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## Surface photovoltage study of perovskite materials and structures for solar cell applications

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## Background:

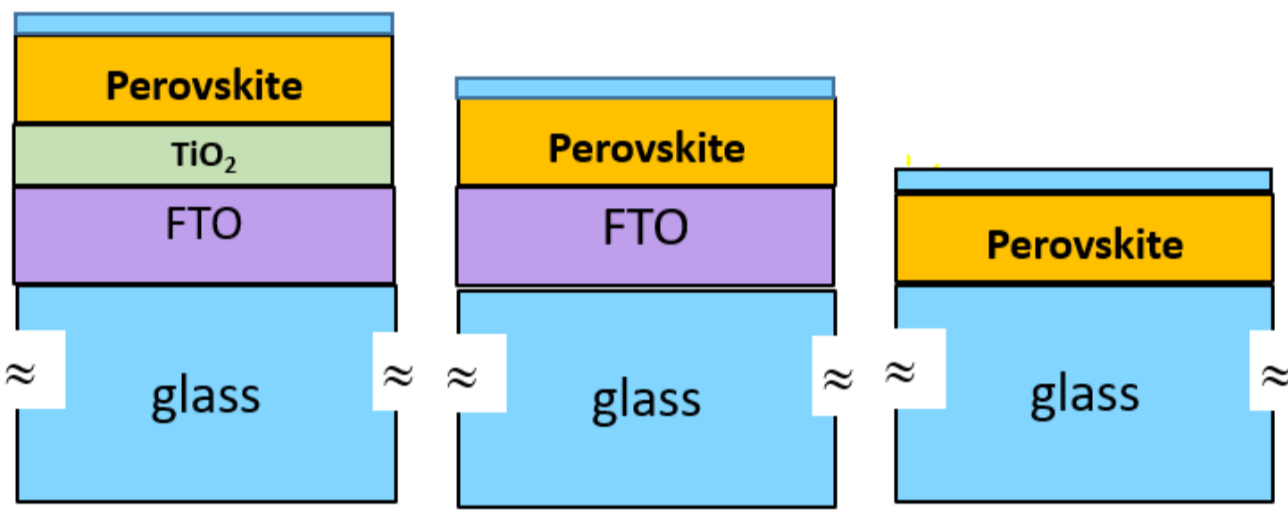
- Perovskites (PSK) are considered as a perspective material for the 4<sup>th</sup> generation solar cells because of their tunable bandgap around 1.6 eV via compositional engineering, high absorption coefficient and steep absorption edge.
- The power conversion efficiency of PSK solar cells has grown from 14.1% to 26.1% during the last 10 years (2013-2023)
- However, their stability is still a problem due to the degradation of the optoelectronic properties of the PSK light absorber, as well as of the selective carrier transport layers (SCTL) used to selectively extract photogenerated carriers.

**A challenge:** Understand the carrier generation, transport and recombination in the PSK and at the PSK/SCTL interface and surface.

## Experimental samples:

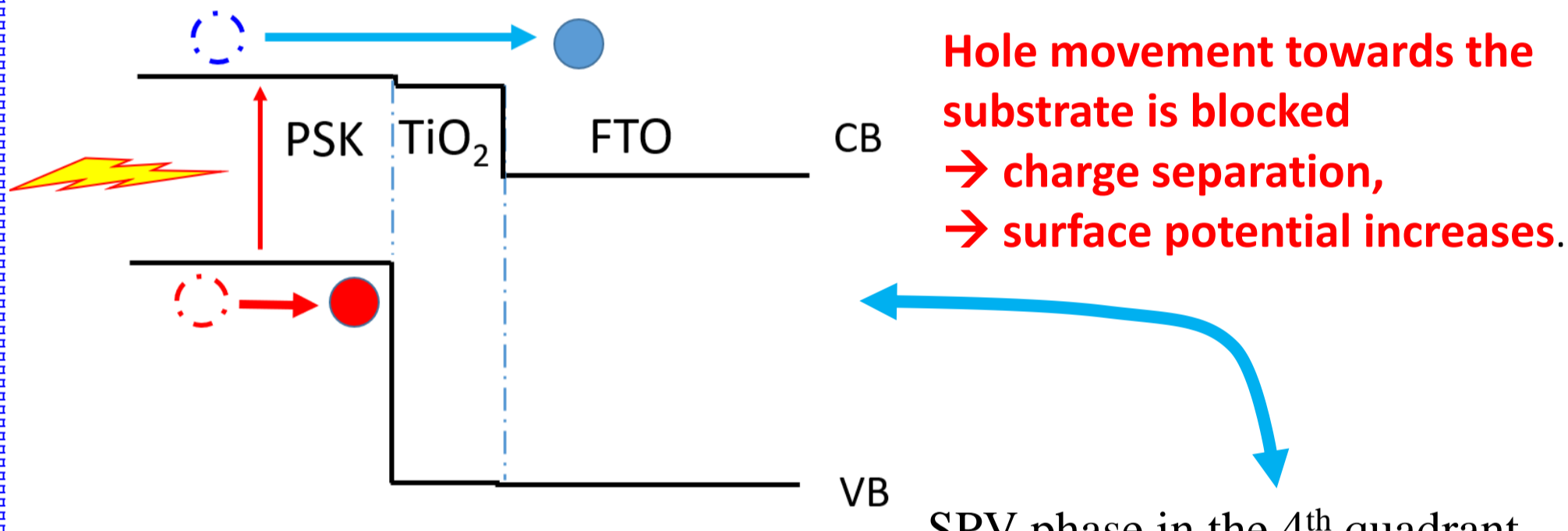
Fully inorganic lead halide PSK thin films CsPbI<sub>3</sub> and partial solar cell structures

- electron transport layer TiO<sub>2</sub> deposited on FTO/glass substrates by spray pyrolysis (FTO=fluorine-doped tin oxide)
- Perovskite - deposited via spin-coating
- glass sheet a few μm thick to protect the perovskite

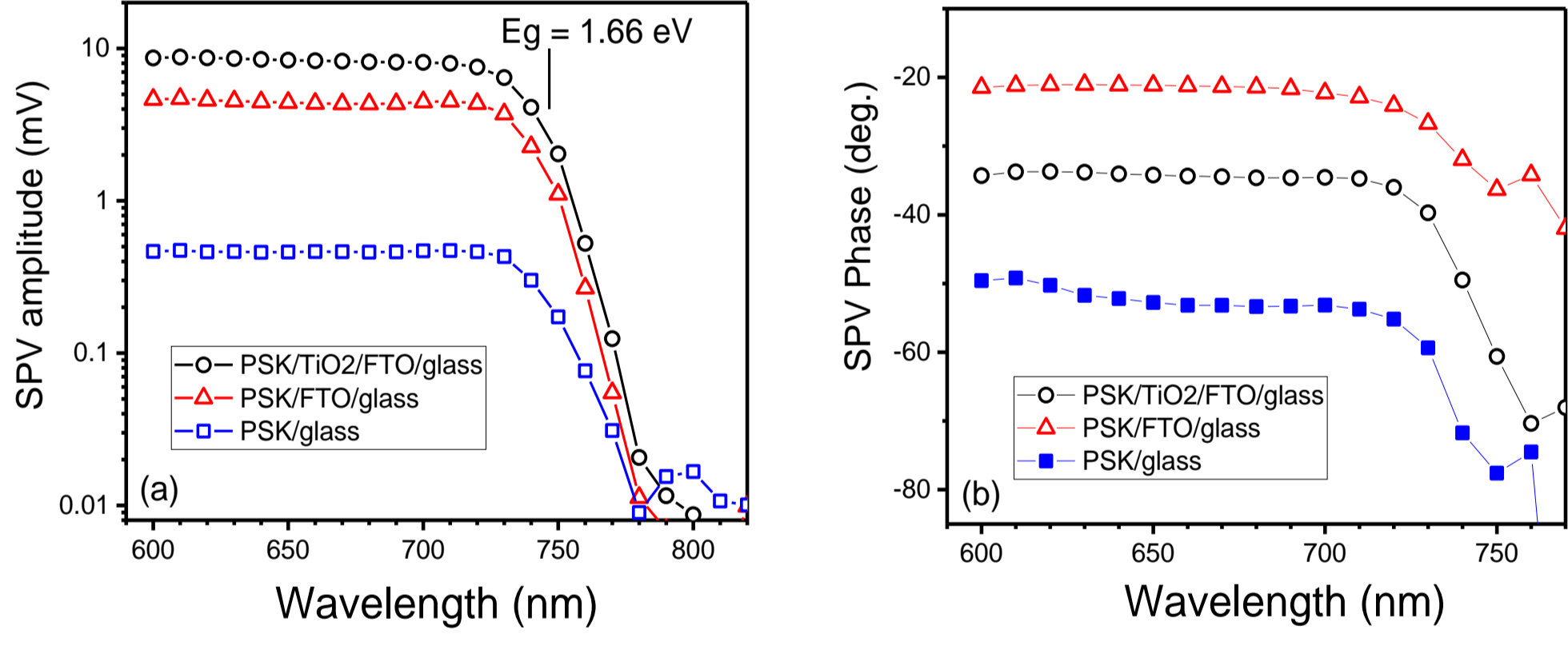


## Results and discussion:

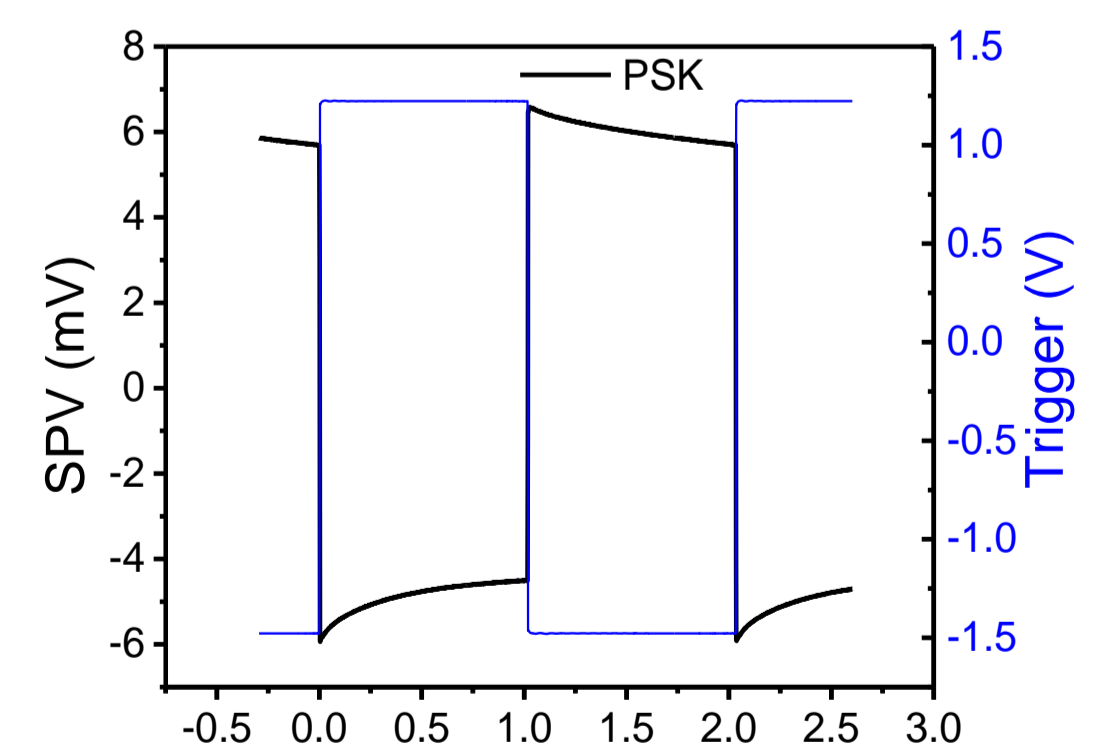
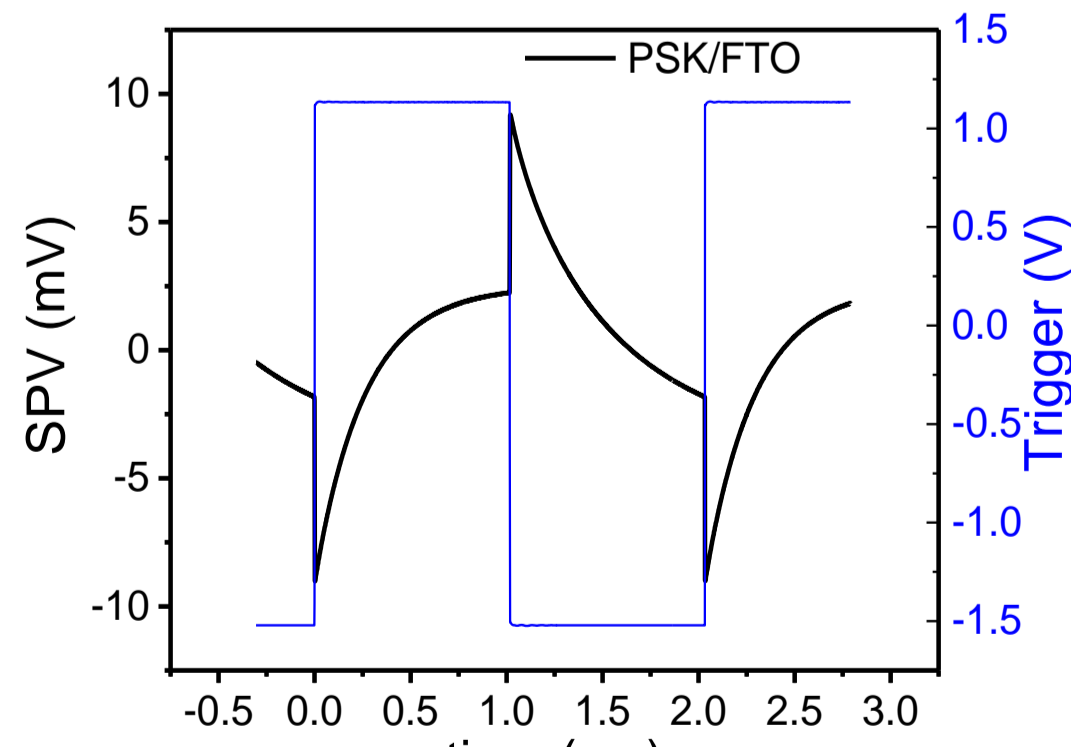
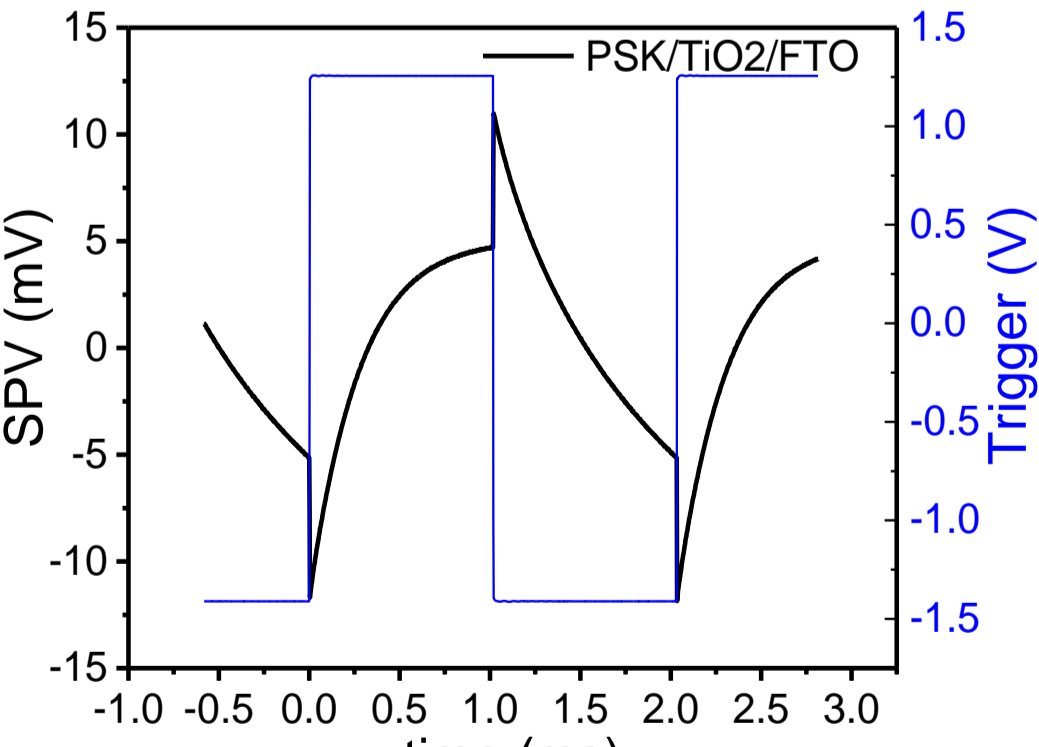
### Generation mechanisms of the SPV signal



### SPV phase in the 4<sup>th</sup> quadrant



MIS-SPV amplitude (a) and phase (b) spectra of the three structures measured at 94 Hz.



### SPV transients of the three PSK structures measured with 640 nm excitation at 12.5 μW and 492 Hz.

- Positive SPV develops in the light semi-period in line with the SPV spectra.
- Strange signal jumps in negative (positive) direction when the excitation is turned on (off). Tentatively explained as the contribution of a negative SPV component (SPV phase in the 2<sup>nd</sup> quadrant), which increases with the excitation and rotates the SPV phase clockwise.

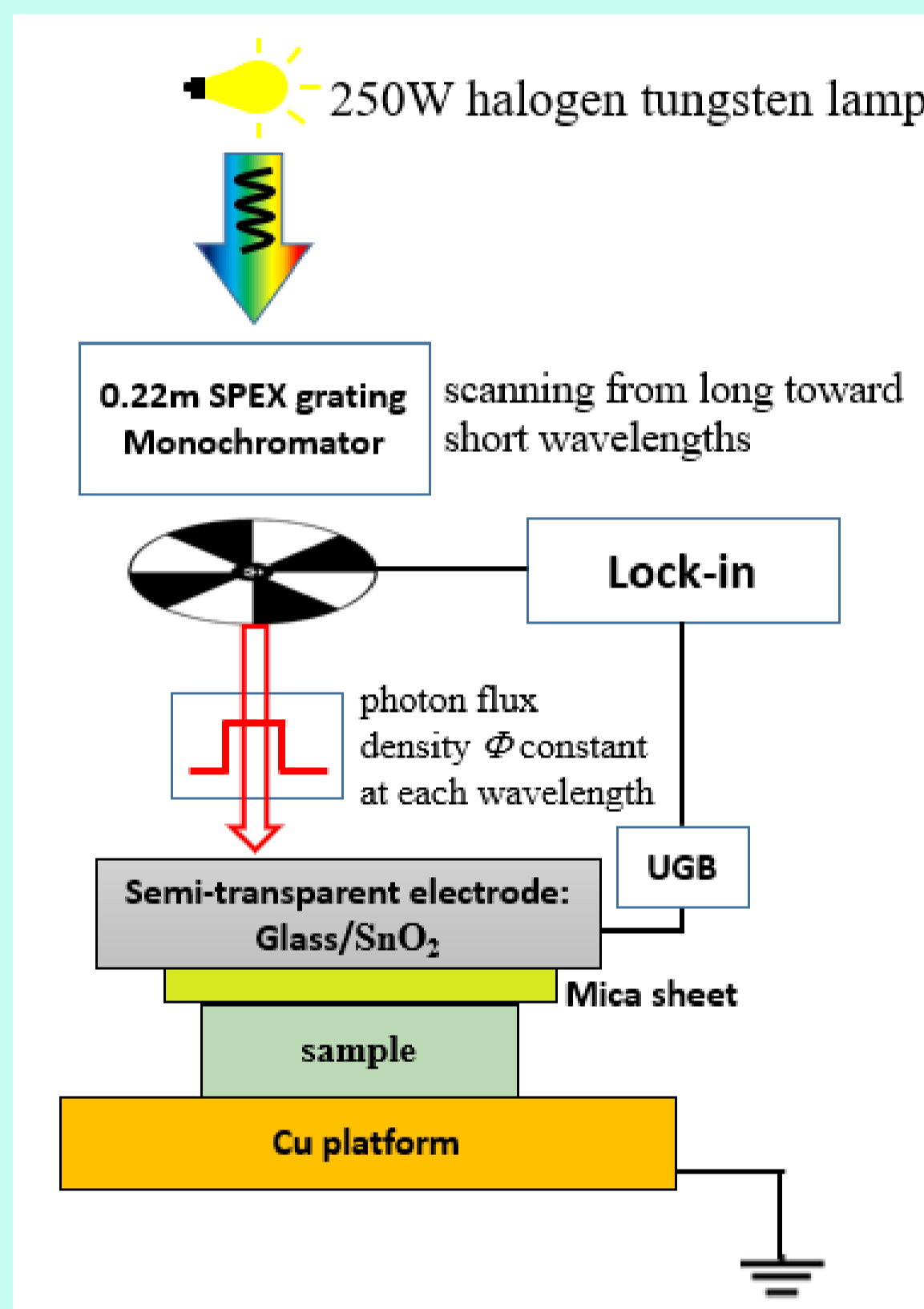
## Conclusions:

- The PSK bandgap is determined.
- The ETL (TiO<sub>2</sub>) has a paramount role for the charge separation and photovoltage generation.
- The mechanism of charge separation is confirmed.
- An unknown SPV negative process is identified that could be related to trapping/recombination of carriers at the PSK interfaces and/or Dember effect.

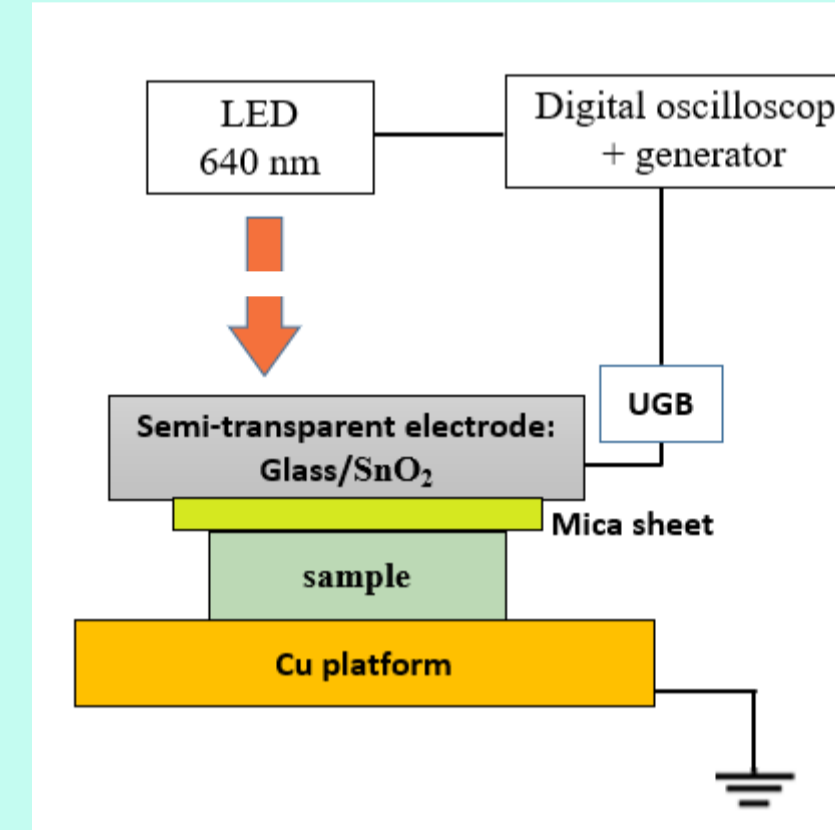
## Surface Photovoltage (SPV) method: The Metal-insulator-semiconductor (MIS) SPV operation mode

- chopped light, flux density  $\sim 10^{13} \text{ cm}^{-2}\text{s}^{-1}$
- $\text{SPV} = V_s^{\text{light}} - V_s^{\text{dark}}$

### SPV spectra, 900 – 600 nm Chopped light @ 94 & 492 Hz



### SPV transients @ 640 nm, 12.5 μW 9.9, 21, 94 & 492 Hz, duty cycle 50%



### The SPV spectra

- Reveal the PSK optical absorption edge of 1.66 eV (assessed from Tauc plot)
- Show the role of the electron transport layer (TiO<sub>2</sub>) in obtaining a good photoresponse.
- SPV phase in the 4<sup>th</sup> quadrant  $\leftrightarrow$  increased surface potential  $\leftrightarrow$  positive SPV

