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The influence of co-deposition on the performance of CuPc/C_{60} heterojunction photovoltaic cells

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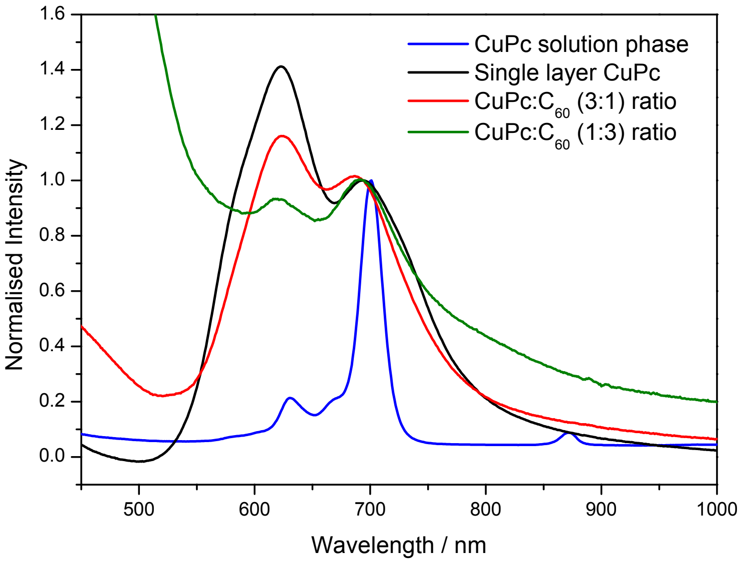
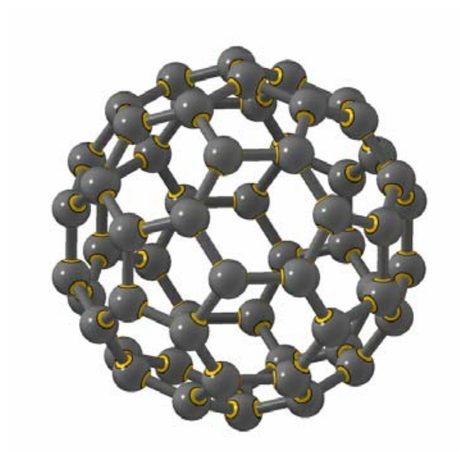
ACKNOWLEDGEMENTS - EPSRC, BP Solar and Kurt J. Lesker Ltd

1. Background and Motivation

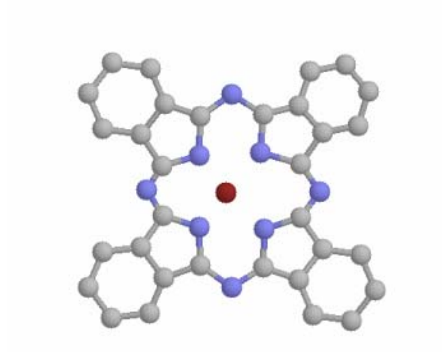
- The donor-acceptor (D-A) interface of two distinct organic semiconductor materials provides a site for efficient exciton dissociation. However, the low exciton diffusion lengths mean that light absorption must occur very close to the heterojunction.
- Co-deposition[1,2] may be used to increase the interface area and hence improve the performance of the basic CuPc-C_{60} heterojunction cells.[3]



Electronic absorption spectra for solution phase CuPc, and thin film layers. All thin film spectra are normalised to the peak at 694nm and the solution spectrum is normalised to the monomer peak.



C_{60}: Electron acceptor



CuPc: Hole acceptor

References
1) M. Hiramoto, H. Fujiwara, M. Yokoyama, Appl. Phys. Lett. **58** (1991) 1062.
2) J. Rostalski, D. Meissner, Sol. Energy Mater. Sol. Cells **61** (2000) 87.
3) P. Peumans, S.R. Forrest, Appl. Phys. Lett. **79** (2001) 126.

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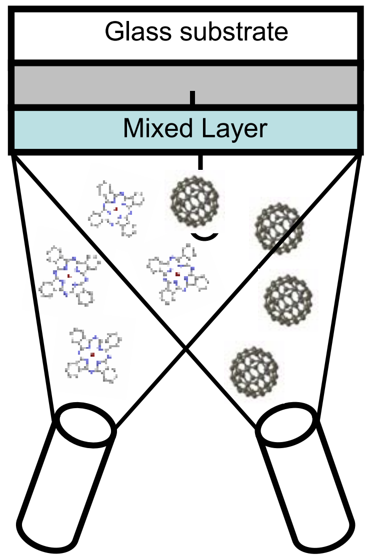
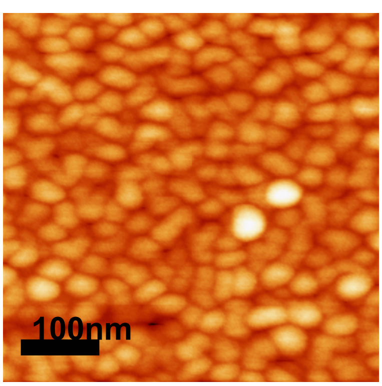
2. Experimental Methods

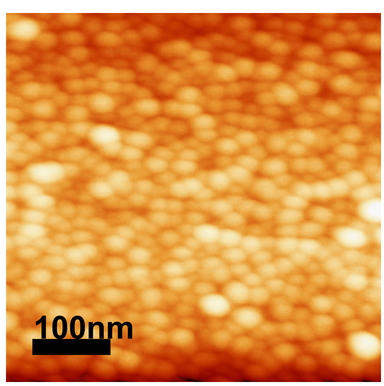
Organic Molecular Beam Deposition (OMBD) under high vacuum conditions (10^{-8} mbar) allows for high control over layer thickness and composition.



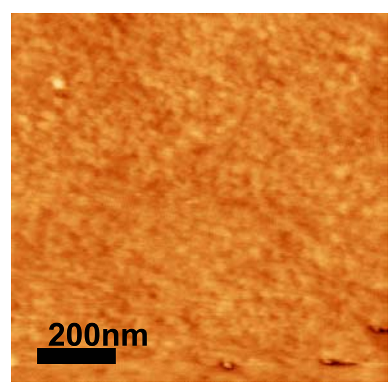
20nm CuPc



20nm CuPc / 40nm C_{60}



60nm CuPc:C_{60} (1:1)



R_q=1.5 nm **R_q=1.9 nm** **R_q=0.3 nm**

AFM shows that the mixed layer films are smooth and amorphous, and undergo intermolecular intermixing

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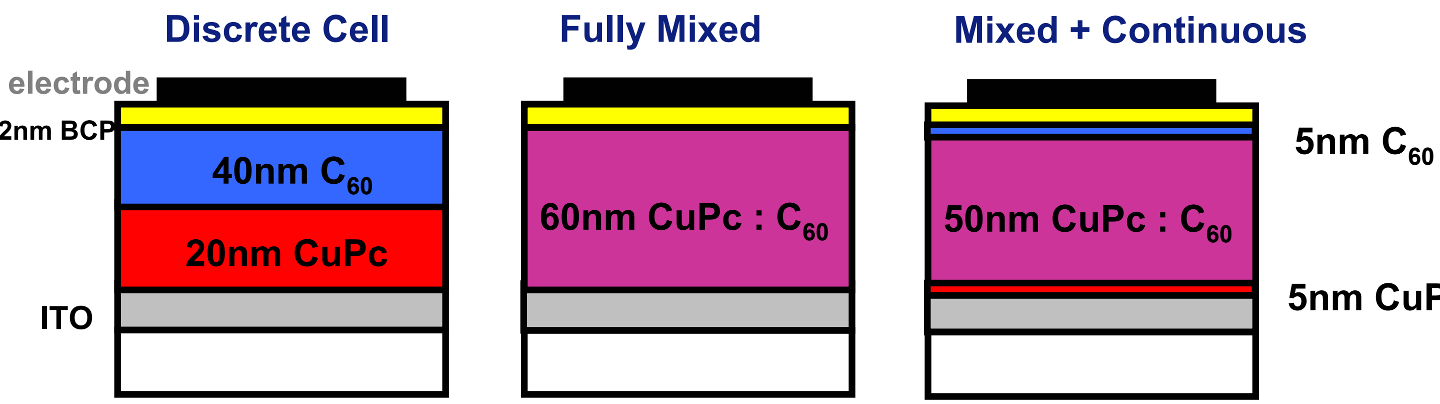
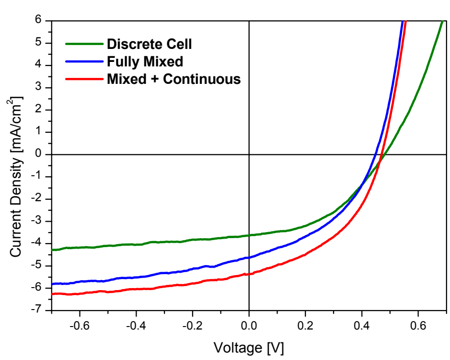
3. Results

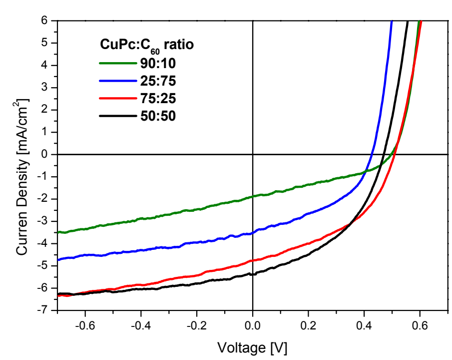
Architectures

Co-deposition can be used to design architectures for improved device performance.
(Devices not optimized with respect to substrate preparation and electrode modification)



Solar Cell Efficiencies





Architecture	η_p (%)
Discrete Cell	**0.75**
Fully Mixed	**0.88**
Mixed + Continuous	**1.18**

CuPc : C_{60} Ratio	η_p (%)
\25:75	**0.67**
50:50	**1.05**
75:25	**1.18**
90:10	**0.40**

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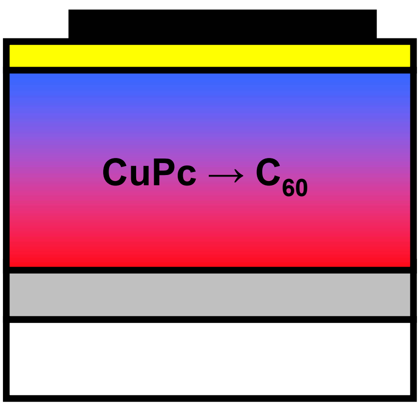
•Mixed layer devices show a much higher I_{sc} indicating that more free charges are produced due to more efficient exciton dissociation.

•The reduction of the internal field found in fully mixed cells can be avoided by adding thin continuous films of the respective materials at the electrodes.

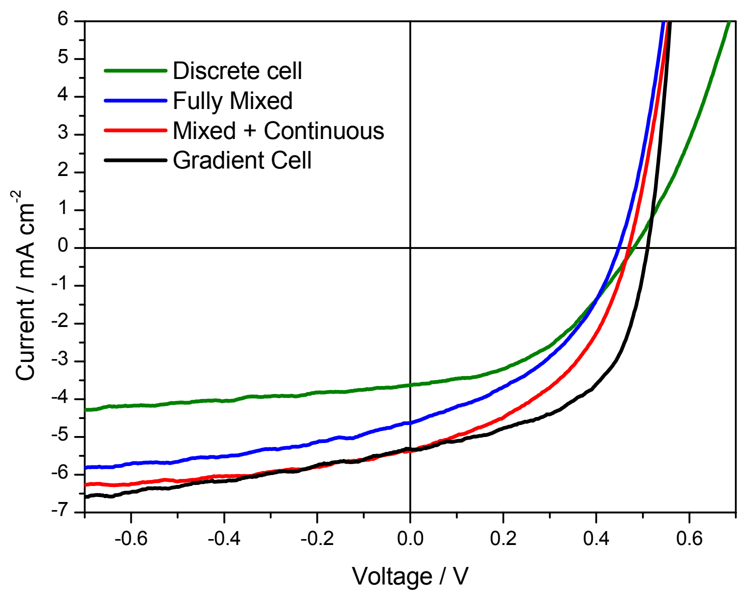
•CuPc absorbs light more strongly than C_{60} in the visible region, and consequently the I_{sc} is small at low CuPc content.

The Gradient Cell

Gradient



η_p = 1.36%



A compositional gradient cell shows increased I_{sc} and *FF* due to an increased charge collection efficiency. The efficiency of this cell is nearly twice that of the discrete cell.

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4. Conclusions

1) Device performance of molecular PV cells based on CuPc and C_{60} can be improved by incorporation of co-deposited layers with well-defined composition ratios.

2) Further improvements in efficiency are obtained using structures where the CuPc:C_{60} composition varies from pure donor to pure acceptor.

3) The improved device performance can be explained by the improved charge transport in the amorphous mixed layers and increased exciton dissociation due to intermolecular mixing.

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