MEM4WIN

Inkjet Inks for Organic Solar Cell Application

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Project Overview

ADVANCED TECHNOLOGIES FOR SMART WINDOWS

- "Ultra thin glass membranes for advanced, adjustable and affordable quadruple glazing windows for zero-energy buildings"
  - EC-call for "Smart Windows" in FP7-programme

- Project Partners

  LISEC, AT | PROFACTOR GmbH, AT | BELECTRIC OPV GmbH, GER | Energy Glas GmbH, AT | Durst Phototechnik AG, AT | TIGER Coatings GmbH & Co.KG, AT | CNR, IT | JKU, AT | Univ. Kassel, GER | Univ. Cambridge, UK | Korea Univ., RK

Project Overview

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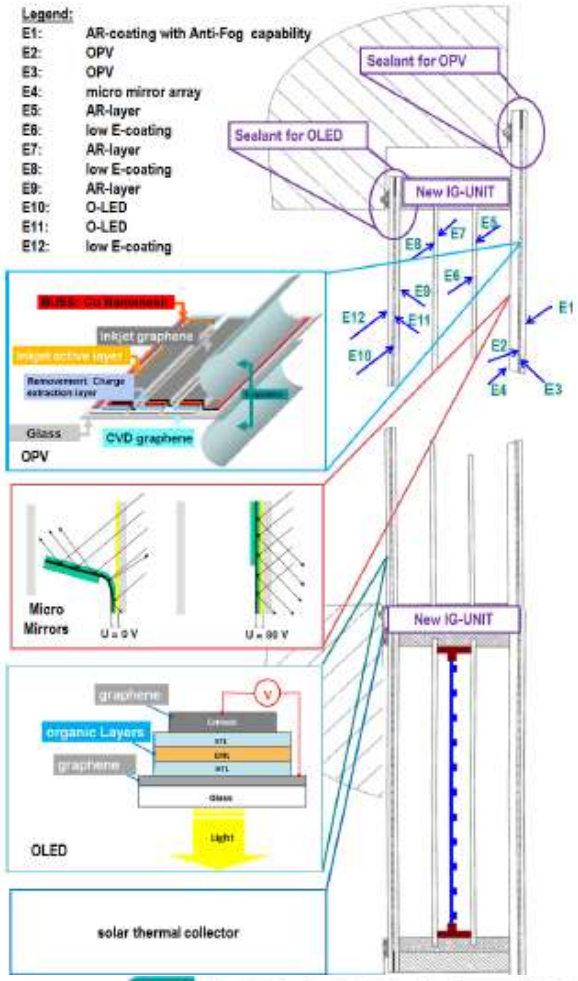
ADVANCED TECHNOLOGIES FOR SMART WINDOWS

- Goals
  - Weight reduction, new IG- Unit and sealing technique
  - Replacement of cost intensive processes and materials
    - Replacement of ITO with CVD graphene and of metallic contacts by graphene inks (large area)
  - Energy control and energy harvesting
    - Energy control with switchable layer (micro mirrors)
    - Harvesting energy with solar thermal collector
    - **Direct inkjet printing of active layer of OPV (ink development) and industrial scale printer development**



Examples of Other Projects

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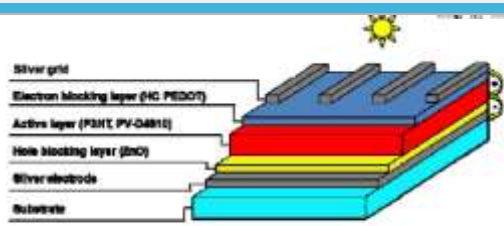
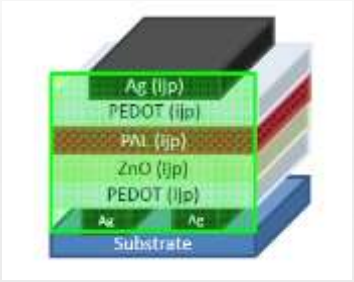
ADVANCED TECHNOLOGIES FOR SMART WINDOWS

- JETSOL
  - Durst Phototechnik AG| ZAE Bayern |FFG
  - Goals:
    - Fully inkjet printed OPV modules
    - R2R inkjet printer for OPV modules



Workshop on Organic Photovoltaics, Nürnberg, 11.12.2014, Scheiber

- SOLLIANCE
  - ECN| imec|TNO |Holst Center |TUe |Jülich
    → group of research institutes in the Eindhoven-Leuven-Aachen triangle
  - All inkjet printed cells
    - Total performance ~ 75 % of spin coated cells



Workshop on Organic Photovoltaics, Nürnberg, 11.12.2014, Gilot

OPV Films

- Advantages of OPVs
  - Light weight, mechanically flexible and semi-transparent,…
- Common production methods
  - Mostly roll-to-roll printing on PET foils
  - For window integration attachment under heat and pressure to glass panes followed by lamination
- Inkjet technology
  - Coating directly on glass is feasible for large areas
  - Design freedom
  - Contrary to OLEDs homogenous coating of large areas is necessary

Solvents for OPV Inks

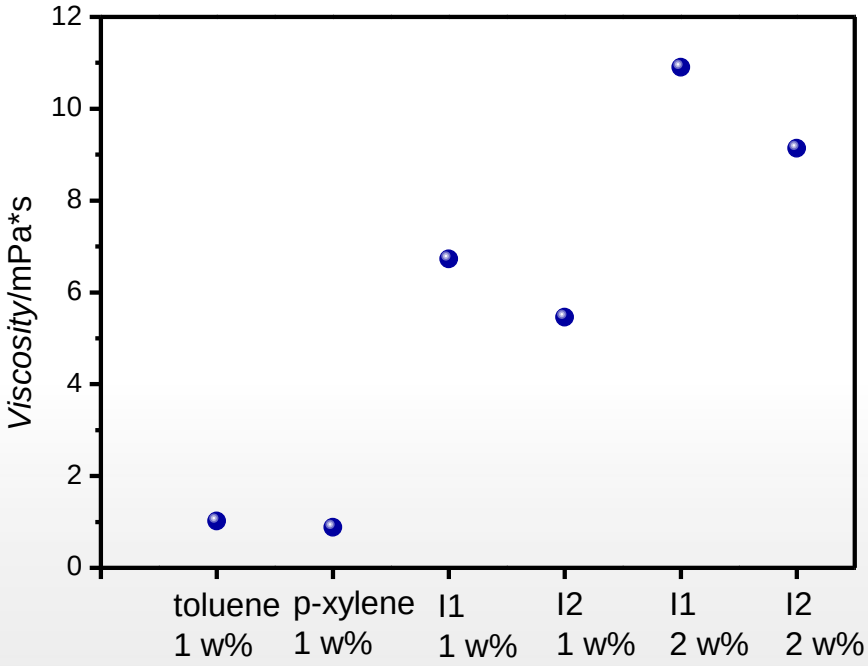
- Slow drying to prevent nozzle clogging
- Non corrosive/destructive
  - For printhead and other printer components

    Commonly used halogenated solvents like o-dichlorobenzene show severe compatibility issues with printing tools (seals, polymer materials used for printhead and fluid delivery system)[1]
- Viscosity of inks in the range of 8 – 15 mPas
- Good solubility of active polymer:fullerene blend (P3HT:PCBM)
  - Higher concentration → printing of active layer in one path

[1] G. –H. Lim, J. –M. Zhuo, L. –Y. Wong, S. –J. Chua, L. – L. Chua, P. H. K. Ho, *Org. Electron.* , **15**, 449 (2014)

Evaluation of Different Solvents

- Several printhead compatible solvents tested
  - Solvents with a naphthalene backbone (I1 and I2) fulfill viscosity requirements
- Inks w/o solvents with naphthalene backbone
  - Poor printing behavior → nozzle clogging even with diluted inks
- Inks with solvents with naphthalene backbone
  - Suitable for jetting of larger areas (up to ~ 65 cm^2) on ZnO covered ITO substrate

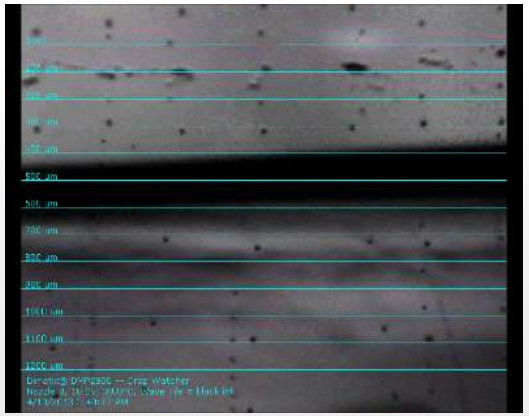


Ink Evaluation: Stability

- Storage of I1 and I2 inks
  - Usually at hotplate (60 °C) in Ar atmosphere under stirring
  - No gelation observed if stored under Ar even for shelf storage (no stirring, room temperature) for several months
  - Transferred into cartridge under ambient conditions
- Open time tests
  - Open time test (in sum 75 min) passed with fresh

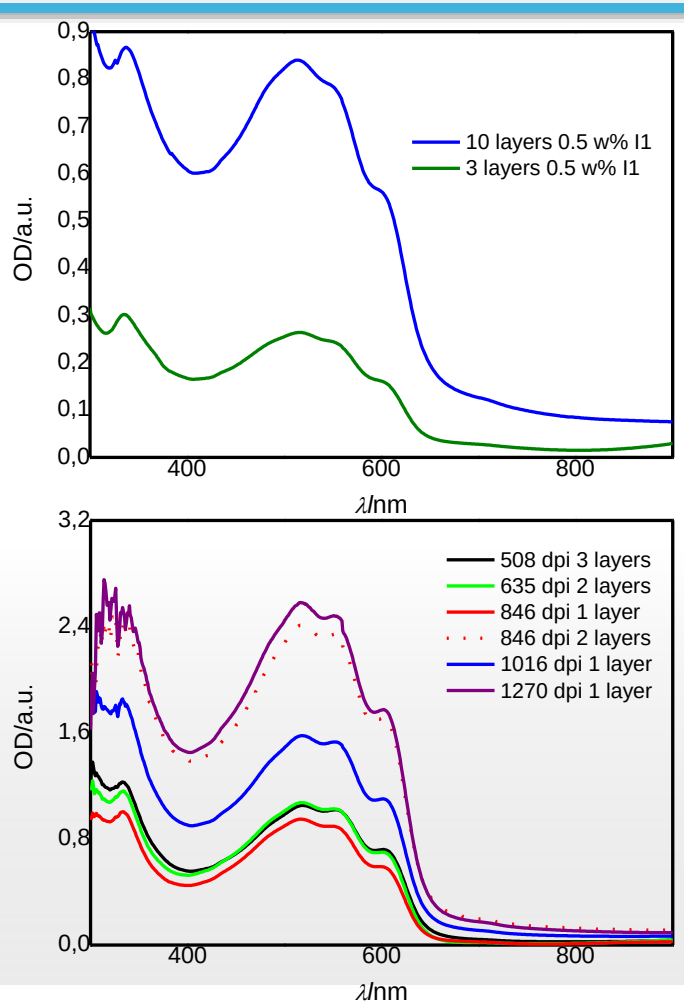
    2 w% I1 ink
  - Prolonged open time test with 6.5 months old

    2 w% I1 ink passed (in sum 24 h)
    - Ink stored for several months on shelf



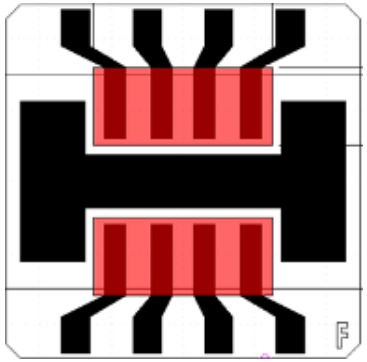
Film Thickness

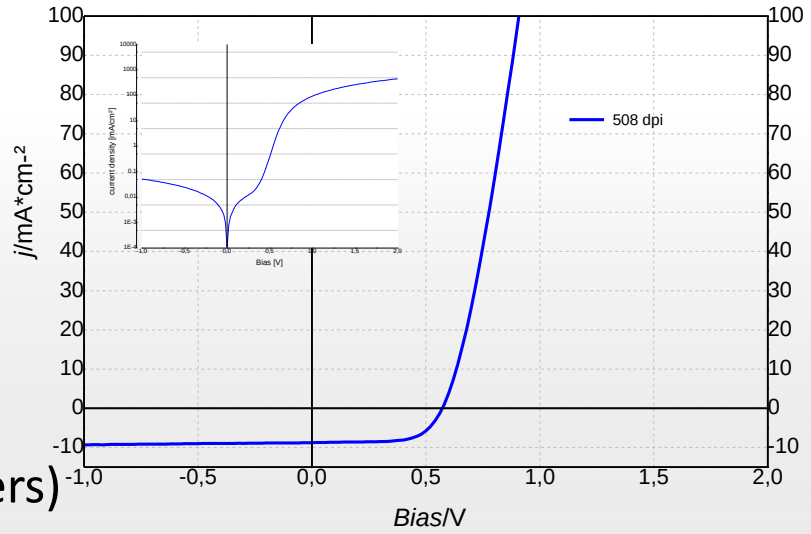
- Absorbance measurements as guidance
  - OD ~ 1 of active layer
  - Films dried at 60 °C on hotplate
- Necessary printing paths depends on
  - Ink concentration
    - Up to 2 w%
  - Printing resolution



OPVs with Jetted Active Layer

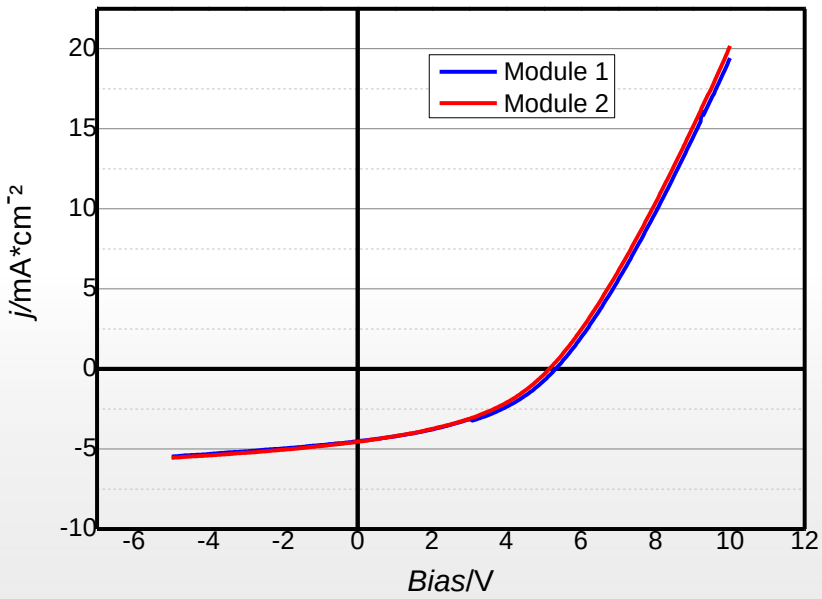
- Labscale Cells
  - Inkjet printing at ambient conditions
  - Inverted structure
    - Glass/ITO/ZnO/P3HT:PCBM/Pedot:PSS/Ag
  - 2 areas with 2.75 cm^2 were printed
  - Active area: 27 mm^2
- I1 and I2 inks
  - Different concentrations, number of layers and resolution
  - V_{OC} ~ 0.51 – 0.61 V; FF ~ 50 – 65 %, I_{SC} ~ 7.5 – 8.5 mA/cm^2
  - Efficiencies up to 3.3 % (508 dpi, 3 layers)

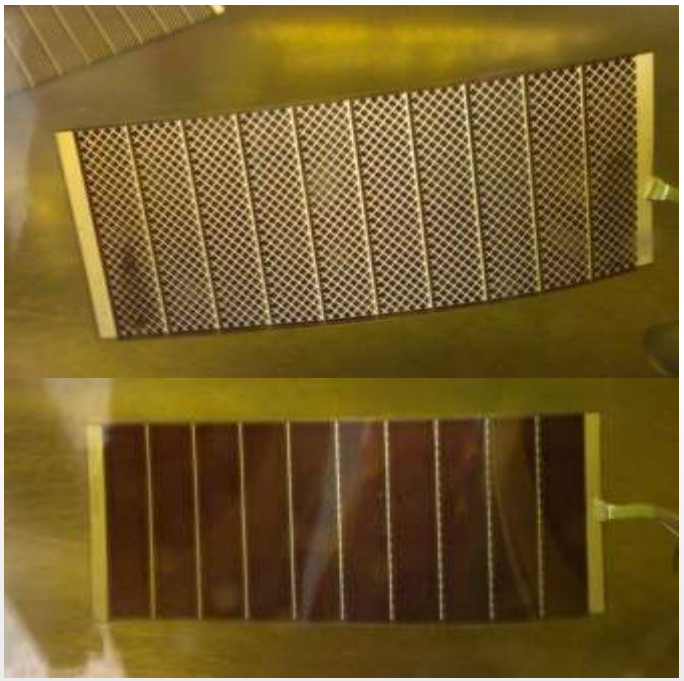




OPV Modules

- Total printed (active) area ~ 65 cm² on flexible substrates (I1 ink, 508 dpi)





V_{OC} ~ 5.1 V, FF and I_{SC} still low

Conclusions

- Solvents with a naphthalene backbone were successfully used as solvents for OPV ink formulation.
- If stored in Ar atmosphere no gelation was observed over several months.
- The number of necessary paths for suitable optical density is determined by the P3HT: PCBM blend concentration and the resolution.
- Labscale solar cells were realized routinely with efficiencies up to 3.3 %.
- Inks were suitable for printing of larger areas (modules) → FF and I_{SC} still need to be improved.

Outlook

Booth of Belectric OPV GmbH on GlassTec

Acknowledgements

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- Fruitful collaboration with involved project partners

THANK YOU FOR YOUR KIND ATTENTION!