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Davide Regaldo, Pilar Lopez-Varo, Nitin Mallik, Javid Hajhemati, Vincent Dufoulon, Guillaume Vidon, Stefania Cacovich, J Alvarez, Jean Baptiste Puel, Philip Schulz, et al.

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## A Lateral Heterojunction Device as a Tool to Study Perovskite-Based Solar Cells

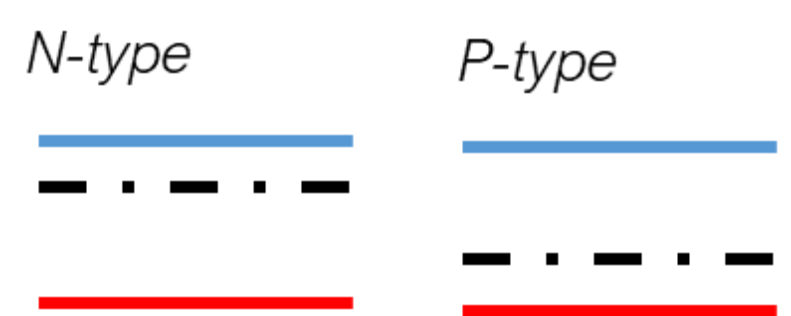
### Scope of the work

Study the perovskite (PSK) properties on top of different substrates:

- Surface work function (WF);
- Defect and ion properties;

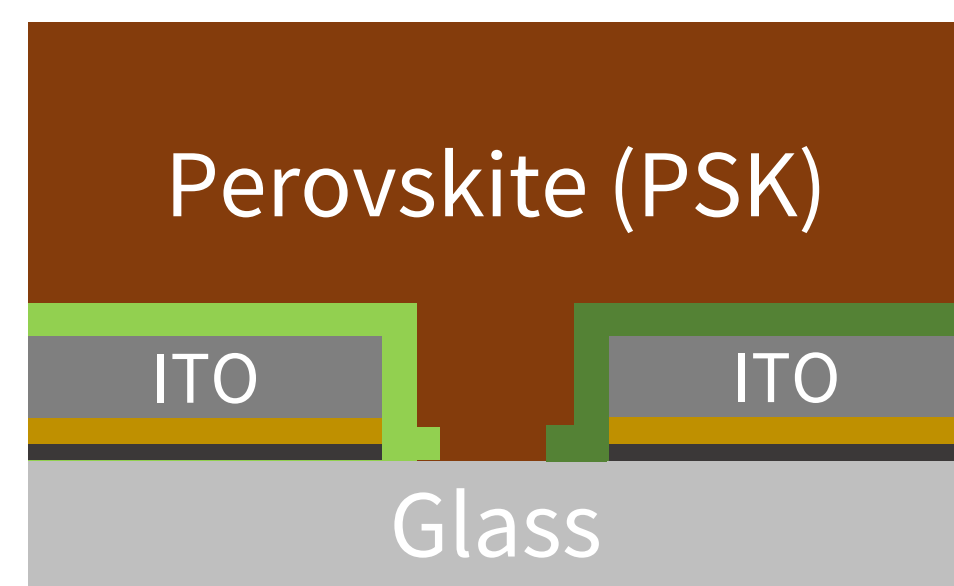
Previous knowledge:

Perovskite WF dependence on the substrate WF



ACS Energy Lett. 2019, 4, 1-7  
 S. P. Dunfield et al., (2021).

Cross section view



Previous device allowed to fix an upper limit of the doping density in the PSK layer:

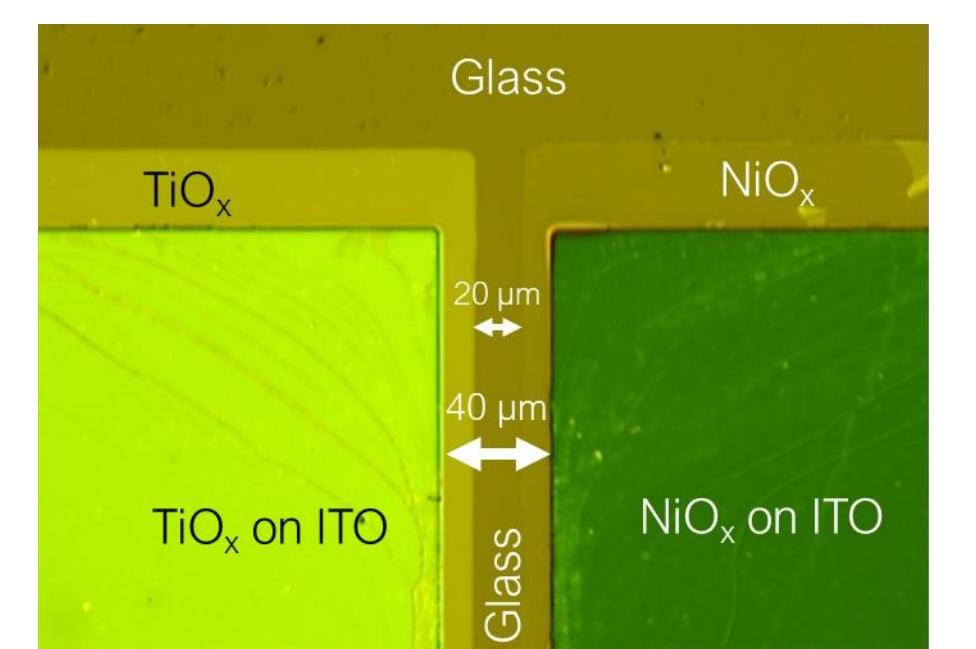
$$N_{\text{dop}} \leq 10^{12} \text{ cm}^{-3}$$

### LHJ structure and fabrication

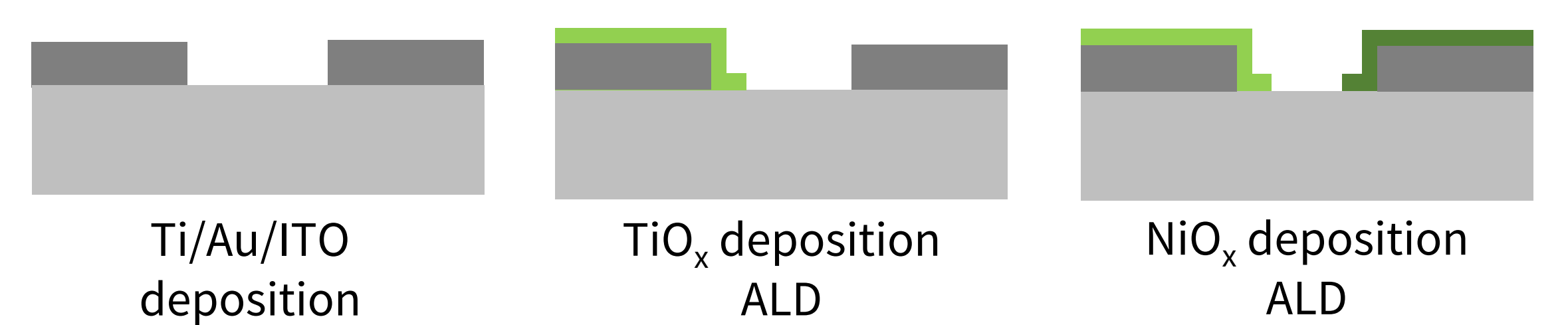
3 photolithography steps to deposit:

- Contact layer: Ti (adhesion to glass) / Au (high conductivity) / ITO (PSK protection);
- Electron transport layer:  $\text{TiO}_x$ ;
- Hole transport layer:  $\text{NiO}_x$ .

Top view (optical microscope image)

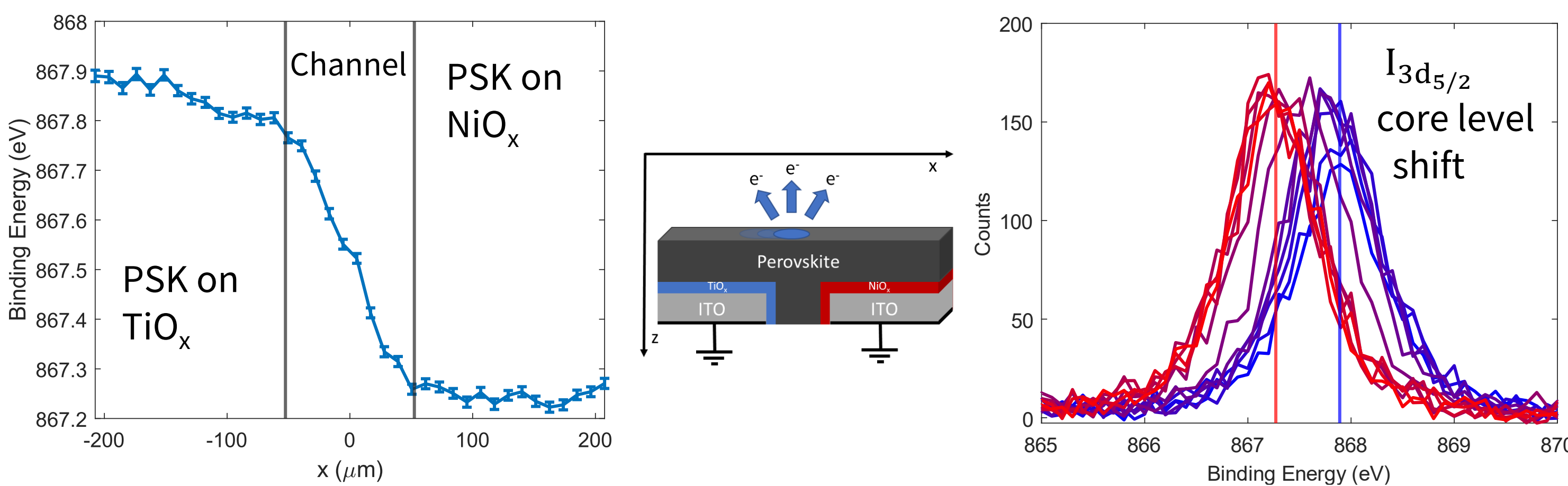


Cross section view



### XPS equilibrium characterization

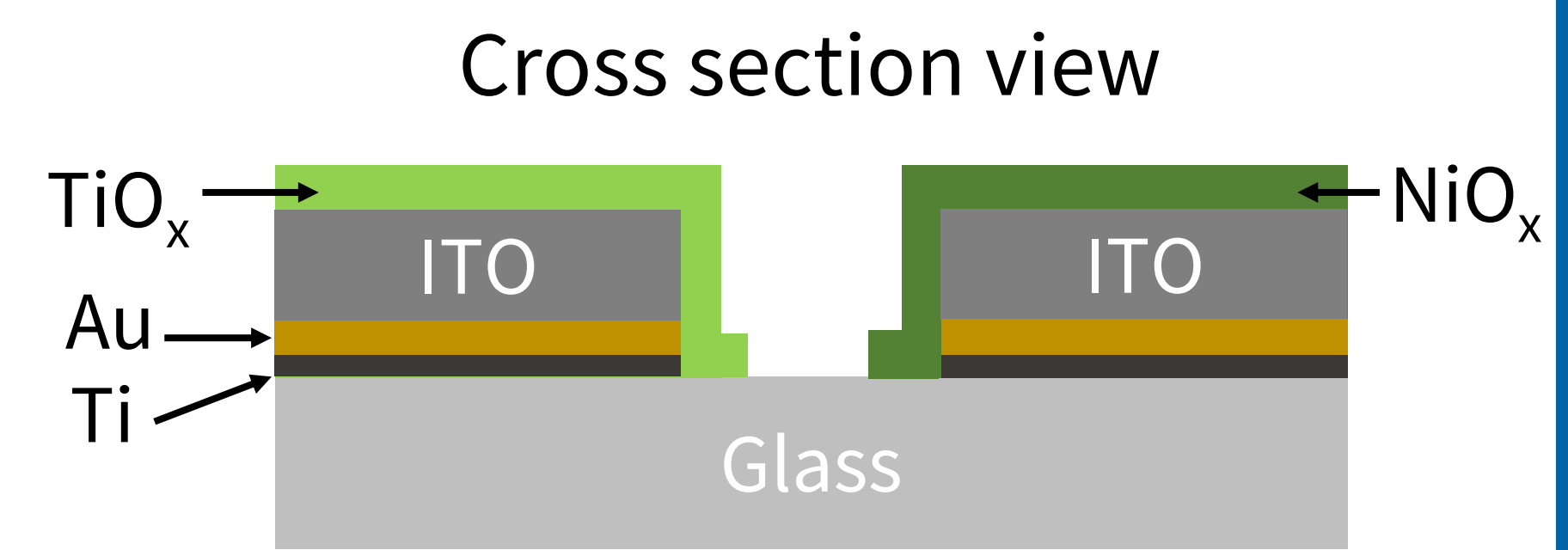
The scan of the X-ray electron collection area (with 10  $\mu\text{m}$  diameter) along the PSK surface, from the  $\text{TiO}_x$  to the  $\text{NiO}_x$  side revealed an iodine core level shift of 650 meV, in agreement with the WF difference between the  $\text{TiO}_x$  and the  $\text{NiO}_x$  surface.



### KPFM substrate characterization

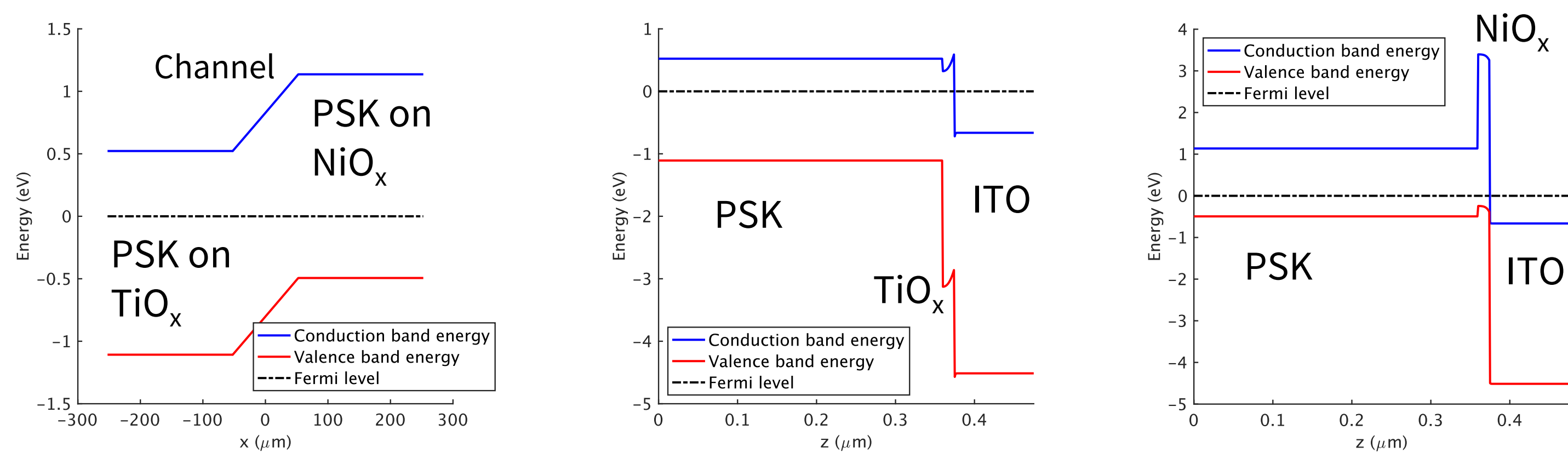
Work functions (KPFM)

ITO	4.95 eV
$\text{NiO}_x$	$\geq 5.10$ eV
$\text{TiO}_x$	$\leq 4.50$ eV

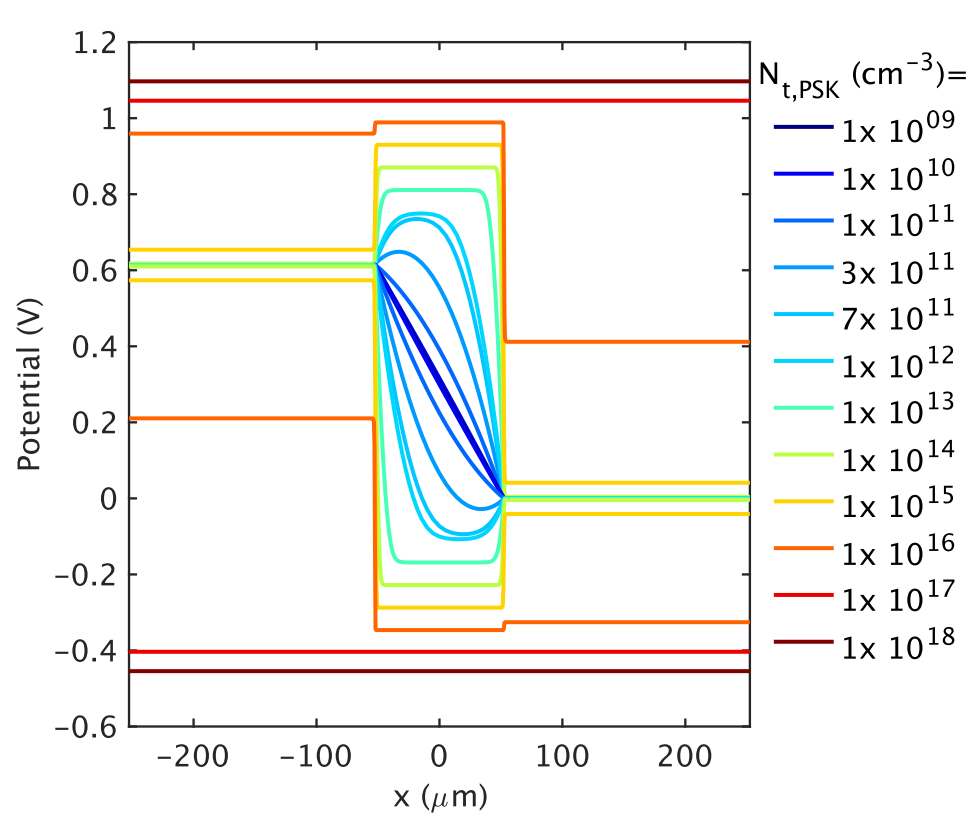


$$\Delta_{WF} = WF_{\text{NiO}_x} - WF_{\text{TiO}_x} \geq 0.6 \text{ eV}$$

### Drift-Diffusion model: band diagrams for intrinsic perovskite



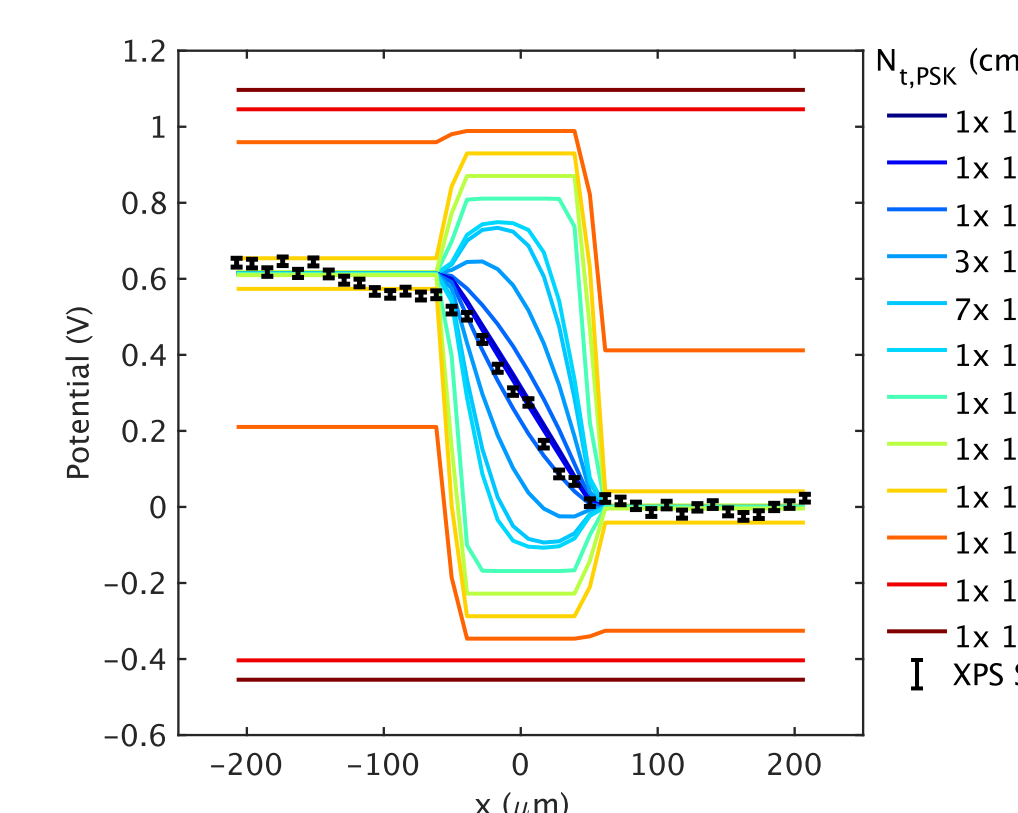
Actual Potential



Surface Potential as a function of PSK doping density

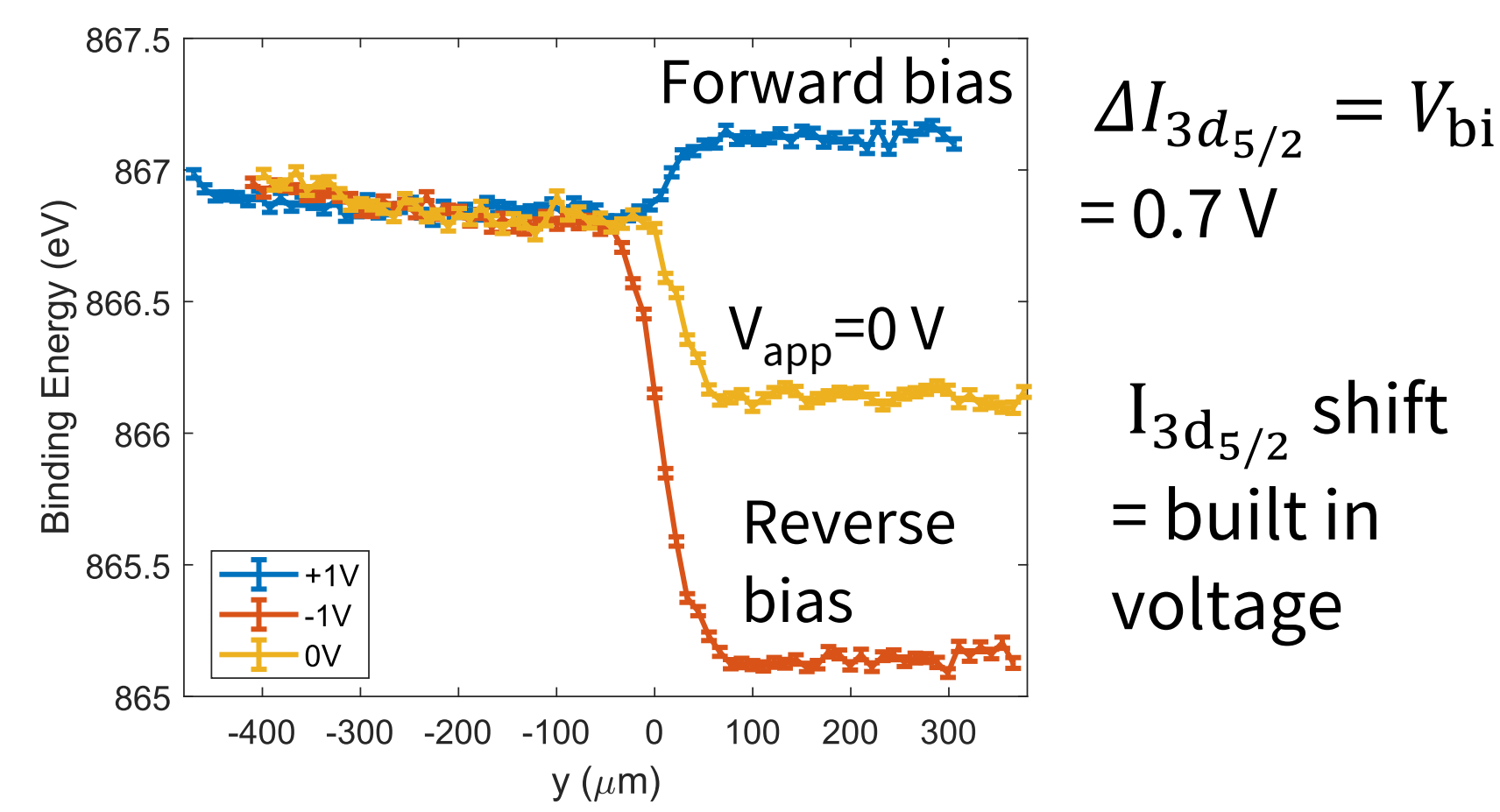
Conclusion:  
 $N_{\text{dop}} \leq 10^{11} \text{ cm}^{-3}$

Convolution with 10  $\mu\text{m}$  spot size

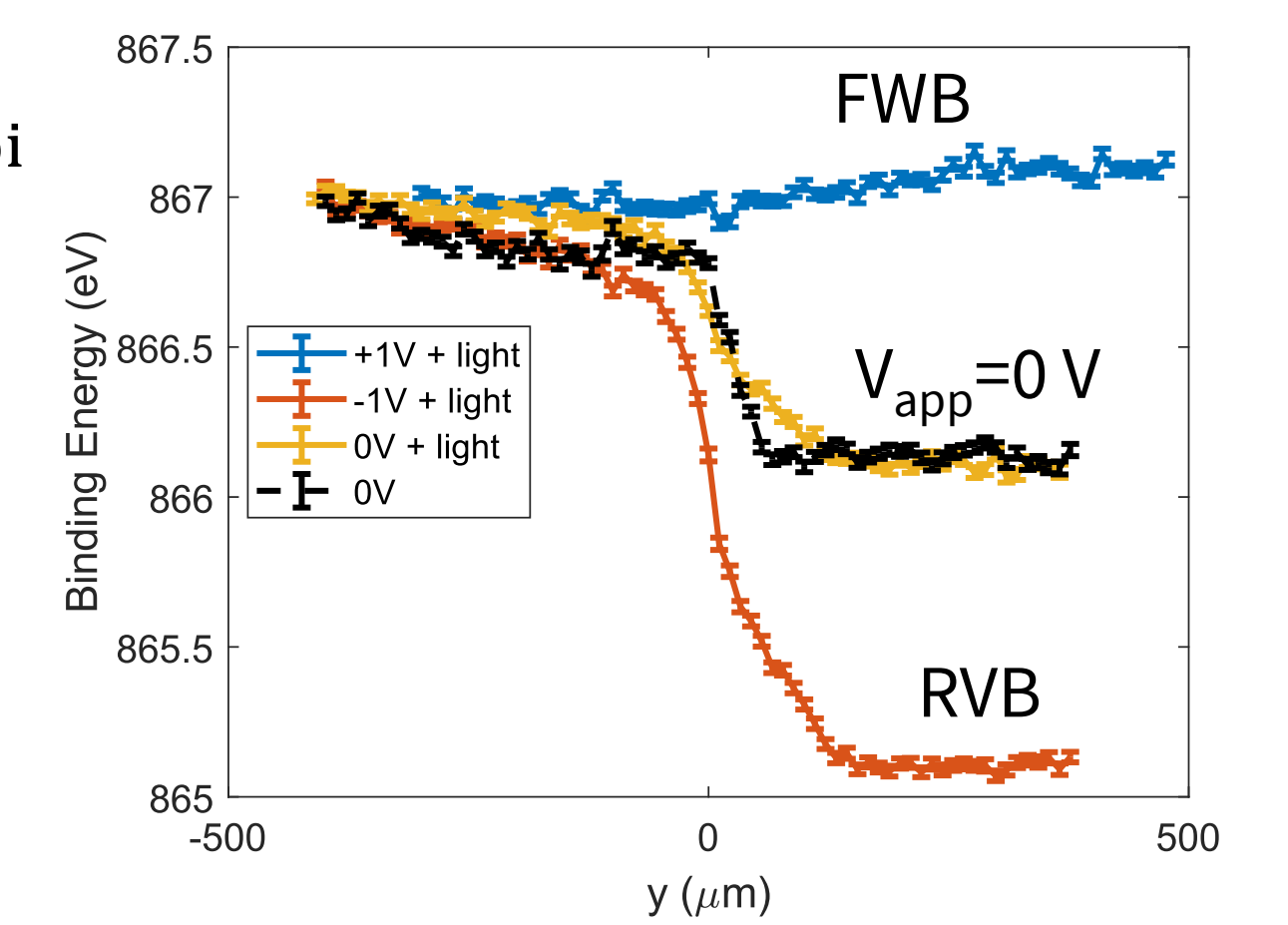


### XPS under Light and Voltage bias

Scan in the « dark »



Scan under illumination

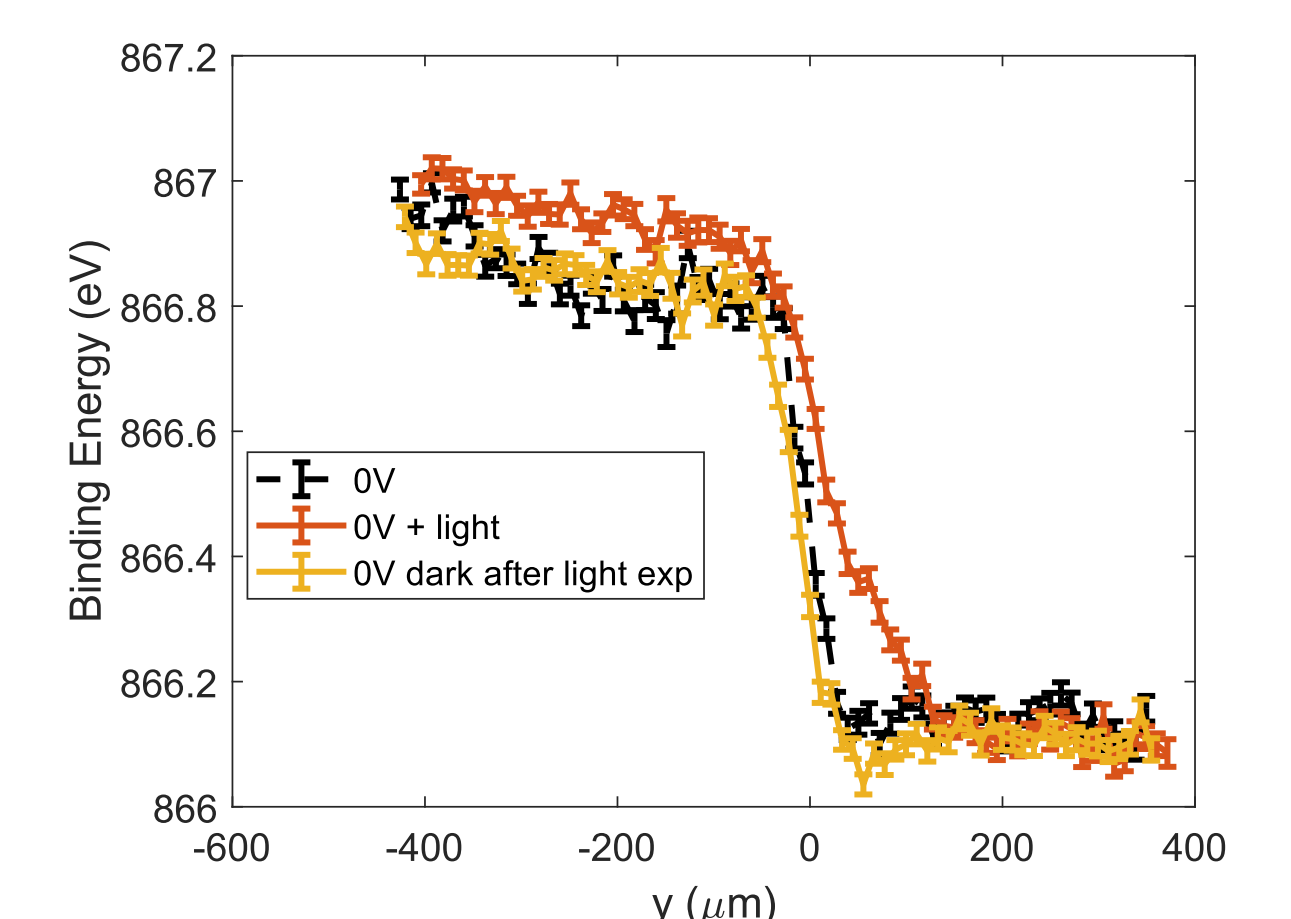
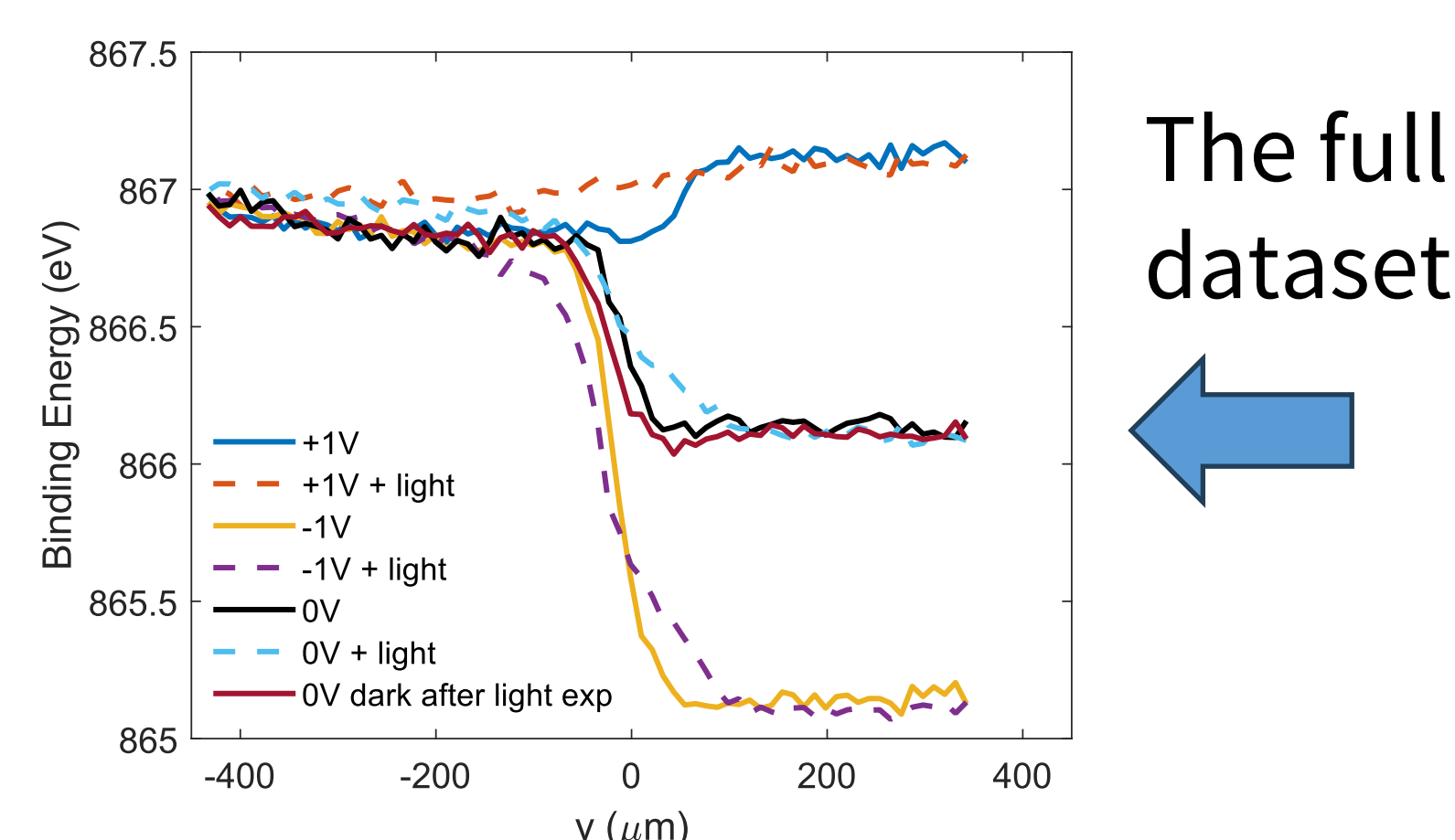


The applied voltage modifies  $V_{bi}$ :

$$\text{RV B: } V_{bi} - V_{\text{app}} = 0.7 + 1 = 1.7 \text{ V}$$

$$\text{FW B: } V_{bi} - V_{\text{app}} = 0.7 - 1 = -0.3 \text{ V}$$

No hysteresis in the dark 0 V scan, after applying light.



## CONCLUSIONS

$\text{NiO}_x$  and  $\text{TiO}_x$  - based LHJ device: various PSK channels created between the two contacts (lengths ranging from 10 to 100  $\mu\text{m}$ ). Double cation perovskite spin coated on the LHJ: the selective contacts under the PSK determine the potential drop in the PSK ( $V_{bi}$ ) which can be modulated by an applied bias. PSK doping density measured  $\leq 10^{11} \text{ cm}^{-3}$ .

Dunfield et al., **Carrier gradients and the role of charge selective contacts in lateral heterojunction all back contact perovskite solar cells**, Cell Reports Physical Science 2, 100520.

Regaldo, D et al, **On the equilibrium electrostatic potential and light-induced charge redistribution in halide perovskite structures**. Prog Photovolt Res Appl. 2022; 1-9.