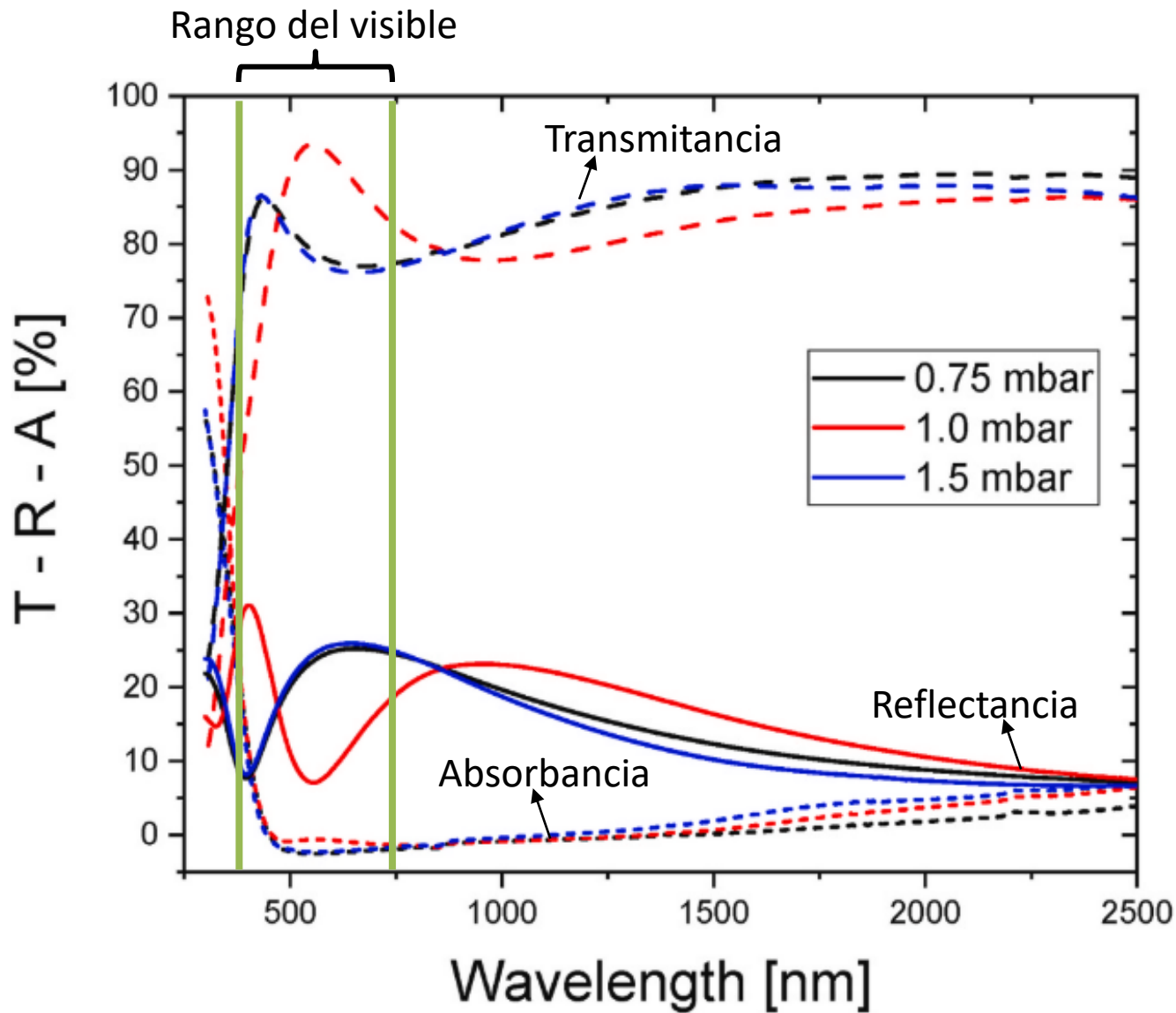
## Equipo 4 puntas



$$R_{sh} = \frac{\rho}{t}$$



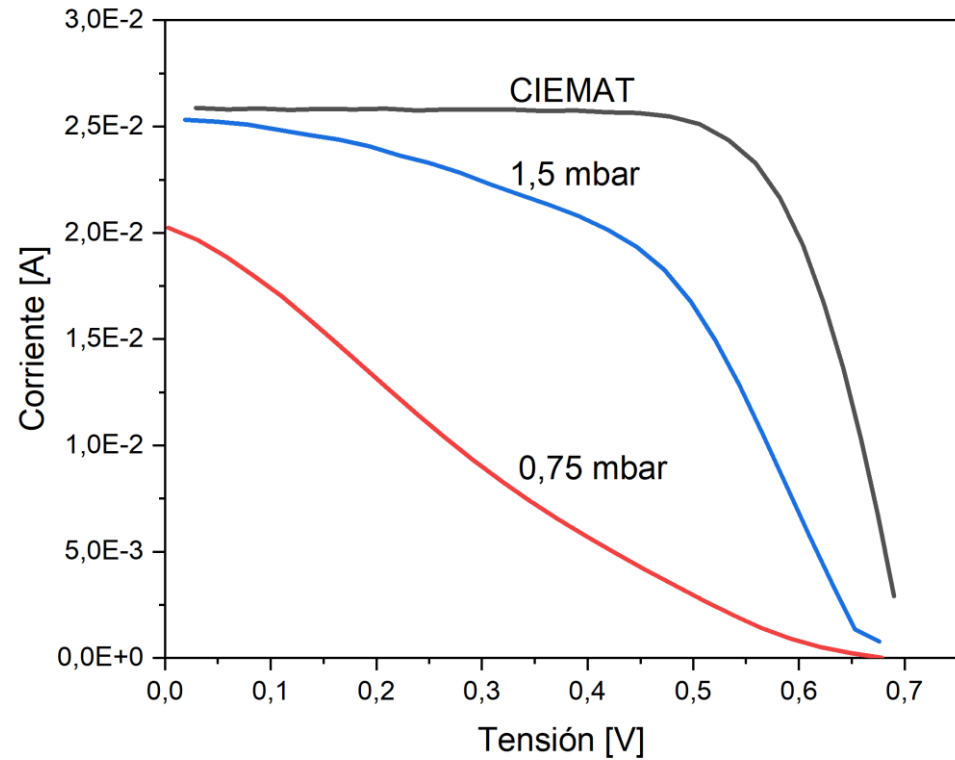
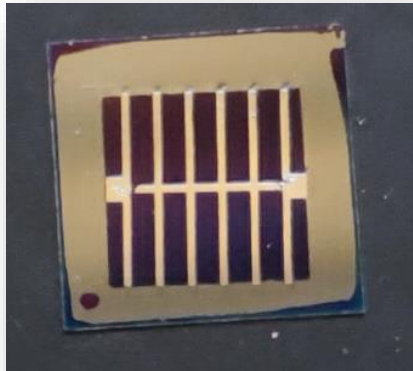
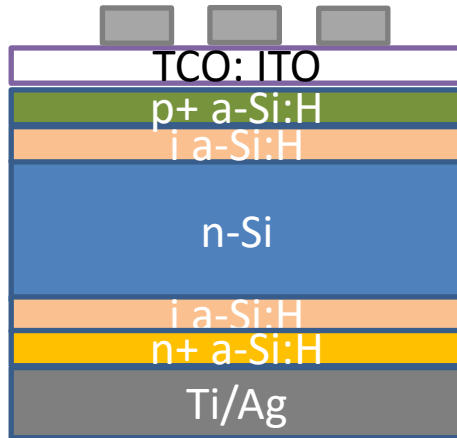
# Resultados: ITO



**<10% absorbancia**

**70 – 90% transmitancia**

**Ciemat**  
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 y Tecnológicas



Muestra	FF (%)	$\eta$ (%)
CIEMAT	71	13
0,75 mbar	22	3
1,5 mbar	50	9

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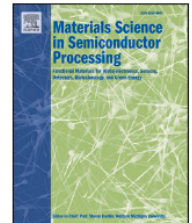


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### Indium tin oxide obtained by high pressure sputtering for emerging selective contacts in photovoltaic cells

D. Caudevilla<sup>a</sup>, E. García-Hemme<sup>a</sup>, E. San Andrés<sup>a,\*</sup>, F. Pérez-Zenteno<sup>a</sup>, I. Torres<sup>b</sup>, R. Barrio<sup>b</sup>, R. García-Hernansanz<sup>a</sup>, S. Algaidy<sup>a</sup>, J. Olea<sup>a</sup>, D. Pastor<sup>a</sup>, A. del Prado<sup>a</sup>

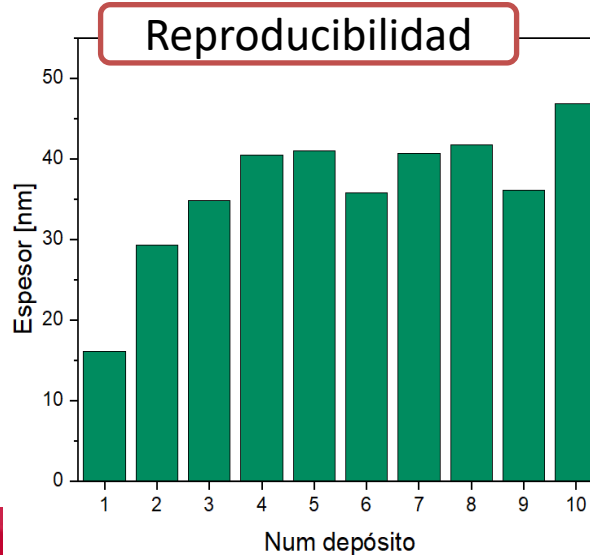
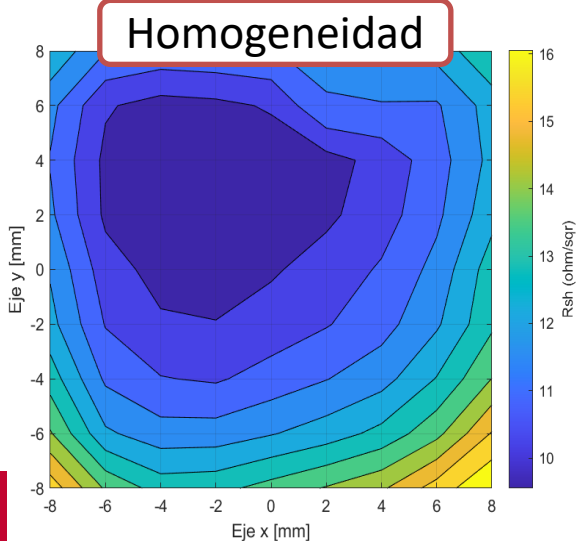
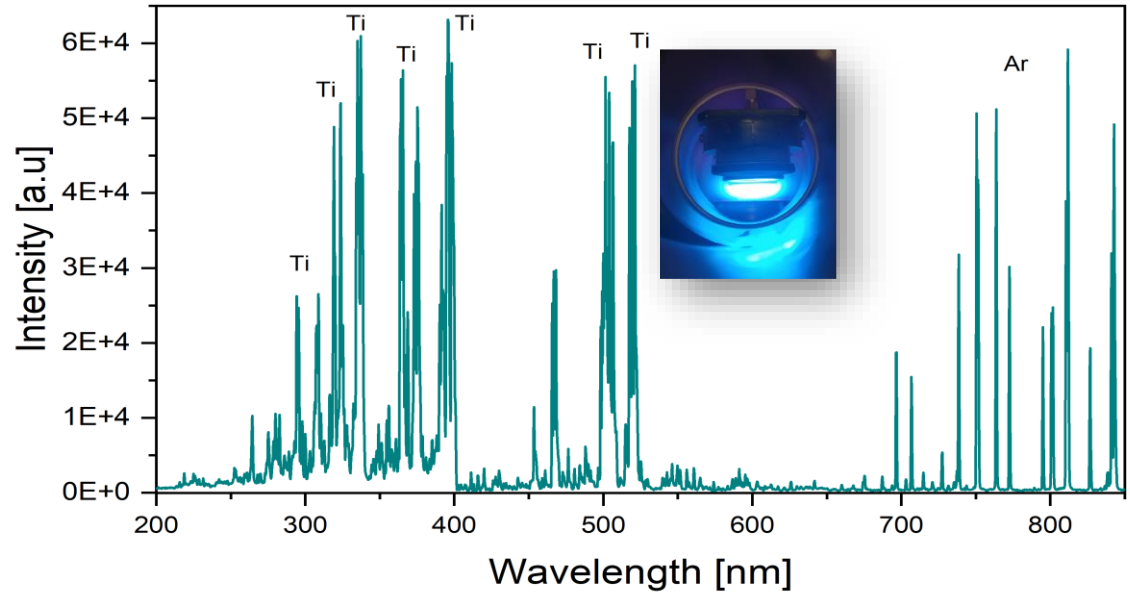
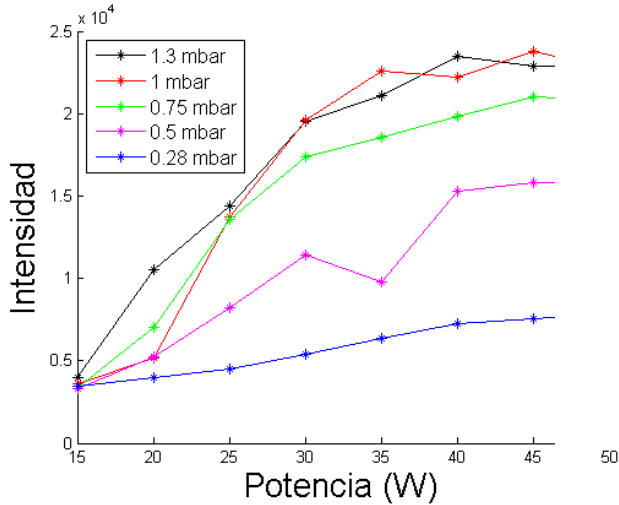
<sup>a</sup> Dpto. Estructura de la Materia, Física Térmica y Electrónica, Universidad Complutense de Madrid, Fac. de CC. Físicas. Plaza de Ciencias 1, E-28040 Madrid, Spain

<sup>b</sup> Unidad de Energía Solar Fotovoltaica, Dpto. de Energías Renovables, CIEMAT. Av/ Complutense 40, E-28040 Madrid, Spain



Proceso dos pasos:

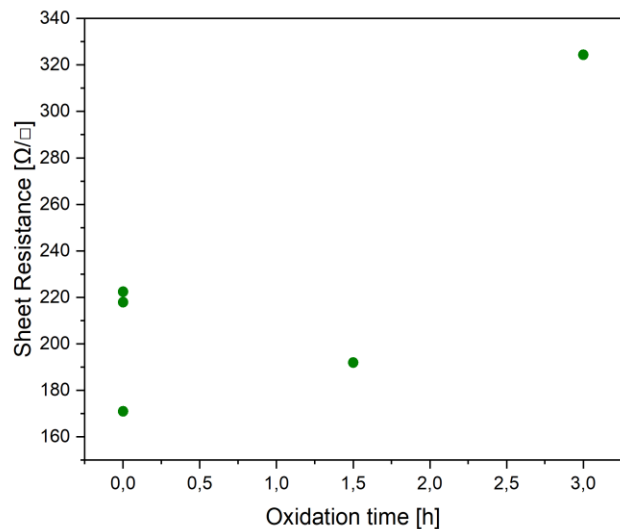
1. Depósito Ti
2. Oxidación



**Acondicionamiento muy importante**

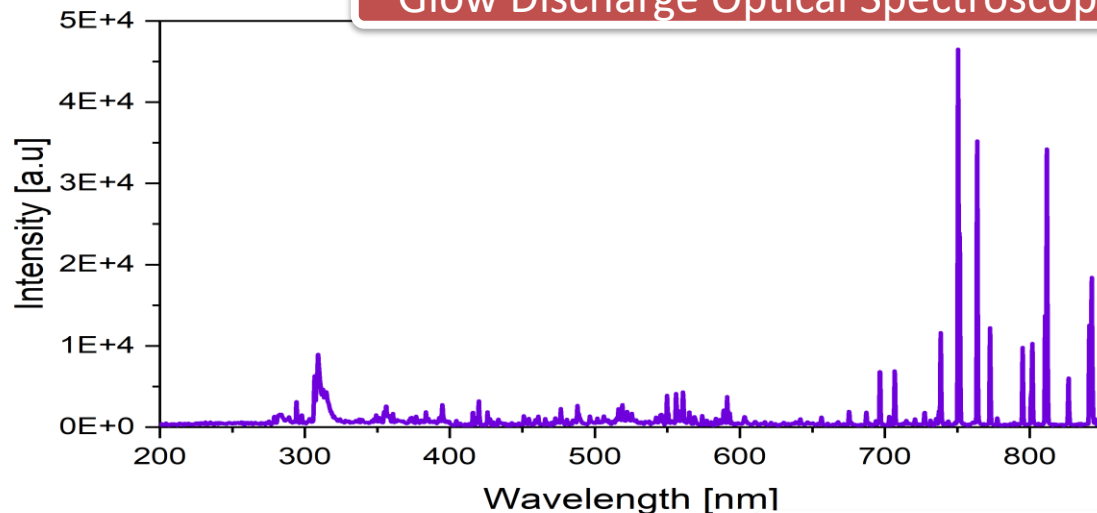
Proceso dos pasos:

1. Depósito Ti
2. Oxidación

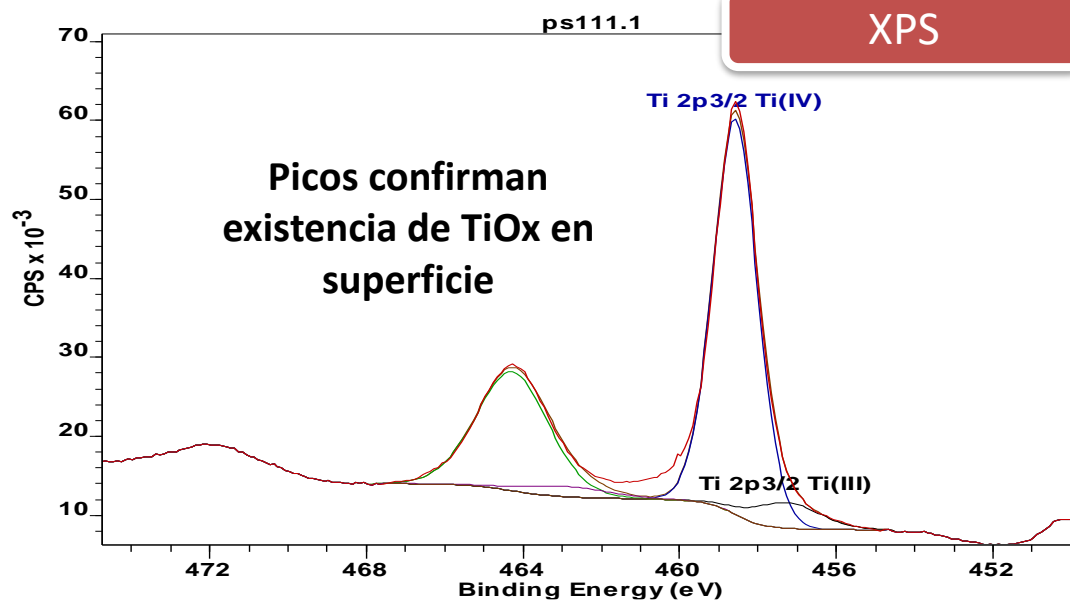


**CENIM**  
Centro Nacional de Investigaciones Metalúrgicas

## Glow Discharge Optical Spectroscopy

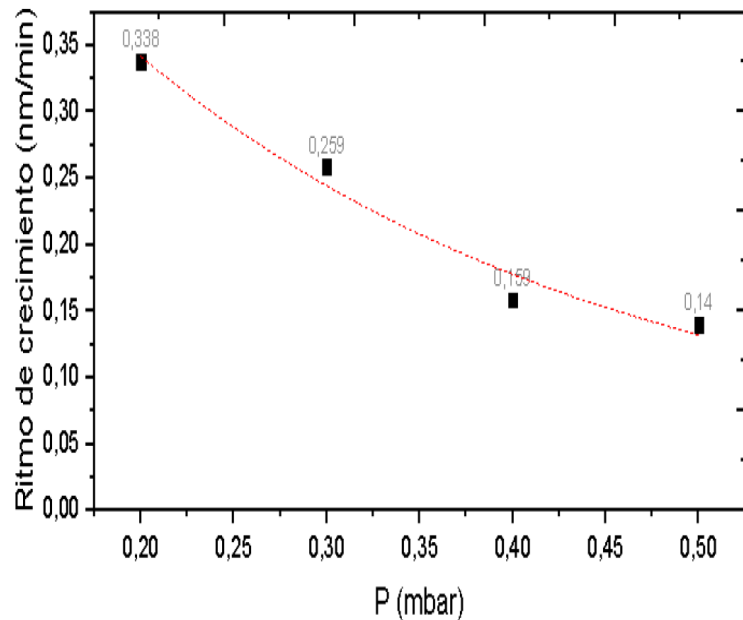


## XPS

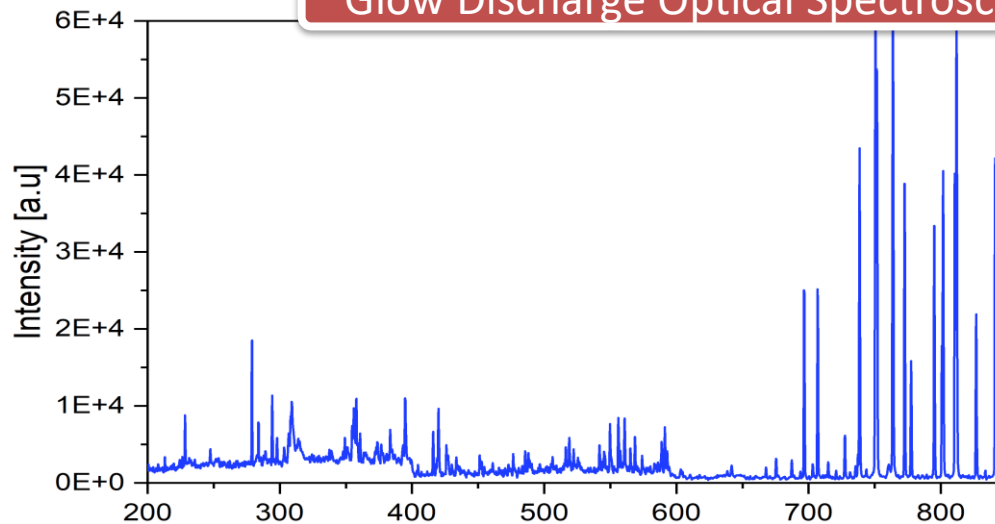


Un solo paso de deposito.

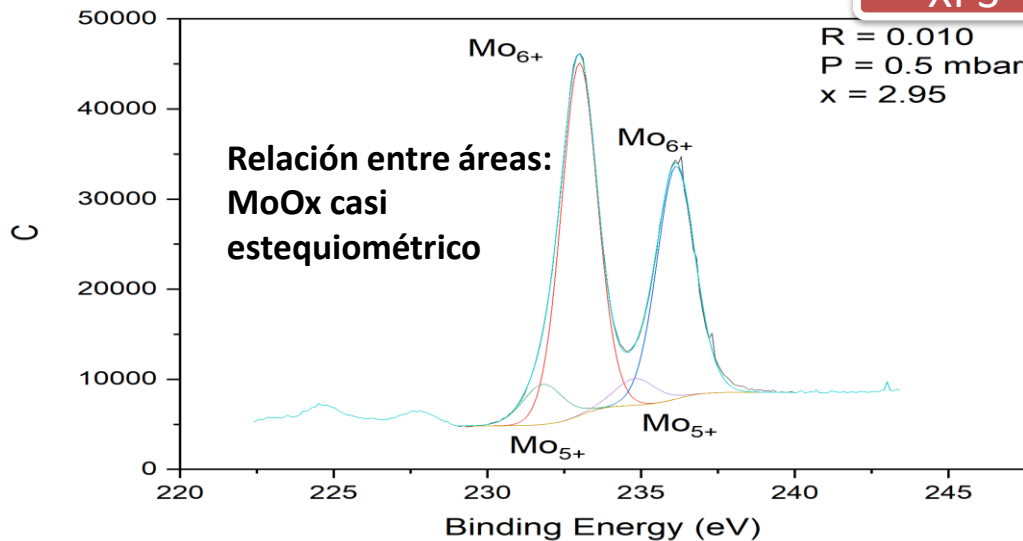
- Plasma Ar +O2 no es capaz de oxidar lámina depositada



## Glow Discharge Optical Spectroscopy



## XPS



- **Investigar aún más el ITO**
- **Caracterizar TiOx**
  - Dos procesos de oxidación o uno solo
- **Caracterizar MoOx**
  - Cambiar composición
- **Fabricar célula DASH**

# Muchas Gracias

Francisco José Pérez Zenteno

Grupo de Láminas Delgadas y Microelectrónica  
Dto. Estructura de la Materia, Física Térmica y Electrónica

[francp05@ucm.es](mailto:francp05@ucm.es)