



Polymer solar cells

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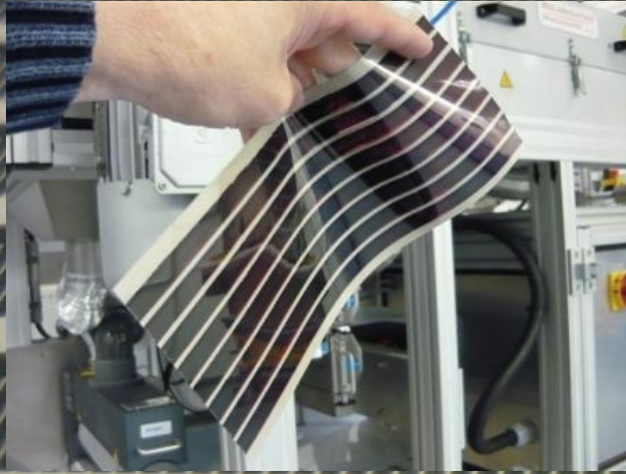
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Polymer Solar Cells



Overview

- What constitutes a polymer solar cell
- What is the potential and why the interest
- Where is the technology today
 - Performance
 - Stability
 - Processing
- Status at Risø DTU
- Outlook
- Conclusions

What constitutes a polymer solar cell

- The carrier substrate may be a polymer (or plastic) material
- The active material is a polymeric material
- Typically it is a multilayered structure
- Flexible



What is the potential and why the interest

- All other solar cell technologies have consistently failed when it comes to reduction of cost

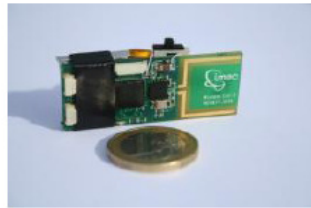
Microdevices

Smart Packaging



Source: Aveso Displays

Wireless Sensors



Source: IMEC

Consumer Products



Battery Charging



Active Clothing

On-Grid Power



Off-Grid Power



Rural Power

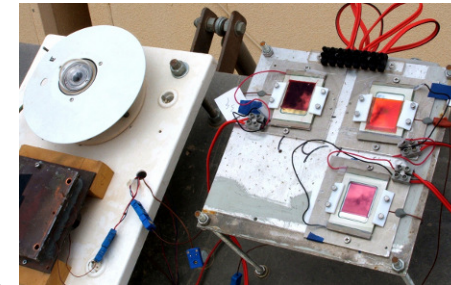
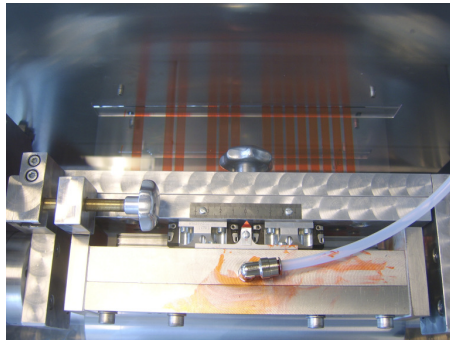


Transportation

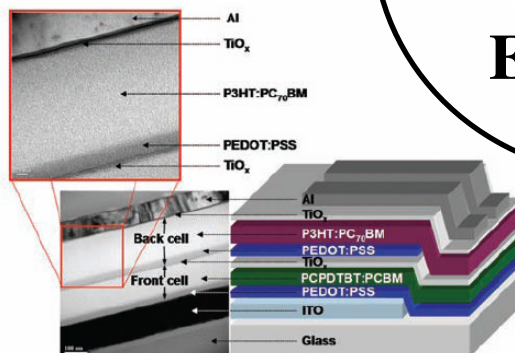
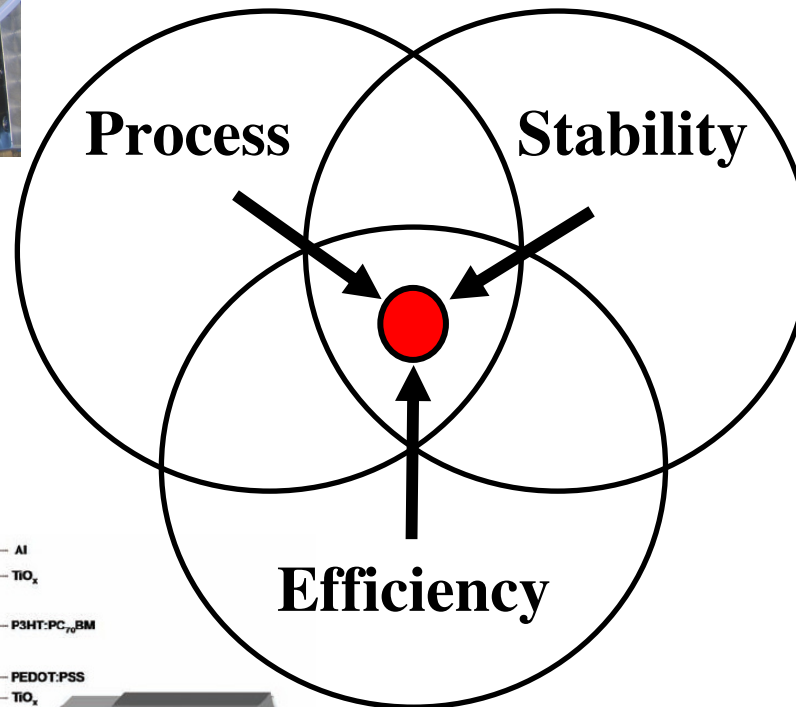
OPV Potential

- Operates well under various lighting sources
- Low dependence on angle of incidence
- Flexible/conformable form factor
- Long-term attractive LCOE

Where is the technology today

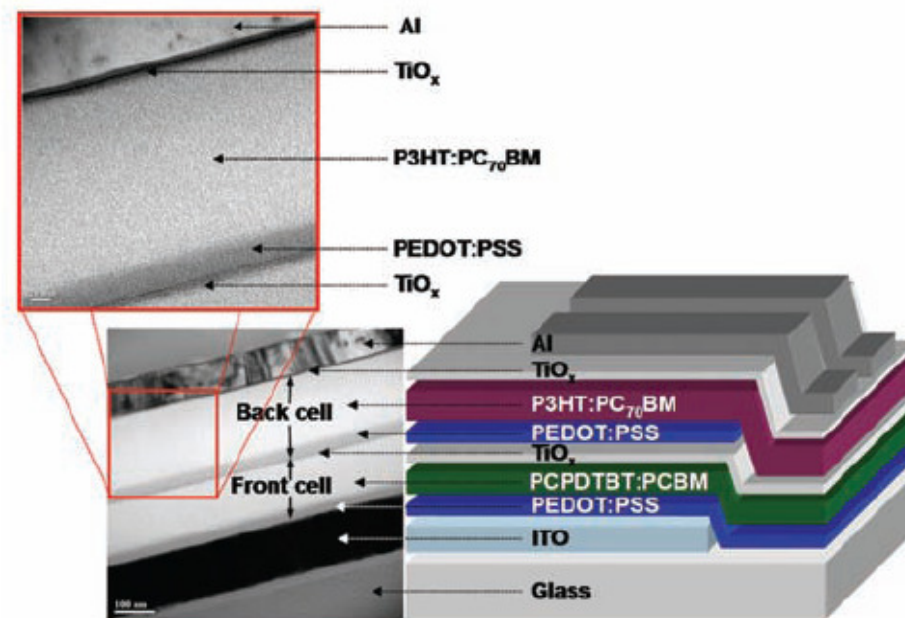


The Unification Challenge



Performance

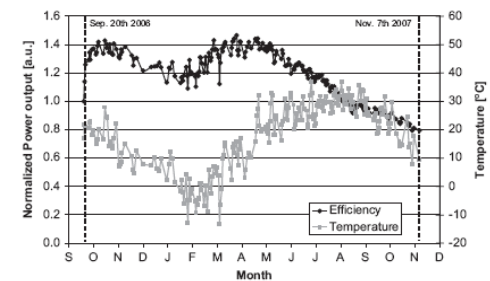
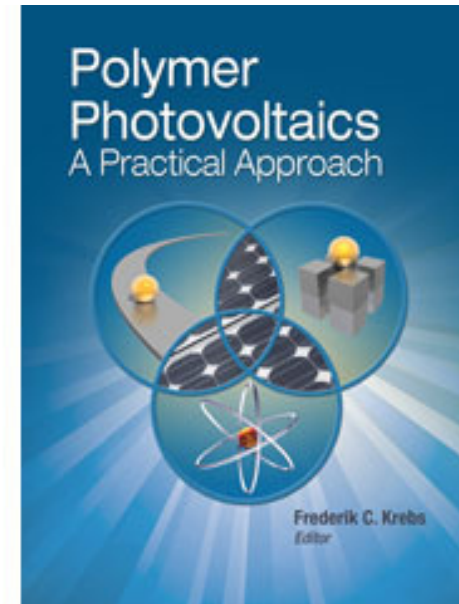
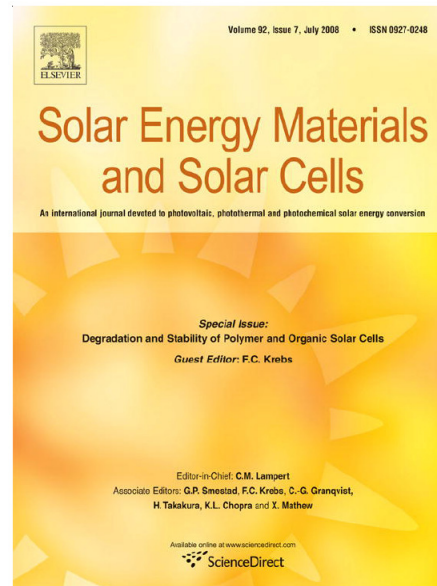
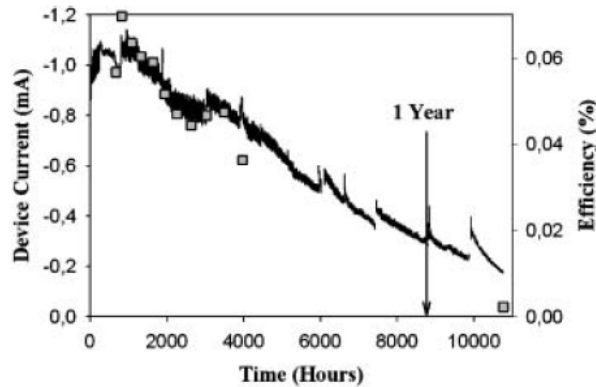
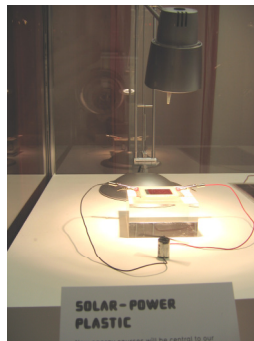
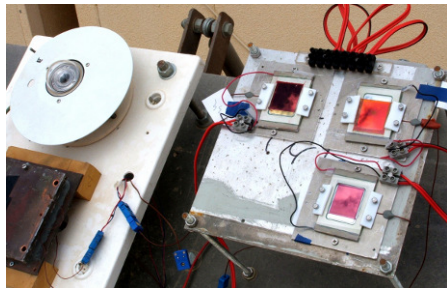
- **6.5% For tandem cells 5% for single junctions**
- > 99.9 % of scientific reports have efficiency as the selling point
- > 99.9 % of scientific reports employ spin coating
- > 99.9% of scientific reports employ evaporated metal back electrodes
- > 99.9% of scientific reports employ indium based transparent electrodes



Science 317 (2007) 222.

Stability

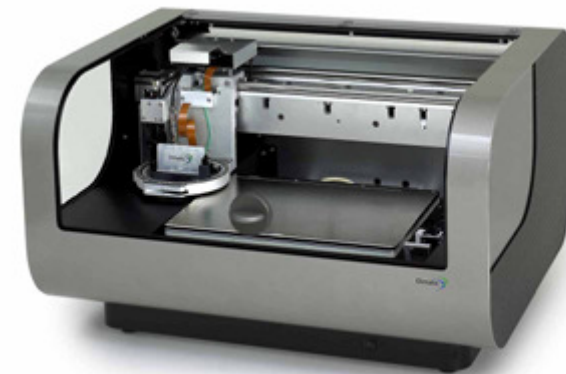
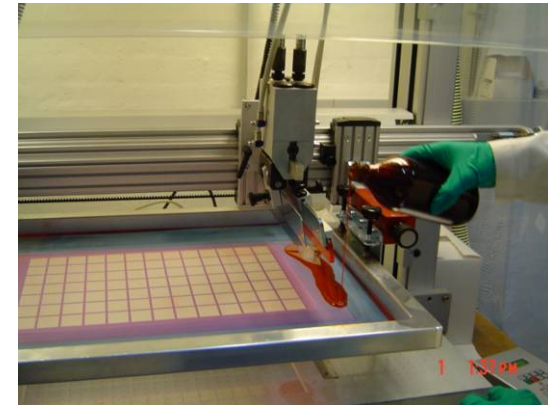
- Rarely reported/documentated – while this is starting to change



Jørgensen et al. Sol. Energy Mater. Sol. Cells 92 (2008) 686-714.
 Hauch et al. Sol. Energy Mater. Sol. Cells 92 (2008) 727-731.
 Krebs et al. Prog. Photovolt.: Res. Appl. 15 (2007) 697-712.

Processing

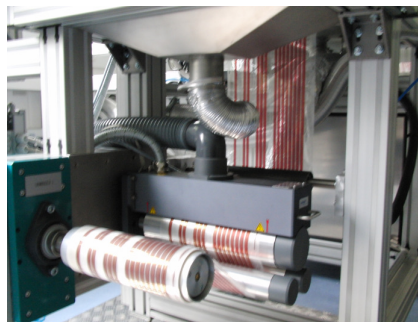
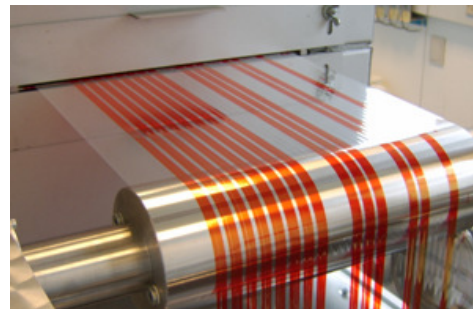
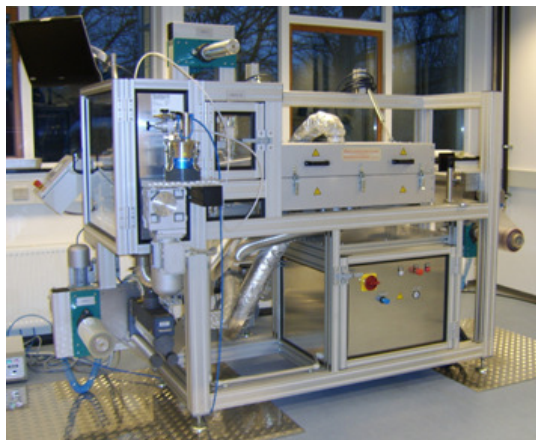
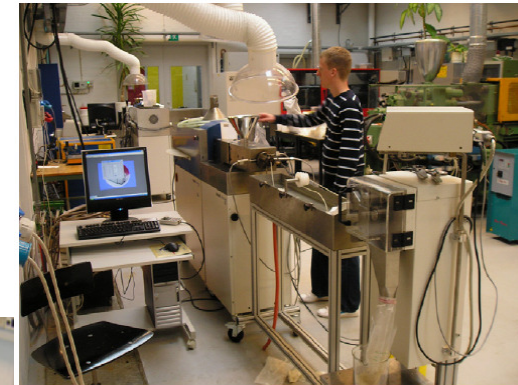
Processing is still rather unexplored and limited to a few materials using virtually one single film forming technique.



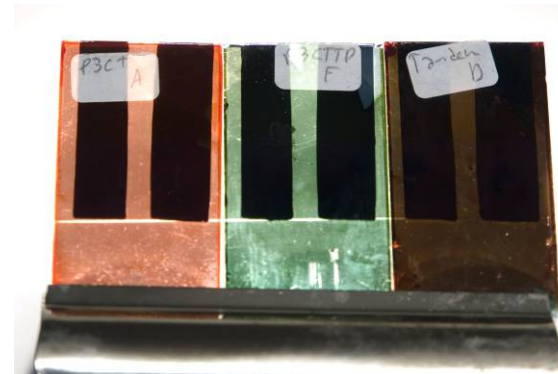
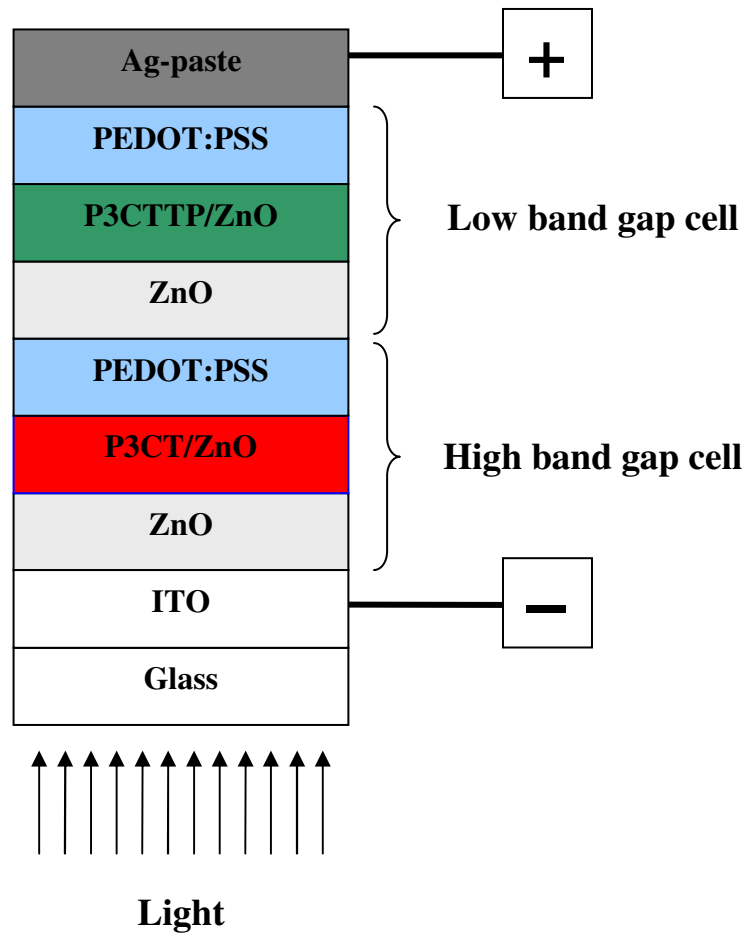
Adv. Mater. 19 (2007) 3973-3978.
Appl. Phys. Lett. 92 (2008) 033306.
Mater. Sci. En. B 138 (2007) 106-111.

New materials and processing techniques are needed

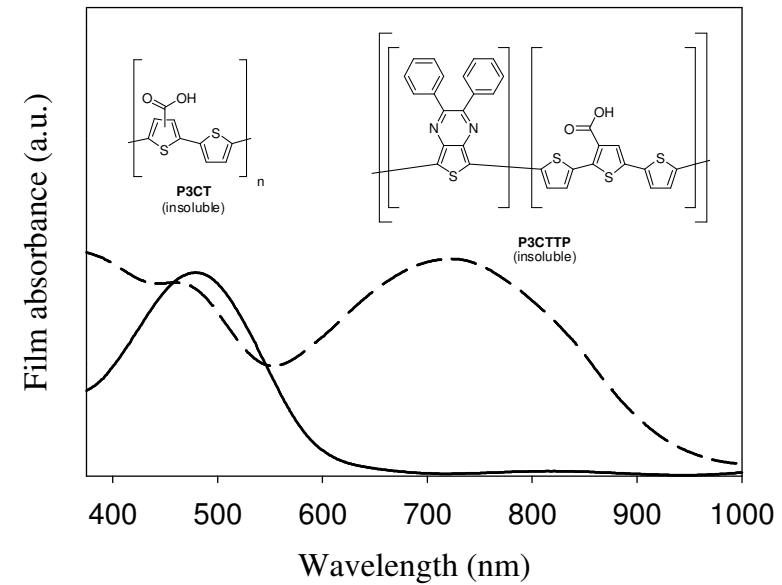
- Low cost
- Fast
- R2R
- Ambient air
- No vacuum steps
- Environmentally friendly



Multilayer processing



— ITO-ZnO-P3CT
 - - - ITO-ZnO-P3CTTP



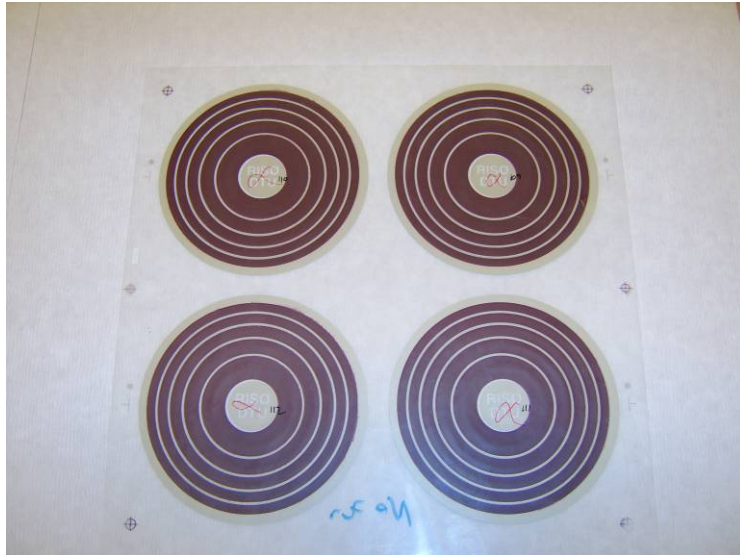
Real world demonstrations

- Many challenges for the development of the process that compromised performance
 - No volatile solvent
 - No toxicity
 - Air stability of printing ink
 - Long open time on mask
 - Solution to large wet thickness obtained with screen printing
 - All 5 layers had to be processed by screen printing
- Demonstration in July 2008



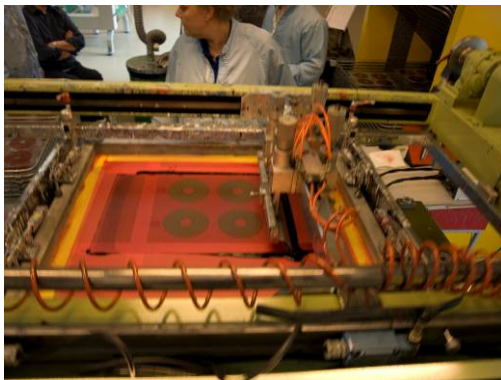
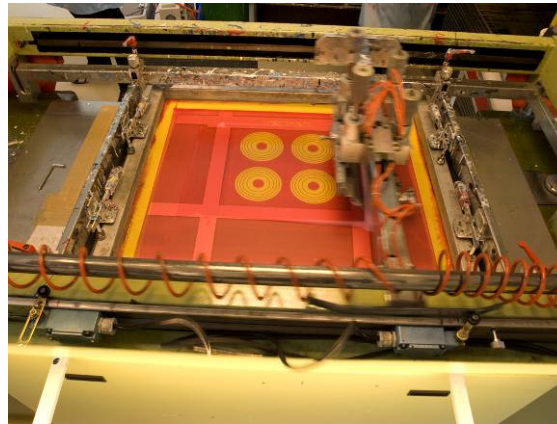
Real world demonstrations

- Concept/Mock-up



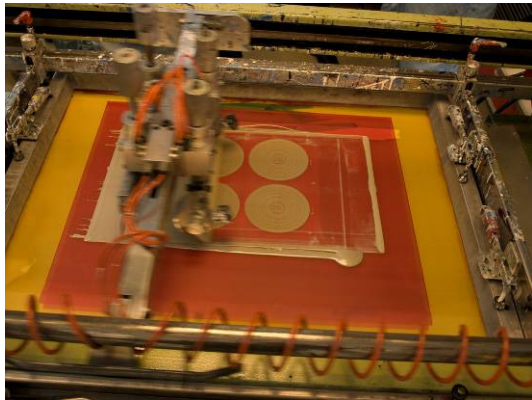
Real world demonstrations

- Processing entirely by screen printing
- All steps done in ambient air
- No special requirements to processing atmosphere



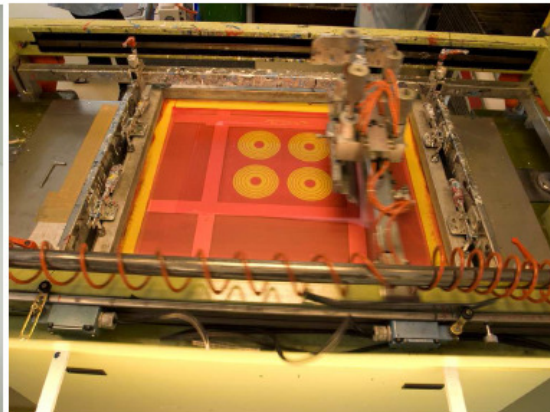
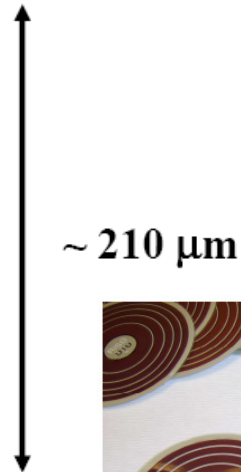
Real world demonstrations

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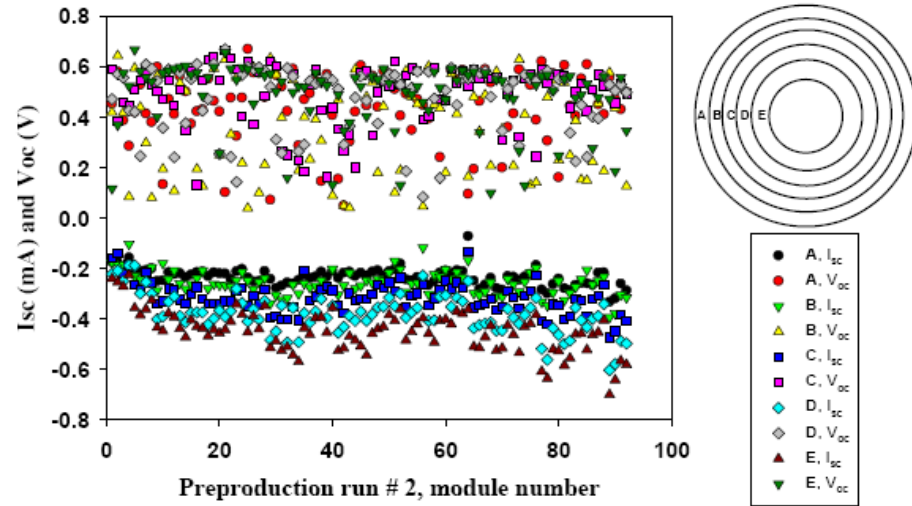
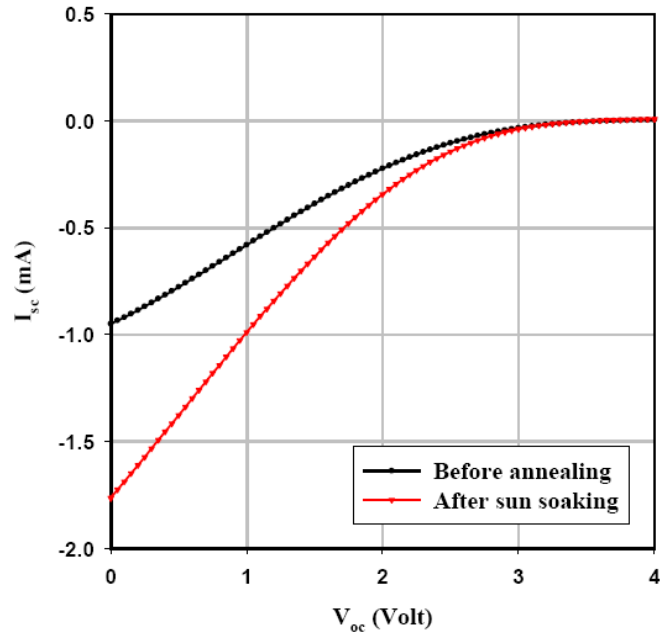
How did it go

Cold laminated PET with acrylic resin (25 μm)
Ag-paste (6 μm)
PEDOT:PSS (250 nm)
P3CT/PCBM/ZnO or P3CT/ZnO (90 nm)
ZnO (30 nm)
ITO (80 nm)
PET (175 μm)

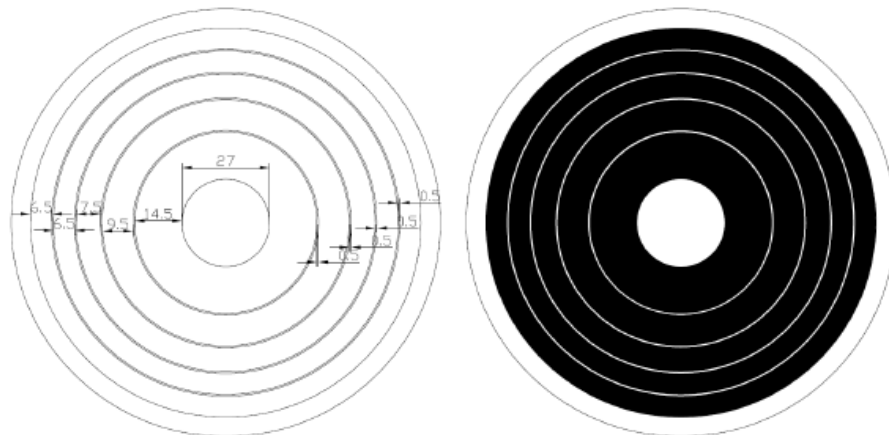


2124 functional modules produced in final run

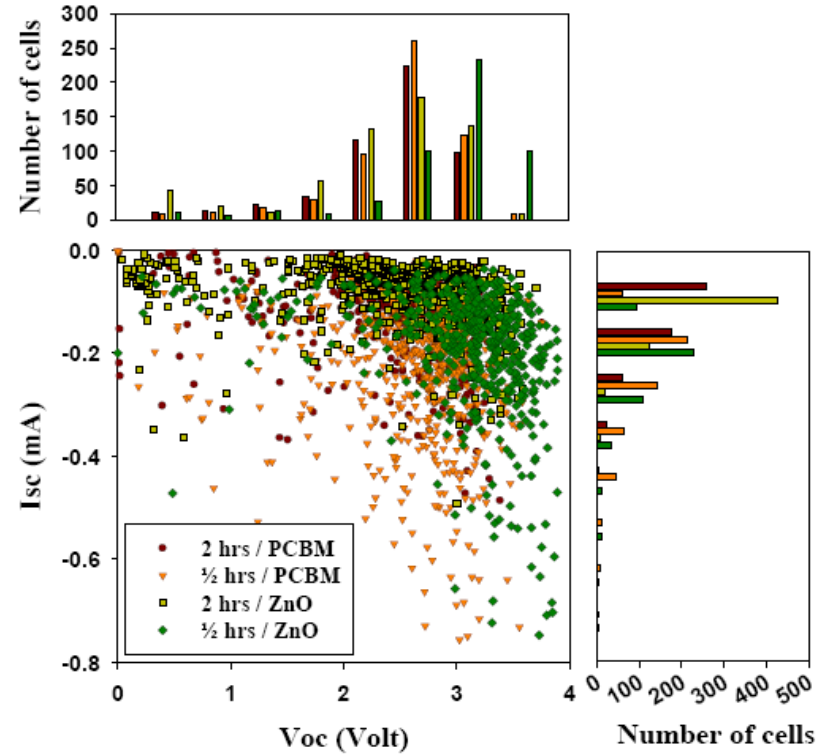
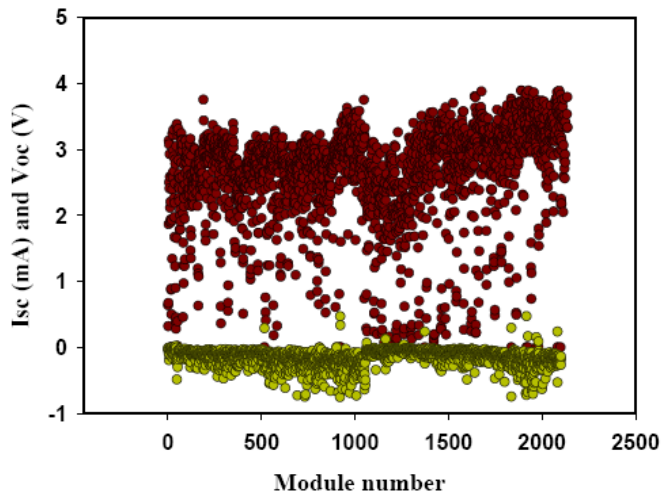
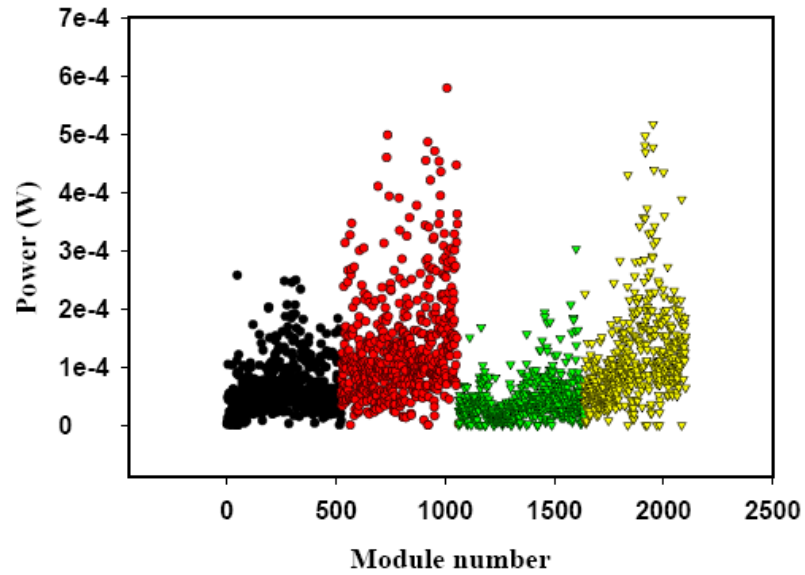
How did it go



Prerun #2/3



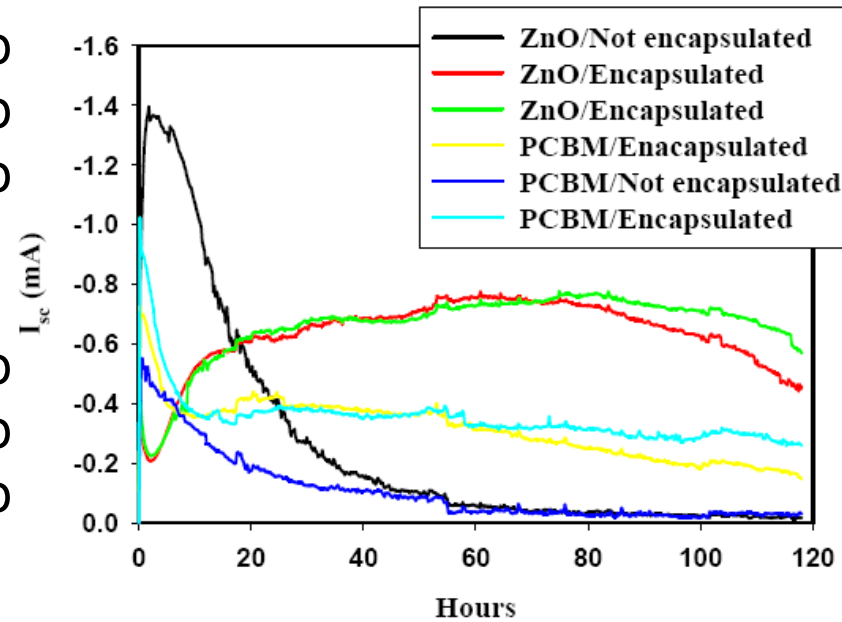
How did it go



Roskilde festival (Denmark)

Module cost complete ~ 4.5 Euro
 Processing cost ~ 1.5 Euro
 Materials cost ~ 3.0 Euro

Cost savings:
 Minus ITO ~ 3.2 Euro
 Minus crimping ~ 2.5 Euro
 New printing method ~ 1.5 Euro



Samsø Energy Academy

- Promotes Danish sustainable energy.
- Permanent exhibition of polymer solar cells.



St. James Park (Loop.PH, London)



Status at Risø DTU

- We believe in the full package (materials, processing and performance)
- First public demonstrations in 2008
- Several processes available
- ProcessOne
 - 2.33% PCE, full R2R, all solution, all air, semitransparent, flexible

Outlook

- The technology is likely to appear in niche products in 2009 onwards
- Potential for low cost and energy savings demonstrated
- On-grid electrical energy production lies somewhere in the future (10-20 years)

Conclusions

- We must find convincing means to combine efficiency, stability and process, thermocleavable materials is one possibility
- Many processing techniques are available that should be explored
- An application example is given, and, while being far from anything that can be rated as a commercial product, it shows some level of feasibility
- Cost analysis show that it is possible to prepare a low cost polymer PV product, but also that it will only come at an effort.