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



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Vesselin Donchev^{1*}, Kiril Kirilov¹, Iliya Stoyanov¹, Davide Regaldo^{2,3,4,5}, Javid Hajhemati^{2,3,4}, Thomas Gries⁶, Jean-Baptiste Puel^{2,3,4},

upélec Philip Schulz^{2,3,4}, Jean-Paul Kleider^{2,3,4}

- ¹ Faculty of Physics, Sofia University, 5, blvd. J.Bourchier, BG-1164, Sofia, Bulgaria
- ² Université Paris-Saclay, CentraleSupélec, CNRS, Laboratoire de Génie Electrique et Electronique de Paris, 91192, Gif-sur-Yvette, France
- ³ Sorbonne Université, CNRS, Laboratoire de Génie Electrique et Electronique de Paris, 75252, Paris, France
- ⁴ IPVF, Institut Photovoltaïque d'Ile-de-France, 91120, Palaiseau France
- ⁵ Center for Nano Science and Technology@PoliMi, Istituto Italiano di Tecnologia, Via R. Rubattino, 81, Milan, 20134 Italy
- ⁶ Helmholtz-Zentrum für Materialien und Energie, Berlin, Germany

Background:

- Perovskites (PSK) are considered as a perspective material for the 4th 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 CsPbI₃ and partial solar cell structures

electron transport layer TiO₂ deposited on FTO/glass
 substrates by spray pyrolysis (FTO=fluorine-doped tin oxide)
 Perovskite - deposited via spin-coating

3) glass sheet a few μ m thick to protect the perovskite



Surface Photovoltage (SPV) method:

The Metal-insulator-semiconductor (MIS) SPV operation mode

chopped light, flux density $\sim 10^{13}$ cm⁻²s⁻¹

 $SPV = V_s^{light} - V_s^{dark}$

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%

Results and discussion:

Generation mechanisms of the SPV signal



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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_2) in obtaining a good photoresponse.
- SPV phase in the 4th quadrant \leftrightarrow increased surface potential \leftrightarrow positive SPV

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





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SPV transients of the three PSK structures measured with 640 nm excitation at 12.5 μ W 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 2nd quadrant), which increases with the excitation and rotates the SPV phase clockwise.

Conclusions:

- 1. The PSK bandgap is determined.
- 2. The ETL (TiO₂) has a paramount role for the charge separation and photovoltage generation.
- 3. The mechanism of charge separation is confirmed.
- 4. An unknown SPV negative process is identified that could be related to trapping/recombination of carriers at the PSK interfaces and/or Dember effect.

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