CKC Optoelectronics Collaboration

Neil Greenham

Cavendish Laboratory
University of Cambridge
Cambridge
  • Optoelectronics Group
    • Dr Neil Greenham
    • Prof. Sir Richard Friend

Korea
  • KAIST
    • Prof. C. S. Yoon
  • GIST (APRI)
    • Prof. Jong-Min Lee
    • Dr Clare Byeon
    • Dr Song Hee Han
  • Seoul National University
    • Prof. Jang Joo Kim
Activities and People

• Dr Chang-Lyoul Lee

  Visitor Korea → Cambridge
  October 2005 – April 2007

  Project: Triplet exciton diffusion and energy transfer

  First publication in preparation

• Dr Xudong Yang

  Postdoc in Cambridge, April 2006 –

  Project: Ultrafast spectroscopy of conjugated polymers
• Inchan Hwang

    Ph.D. student at Cambridge, May 2006-

    Project: Modelling polymer photovoltaic devices

• Jinyoung Hwang

    Visiting summer student, 2006

    Project: Ellipsometry and optical modelling
Visits

NG to Korea, May 2006
  • APRI Anniversary Symposium
  • KAIST, Seminar and discussions
  • SNU, Seminar and discussions

Drs Byeon and Han to Cambridge, May 2006
Recent Developments in Polymer Photovoltaic Devices

Neil Greenham

Cavendish Laboratory
University of Cambridge
Polymer solar cell:
Device structures

- Tightly bound exciton
- Electron acceptor needed to dissociate exciton
Semiconductor nanoparticles as electron acceptor

- **CdSe tetrapods**
- Improve transport perpendicular to film

---

**Increasing diameter**

- Best power efficiencies ~ 2.8%

![Graph showing current density vs. voltage](image)

1 sun AM1.5G
Polymer blend devices

Atomic force microscopy

ITO  Polymer blend  Al
Best polymer blend performance

Red17

P3HT

Power efficiency 1.4%
Mapping chemical composition of polymer blends

Scanning Transmission X-ray Microscopy

Scintillator and PMT
Piezo stage
scanned sample

Order sorting aperture
Zone plate
Monochromatic X-rays

X-ray Optical Density
Energy (eV)

Ionisation Threshold
LUMO
HOMO
Core state

\[ \pi^* \]
\[ \sigma^* \]
Results:
Raw images of 1:1 80 nm PFB:F8BT film

X-ray Energy (eV): 284.0
Results:
Raw images of 1:1 80 nm PFB:F8BT film

X-ray Energy (eV): 284.1
Results:

Raw images of 1:1 80 nm PFB:F8BT film

X-ray Energy (eV): 284.2
Results:
Raw images of 1:1 80 nm PFB:F8BT film

X-ray Energy (eV): 284.3
Results:

Raw images of 1:1 80 nm PFB:F8BT film

X-ray Energy (eV): 284.4
Results:

Raw images of 1:1 80 nm PFB:F8BT film

X-ray Energy (eV): 284.5
Results:

Raw images of 1:1 80 nm PFB:F8BT film

X-ray Energy (eV): 284.6
Results:

Raw images of 1:1 80 nm PFB:F8BT film

X-ray Energy (eV): 284.7
Results:
Raw images of 1:1 80 nm PFB:F8BT film

X-ray Energy (eV): 284.8
Results:
Raw images of 1:1 80 nm PFB:F8BT film

X-ray Energy (eV): 284.9
Results:
Raw images of 1:1 80 nm PFB:F8BT film

X-ray Optical Density

X-ray Energy (eV): 285.0
Results:

Raw images of 1:1 80 nm PFB:F8BT film

X-ray Energy (eV): 285.1
Results:
Raw images of 1:1 80 nm PFB:F8BT film

X-ray Energy (eV): 285.2
Results:

Raw images of 1:1 80 nm PFB:F8BT film

X-ray Energy (eV): 285.3
Results:
Raw images of 1:1 80 nm PFB:F8BT film

X-ray Energy (eV): 285.4
Results:
Raw images of 1:1 80 nm PFB:F8BT film

X-ray Optical Density

X-ray Energy (eV): 285.5
Results:
Raw images of 1:1 80 nm PFB:F8BT film

X-ray Energy (eV): 285.6
Results:

Raw images of 1:1 80 nm PFB:F8BT film

X-ray Energy (eV): 285.7
Results:

Raw images of 1:1 80 nm PFB:F8BT film

X-ray Energy (eV): 285.8
Results:
Raw images of 1:1 80 nm PFB:F8BT film

X-ray Energy (eV): 285.9
Results:

Raw images of 1:1 80 nm PFB:F8BT film

X-ray Energy (eV): 286.0
STXM vs AFM

~ 60 % F8BT

~ 90 % F8BT
Modelling polymer blend devices

- Generate blend structures
- Cartesian lattice 20 nm × 20 nm × 20 nm
- Simulated annealing
Charge transport – Monte Carlo simulations

- Physics: the model includes
  - Charge pair generation at heterojunction
  - Hopping through energetically disordered lattice
  - Coulombic interactions between carriers
  - Recombination at heterojunction
  - Charge extraction at electrodes
  - Image charge effects at electrodes
Results

Simulated current-voltage curves

- Larger scale phase separation gives better charge extraction
- Balanced by poorer exciton dissociation
- Open-circuit voltage increases with intensity
- Early-time “geminate” recombination dominates efficiency
Conclusions

- Photovoltaic device efficiencies are improving
- Understanding microscopic structure and processes is crucial

Acknowledgements

- Nanoparticle devices: Baoquan Sun
- Polymer blend devices: Chris McNeill, CDT
- STXM: Chris McNeill, Paul Dastoor et al. (Newcastle, Australia), Advanced Light Source, Berkeley
- Modelling: Alex Marsh, Chris Groves