UV-Selective Zn(O,S)-based Solar Cells for BIPV Applications

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Outline

1. Introduction
2. Experimental methods
3. Results and Discussion
4. Summary and Outlook

INTRODUCTION

Building Integrated PV

Focus

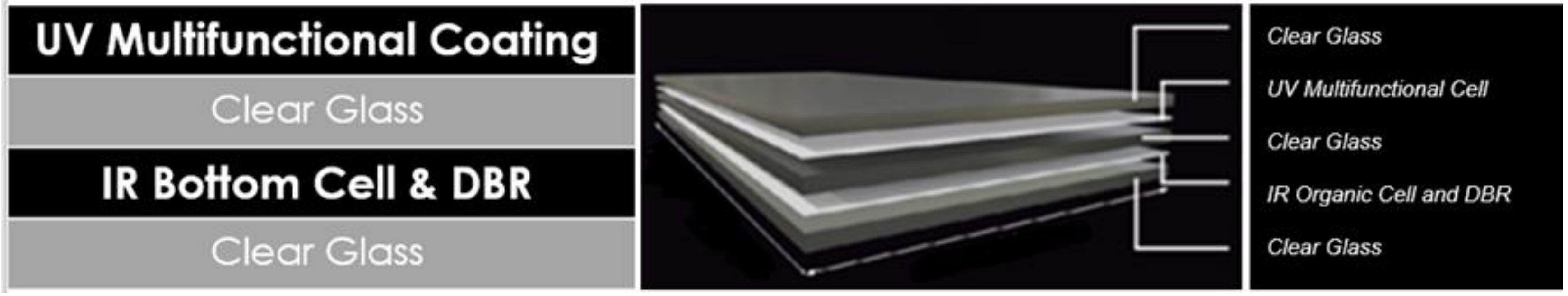
Build transparent colorless window that filters UV light and integrates PV functionality (wavelength-selective)

HOW? → **Tandem inspired structure: UV (Filter+PV) + IR (PV)**

OXIDES/CHALCOGENIDES

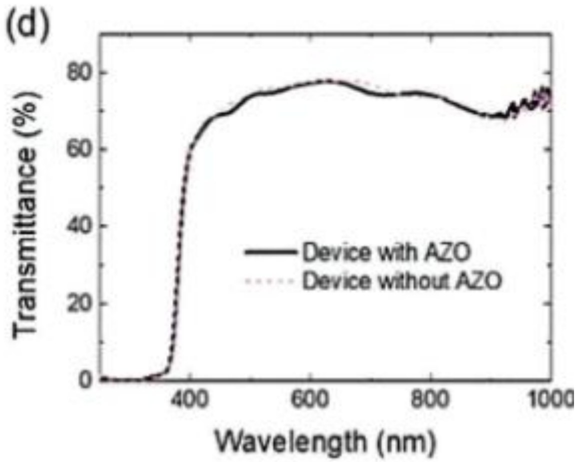
- Stable
- Low-cost
- Non-CRM

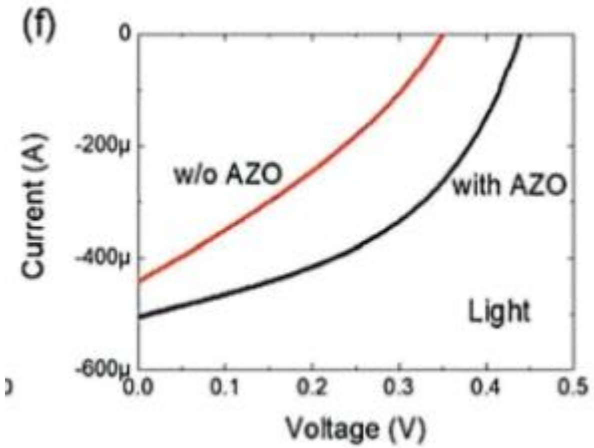
Use of WBG oxides for UV-selective multifunctional coating



State of the art UV-selective transparent solar cells

1. Inorganic heterojunction devices
2. n-**ZnO** used as absorber layer
3. **E_g = 3.3 eV**
4. **UV onset at 2.7-2.9 eV** → SPECTRAL MISMATCH
5. Low efficiency devices: Record (measured under intense "monochromatic" LED illumination) at PCE<0.2% (AM1.5G, estimated)





Ban et al. *Adv. Elec. Mat.*, 5, 10 *(2019)*

Introducing Zn(O,S)…

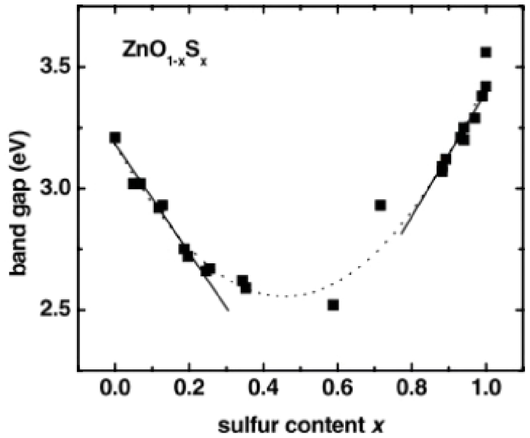
1. Zn(O,S) mixed crystals can be fabricated throughout whole compositional range

2. Bandgap bowing: minimum around x=S/(S+O)=0.5

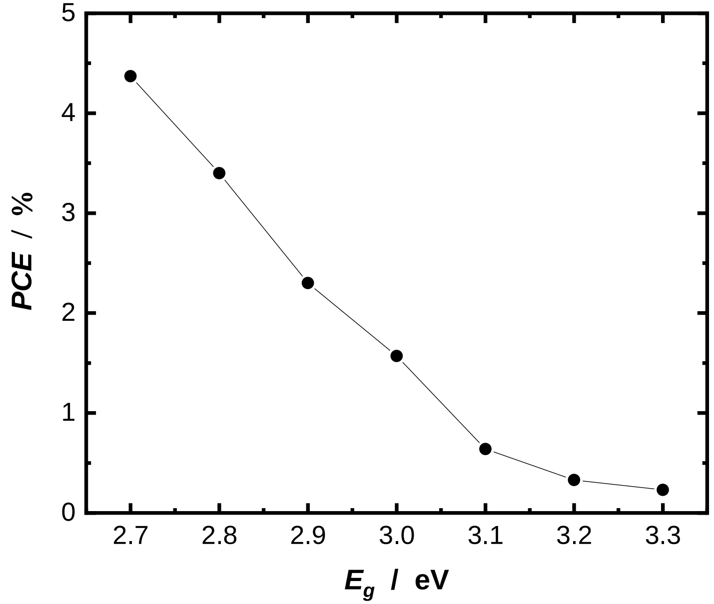
3. **Minimum bandgap around 2.7-2.8 eV**

4. **UV onset at 2.7-2.9 eV** → SPECTRAL MATCH

5. Increase in photocurrent as compared with ZnO, due to possibility of reducing the bandgap by alloying Zn(O,S)



Polity et al. *Phys. Stat. Sol. A*, 203, 2867 *(2006)*



1. Zn(O,S) device fabrication

I. FTO substrate preparation (Acetone, IPA, H_2O, O_3)

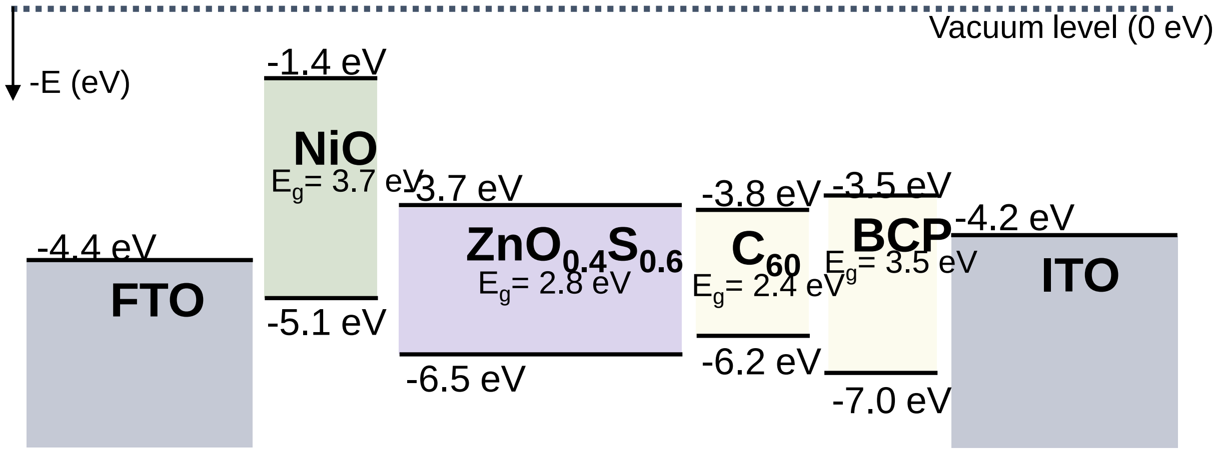
II. NiO by e-beam evaporation of NiO powder

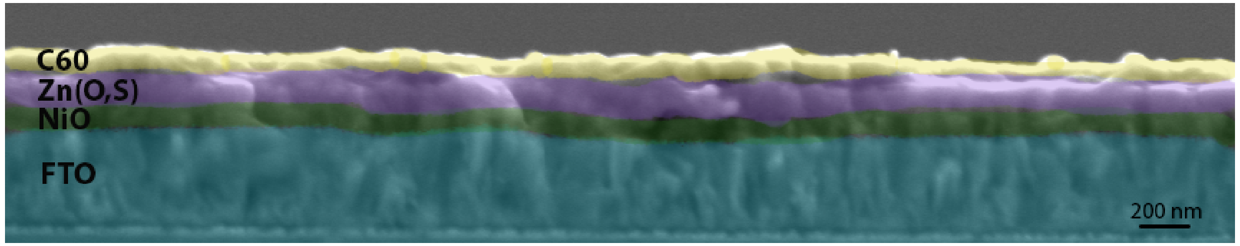
III. Zn(O,S) deposition by RF Sputtering of mixed ZnO/ZnS target

IV. (Opt.) C_{60}/BCP by spin coating

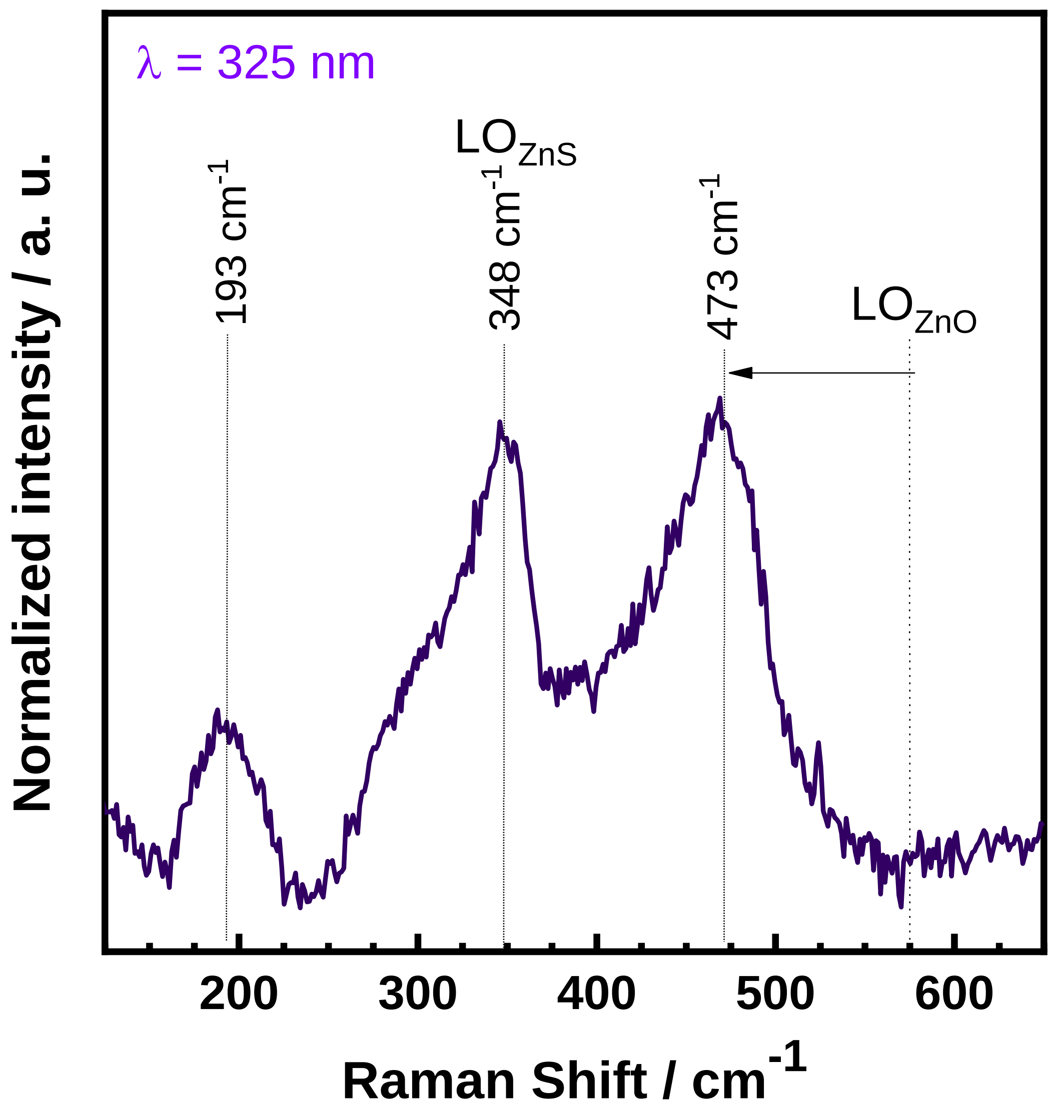
V. ITO by DC-Pulsed Magnetron Sputtering of In_2O_3/SnO_2 target in Ar/O_2 atm.

VI. Wet etching (Aqua Regia 60%) on edge to get to FTO back-contact





Raman Characterization



$$\omega\ (cm^{-1}) = 574.0 - 170.8\left(\frac{S}{S+O}\right)$$

Guc et al. *RSC Advances*, 6, 24536 *(2016)*

a. Main $ZnO_{1-x}S_x$ peaks confirm formation of mixed crystal

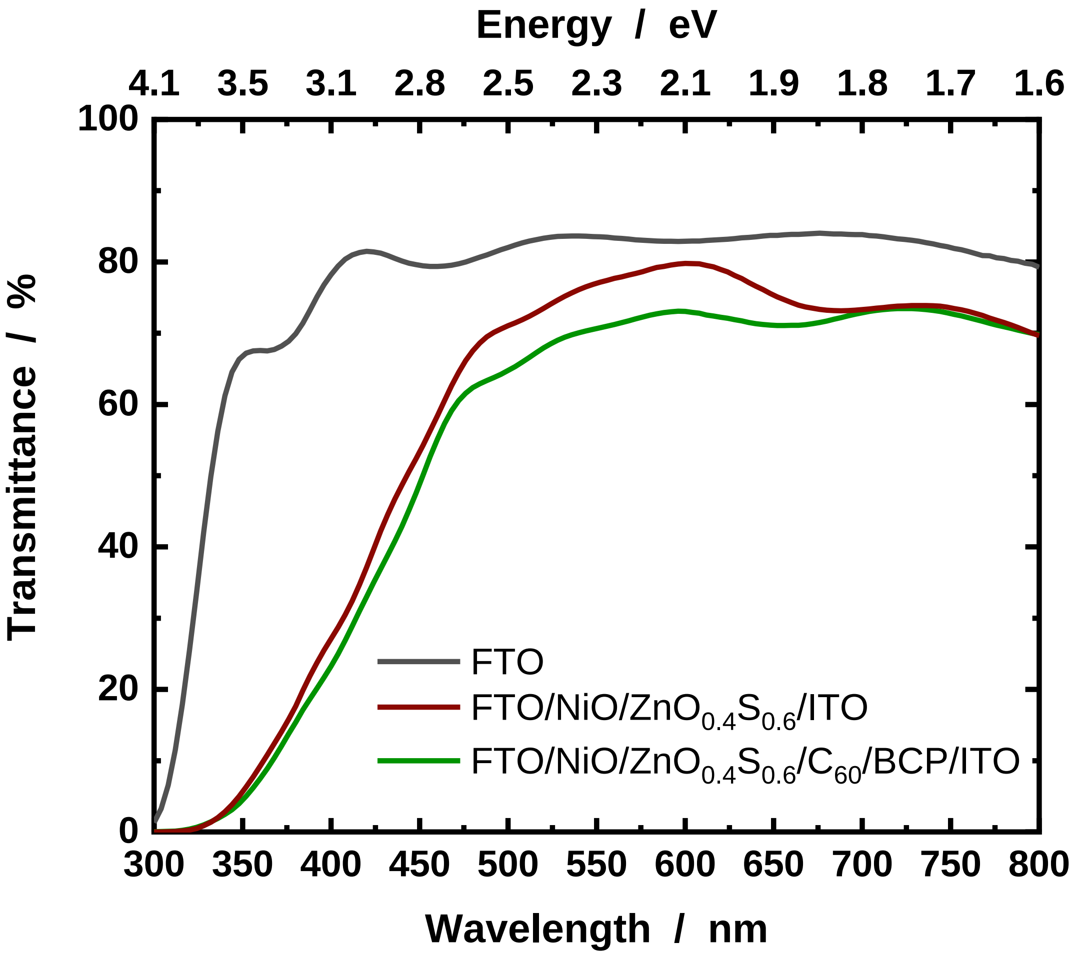
b. Three peaks are observed:

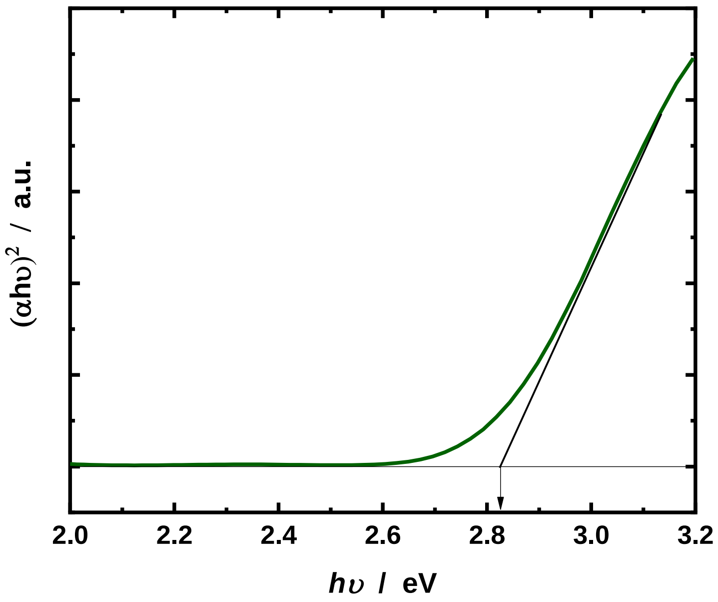
- 193 cm^{-1} : Peak attributed to Zn(O,S) phase
- 348 cm^{-1} : Peak related to LO_{ZnS}
- 473 cm^{-1} : (Shifted) peak related to LO_{ZnO}

c. Methodology developed at IREC allows to experimentally quantify relative sulphur content (x) by determining the position of the shifted LO_{ZnO} like peak

Calculated value: x=S/(S+O)=0.6

Optical Characterization





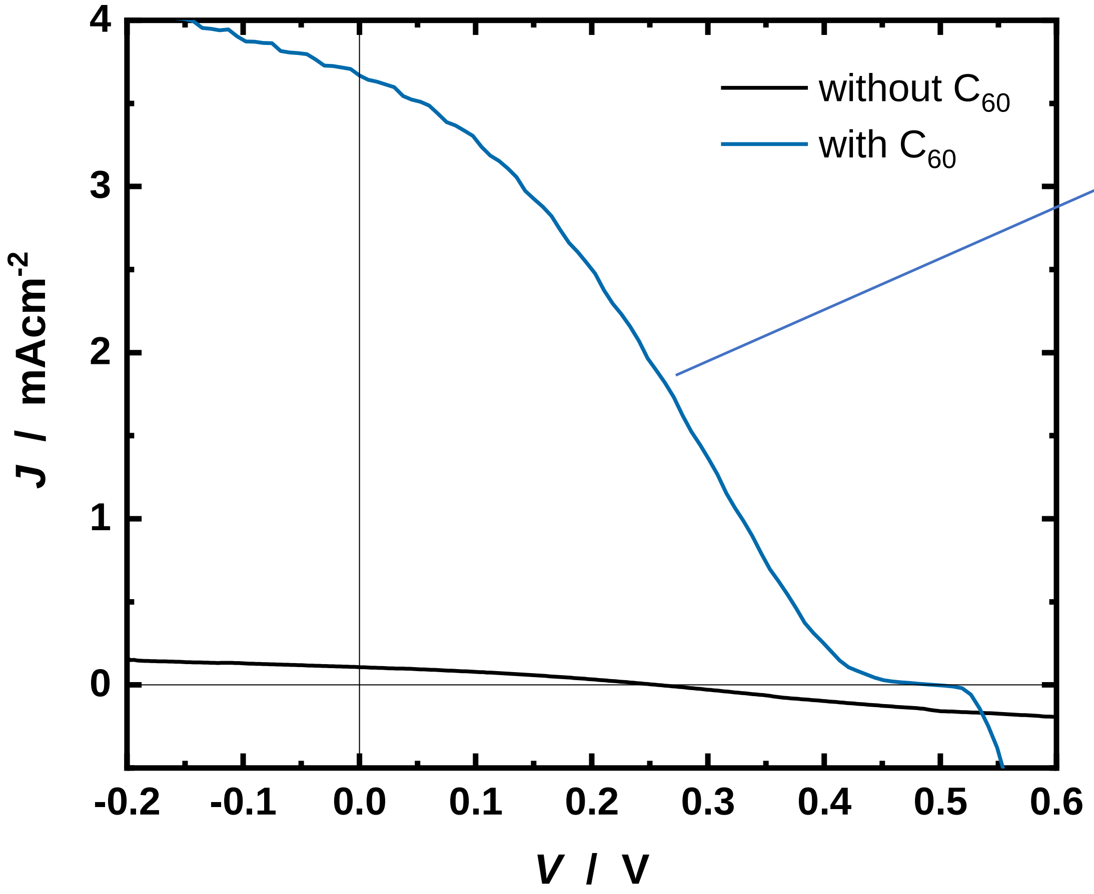
a. Tauc's plot bandgap estimation confirms Zn(O,S) $E_g < 3$ eV

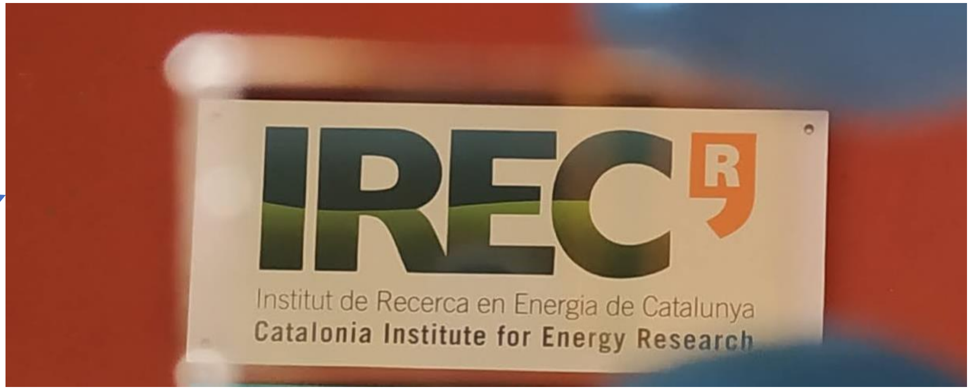
b. AVT(**w/o C_{60}**) = 75%; AVT(**w/ C_{60}**)=69%

c. Devices absorb (UV light) past 2.8 eV

$$AVT\ (\%) = \frac{\int T(\lambda)P(\lambda)S(\lambda)d\lambda}{\int P(\lambda)S(\lambda)d\lambda}$$

Device PV characterization

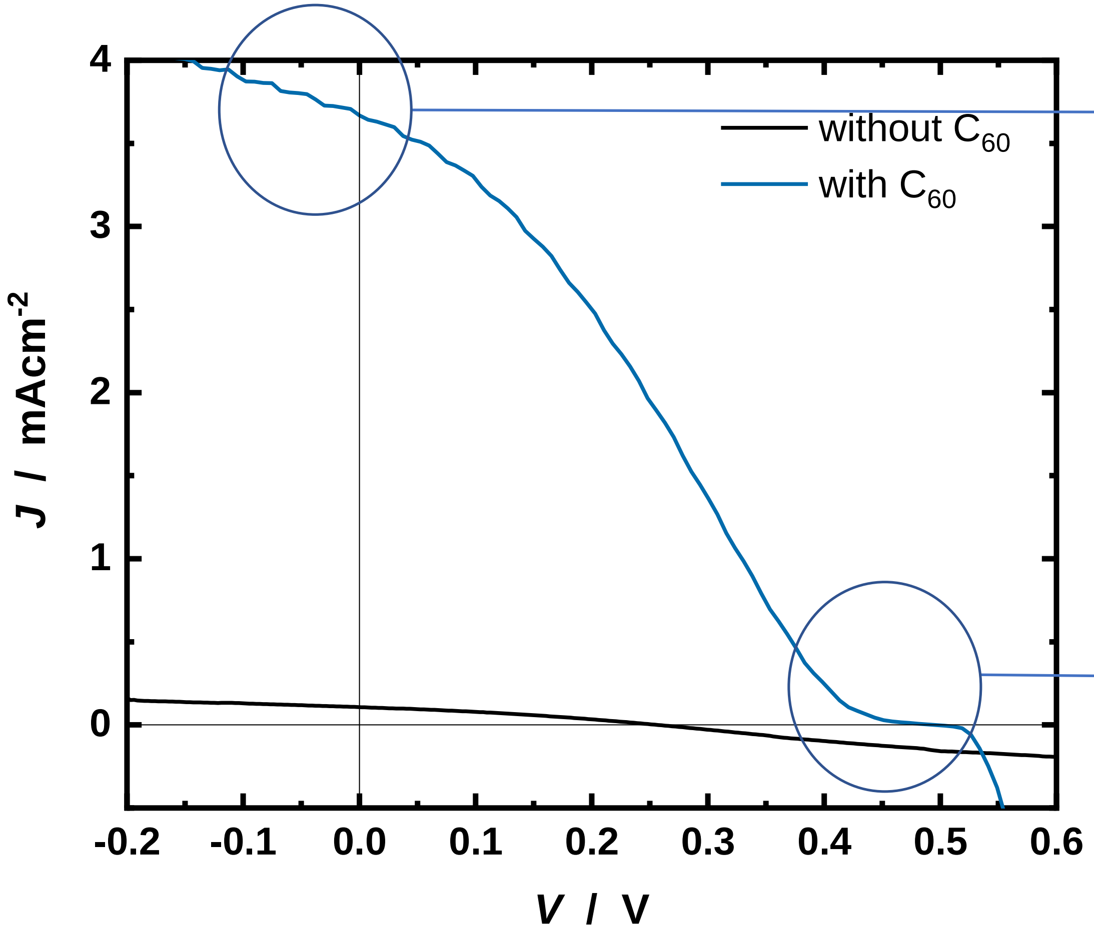




1. PV effect observed in Zn(O,S)-based devices
2. Device w/o C_{60}: PCE<0.1% due to very low V_{OC}
3. Device w/ C_{60} ETL: PCE=0.48% at AVT=69% (LUE=0.34%)

A.J. Lopez-Garcia et al. *Solar RRL (Accepted Sept 2nd)*

Device PV characterization



1. Voltage dependent photocurrent close to 0 V
2. Bulk ionization photoconductivity: Attributed to C_{60}
   Jeong et al. *Adv. Funct. Mat. 14, 3089, (2011)*
3. Indication that C_{60} can participate in absorption/extraction

1. S-kink close to V_{OC}
2. Hypothesis: Injection barrier at absorber/CTL interface
   Tress et al. *Adv. Funct. Mat., 21, 2140, (2011)*

Lopez-Garcia et al. *Solar RRL (Accepted Sept 2nd)*

SUMMARY & OUTLOOK

1. **Zn(O,S) is better suited for UV applications due to better spectral match (in mid compositional range)**

2. PV effect has been demonstrated in planar heterojunction devices based on Zn(O,S)

3. **Hybrid devices with C_{60}/BCP ETL show a dramatic increase in Jsc (and slightly Voc), showing a device with a PCE=0.48% at an AVT=69% (LUE=0.34%).**

4. It is necessary to study alternative novel (PV) applications! Not just conventional PV

- **On-going research**: I. fundamental characterization of the Zn(O,S) absorber films. II. Device characterization. III. Remove S-kink in devices.

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THANKS FOR YOUR ATTENTION!

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