ICTM INSTITUTE FOR CHEMISTRY AND TECHNOLOGY OF MATERIALS

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Influence of Polymer Phase, Polymer/Nanoparticle Ratio and Organic Additives on the Performance of Hybrid Solar Cells

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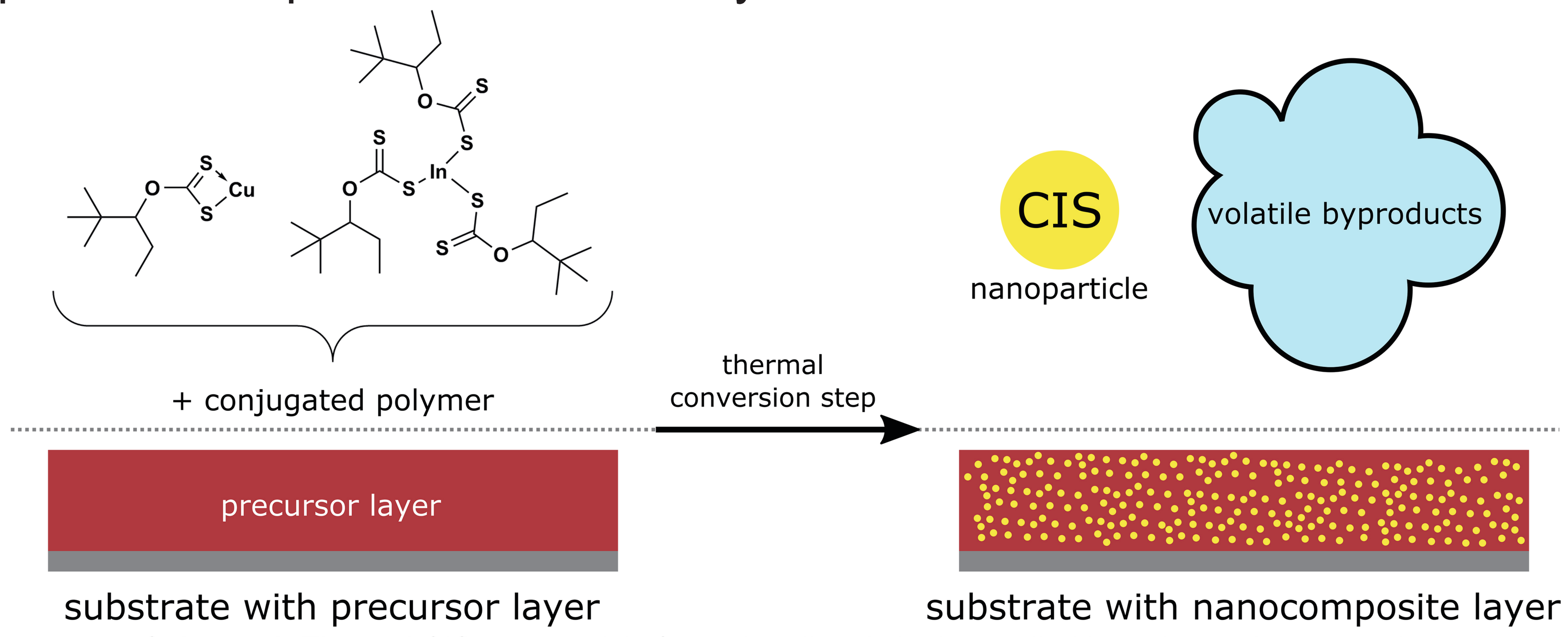
Introduction

Polymer/copper indium sulfide (CIS) nanoparticle hybrid solar cells represent an interesting solar cell system combining advantages of inorganic semiconducting materials and polymers. The cells are solution processable, lightweight and flexible. In this study, we prepare the CIS nanoparticles directly in the polymer matrix. This in situ formation of the CIS nanoparticles from copper and indium xanthates as precursors makes them, besides other benefits, suitable for cheap production routes at temperatures compatible with flexible substrates.

CIS Nanoparticle Formation

The precurors copper O-2,2-dimethylpentan-3-yl dithiocarbonate and indium O-2,2-dimethylpentan-3-yl dithiocarbonate were dissolved in a polymer solution and applied to a substrate. After a thermal conversion step (140 °C to 195 °C) the CIS nanoparticles were formed. Volatile byproducts evaporated out of the layer[1,2].



Scheme 1: Thermal CIS nanoparticle formation directly in the applied layer in a polymer matrix.

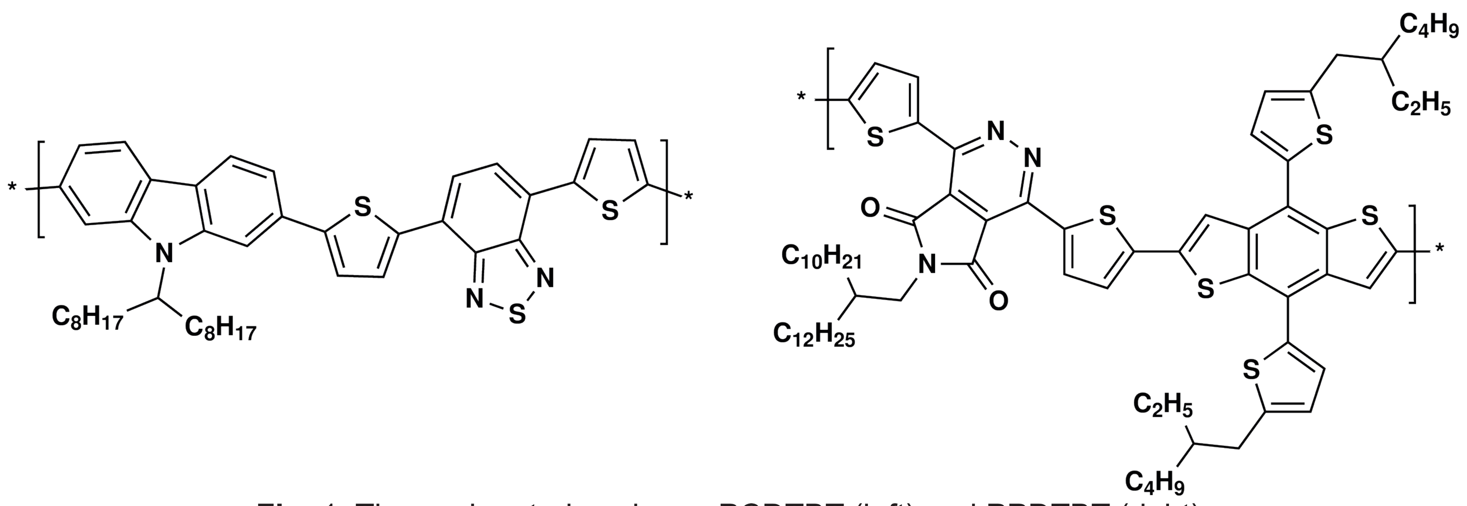


Fig. 1: The conjugated poylmers PCDTBT (left) and PPDTBT (right).

J-V Characteristics

The best performing solar cell in this study, a glass|PEDOT:PSS|PCDTBT/CIS|Ag device, showed a power conversion efficiency of 2.45 %. Its J-V characteristics are shown in Fig. 2. Compared to this a device with PPDTBT (same architecture) and similar layer thickness was measured with 1.93 %. As it can be seen in the graph it shows a higher open circuit voltage but a lower short circuit current density.

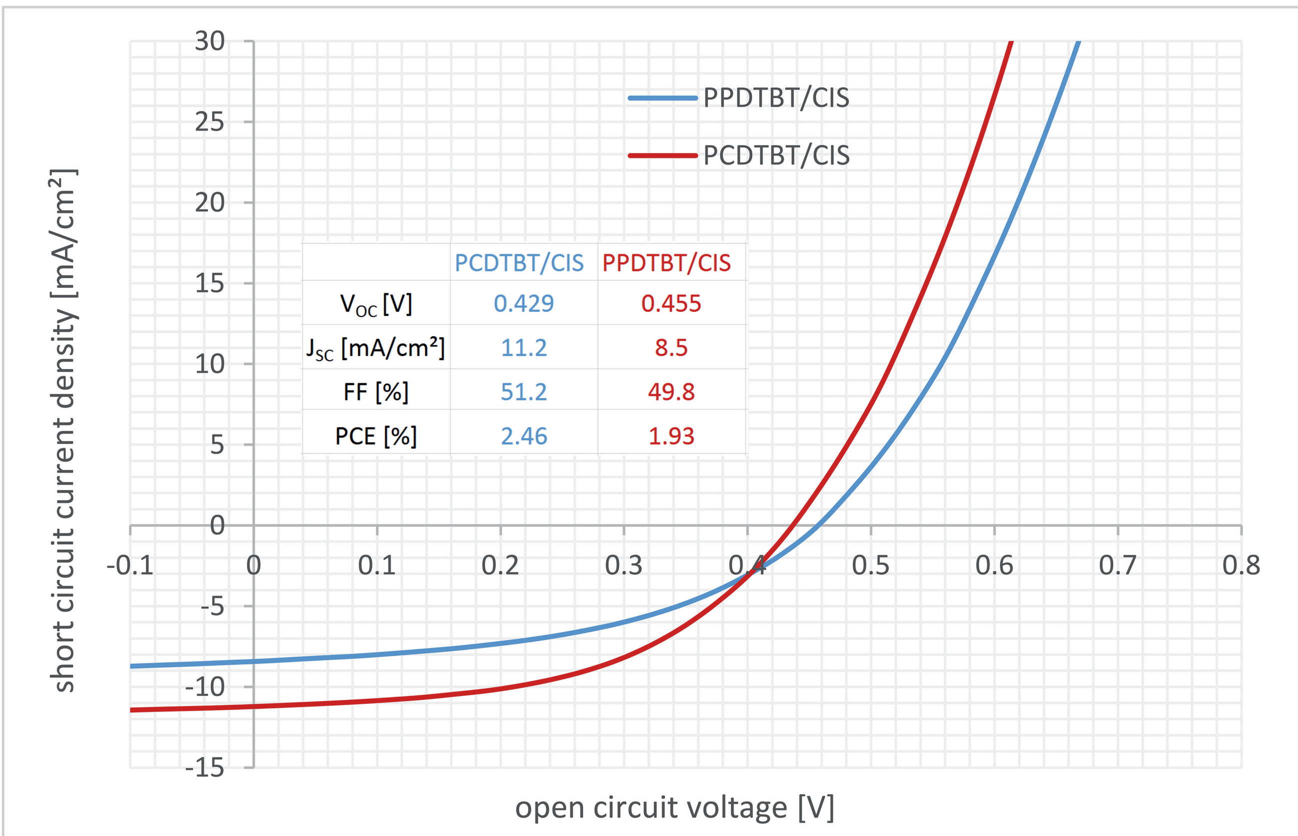


Fig. 2: The J-V chcaracteristics of two glass|PEDOT:PSS|polymer/CIS|Ag devices under illumination.

Conclusion

The in situ formation of the CIS nanoparticles proofed itself as a facile and elegant way to produce nanocomposite absorber materials for solar cells. A content of 70 vol% of inorganic phase seems to be preferable. Devices with PCDTBT and PPDTBT and 70 vol% CIS showed good solar cell parameters. An enhancement of PCDTBT/CIS devices by BDT treatment is suggested by the performed experiments.

Influence of Polymer/Nanoparticle Ratio

It was observed that the power conversion efficiency of PCDTBT/CIS solar cells increased with a higher amount of inorganic phase until reaching 68.5 vol% CIS (Fig. 3D). This corresponds to a polymer/CIS weight ratio of approx. 1:9. Significantly affected by the CIS content was the short circuit current density (Fig. 3B) with an increase from 2.46 ± 0.18 mA/cm² (38 vol% CIS) to 8.01 ± 0.49 mA/cm² (68.5 vol% CIS). Equally, the fill factor (Fig. 3C) reaches the maximum value at 68.5% CIS (59.2 ± 1.0 %). The open circuit voltage (Fig. 3A) was similar around 40 vol% to 50 vol% (0.43 ± 0.01 V), increases just slightly for 68.5 vol% and decreases for 79 vol% CIS (0.46 ± 0.02 V).

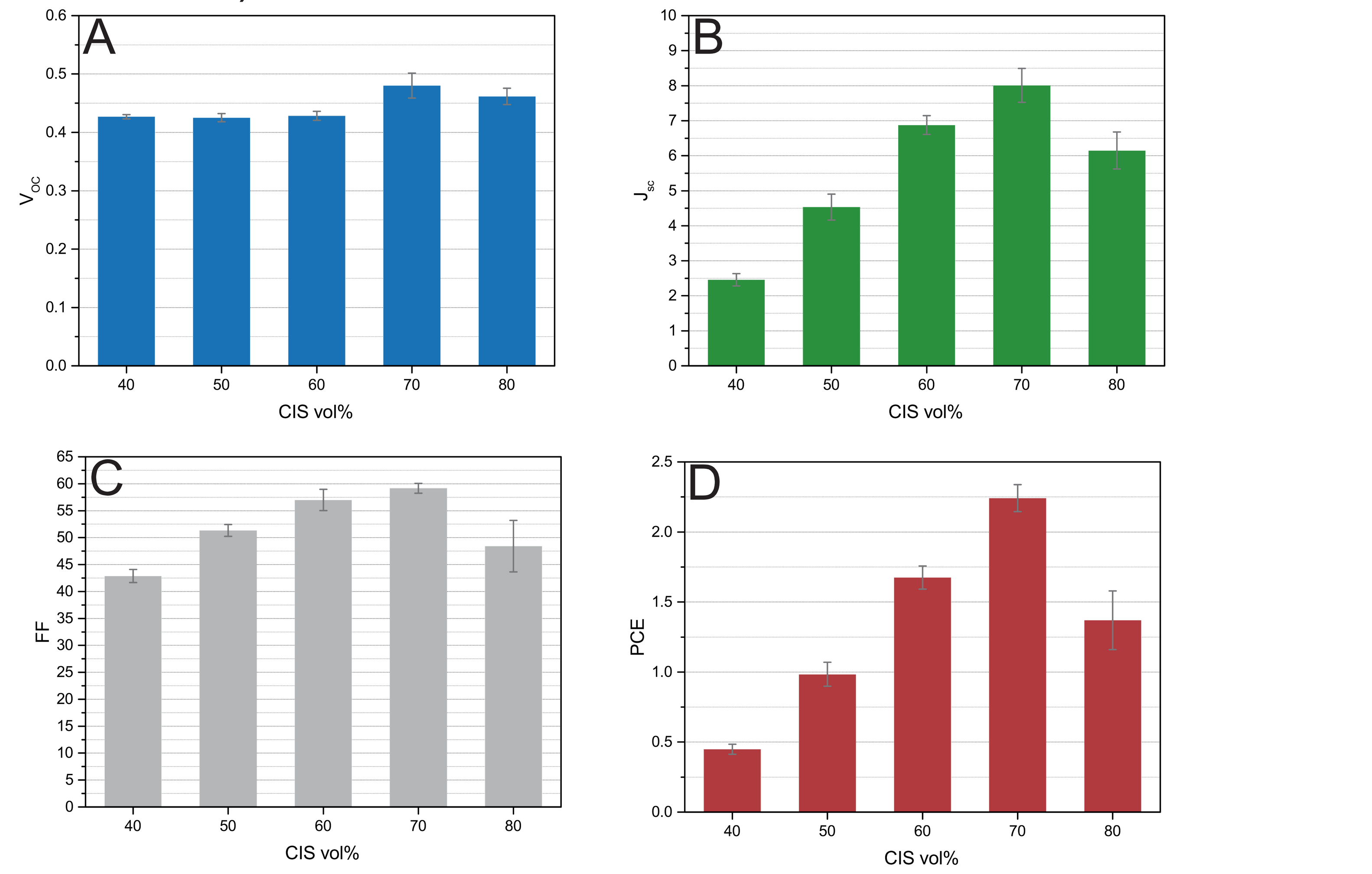


Fig. 3: Average values for the open circuit coltage V_{OC} (A), the short circuit current density J_{SC} (B) the fill factor (C), and the power conversion efficiency (D) for solar cells with 40 vol% to 80 vol% CIS.

Influence of Organic Addtives

1,3-Benzenedithiol, 1,2-ethanedithiol, pyridin and 1,8-diiodooctane were investigated on their influence on polymer/CIS solar cells. In this study only 1,3-benzenedithol (BDT) showed an enhancement of PCDTBT/CIS solar cells, when dropped onto the heat treated layer.

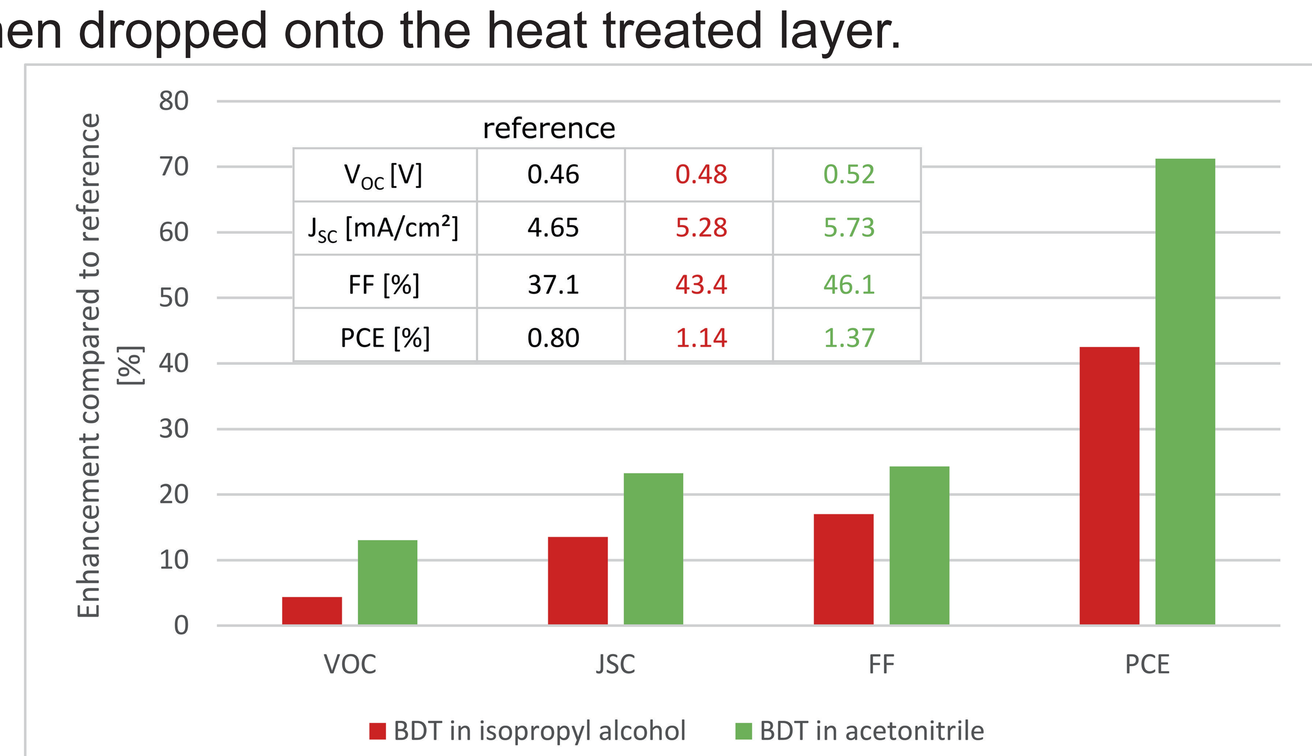


Fig. 4: Average enhancement of solar cell parameters (open circuit voltage, short circuit current density, fill factor, power conversion efficiency) with BDT treatment compared to a reference.

Acknowledgments

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