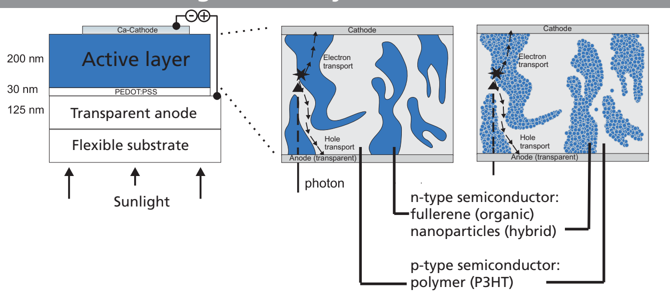
Karlsruhe Institute of Technology

Lukas Wengeler, Benjamin Schmidt-Hansberg,
Philip Scharfer, Wilhelm Schabel.

Processing of nanoparticle polymer mixtures for organic photovoltaic films:

Introduction

Organic- and hybrid solar cells



Motivation

- Cost efficient:
  - Low energy consumption for raw materials
  - Roll to roll production
  - Low thickness
- Flexible, lightweight, good utilization of diffuse light
- Design: Transparency, color, form

➡ Solvent based deposition, roll to roll process

- Processing strongly influences morphology and device perfomance
- State of the art: power conversion efficiency:
  - Lab scale: ~7% (Organic solar cells)
  - Pilot scale: ~2%(Organic solar cells)
- Lab scale spin coating does not allow independent process controll

➡ Investigation of the processing of functional films

Processing

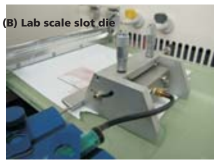
Development of coating tools

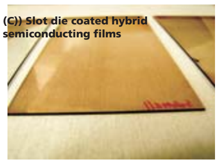
- Roll to roll compatible coating tools for organic electronic are necessary
- Slot die coating and gravure printing show highest potential
- Material prices are still high thus reduction holdup is essential

➡ Lab scale slot die coater with holdup of ~2 ml for wet film thicknesses >5 µm

(A) Characterisation of inks and definition of a model system

System Function	Solid	Solvent	Density [g/cm³]	Viscosity [mPas] 5 1/s	Viscosity [mPas] 1000 1/s	Surface tension [mN/m]	Concentration [wt.%]
Active layer	QD/P3HT	CB/PYR	1,29	4,85	2,87	36,01	5,2
Hole conducting layer	PEDOT:PSS	H2O	1	60,3	12,5	69,2	2,4
Model AL	PS	o-XYL	0,865	3,56	3,9	23,07	3
Model HCL	PAA	H2O	1	70,2	24,5	71,8	0,34

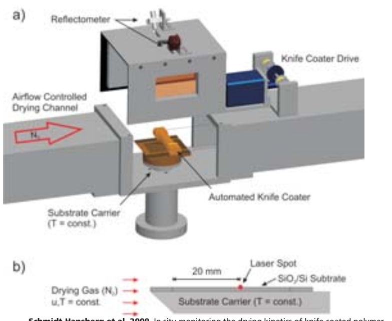

(B) Lab scale slot die


(C)) Slot die coated hybrid semiconducting films

Drying of organic electronic films

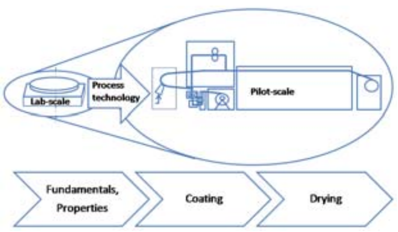
- Drying determines cell efficiency
- Experimental setup enables controlled drying with in-situ film thickness measurement
- In-situ GIXRD is possible
- Local transfer coefficients and drier optimization are investigated (separate poster)

➡ Independent variation of drying conditions



Schmidt-Hansberg et al. 2009. In situ monitoring the drying kinetics of knife coated polymer-fullerene films for organic solar cells. Journal of Applied Physics. 2009.

Process scaleup



Coating method	Materials	Substrate	Conditions	Electrode	R2R	PCE	Area	Date	Ref
Spin coating	PBDTTT/PC70BM	Glas	Inert	ITO	NO	7,90%		2009	Yang Yang et al.
Brush painting	P3HT/PCBM	Glas	Inert	ITO	NO	5%	0,04cm²	2007	Kim et al.
Spin coating	P3HT/PCBM	Glas	Inert	ITO	NO	5%		2009	Dennler et al
Doctor blade	P3HT/PCBM	Glas	Inert	ITO	NO	4%	16mm²	2009	Schilinski et al.
Ink jet	P3HT/PCBM	Glas	Inert	ITO	NO	3,50%		2009	Hoth et al.
Roll (ESSENCIAL)	P3HT/PCBM	PET		ITO	YES	3,50%	9,6mm²	2010	Park et al.
Spray	P3HT/PCBM	Glas	Inert	ITO	NO	2,50%	0,164cm²	2007	Vak et al.
Slot die	P3HT/PCBM	PET	Ambient	ITO	YES	2,33%	4,8cm²	2009	Krebs et al.
Slot die	P3HT/PCBM	PET	Ambient	ITO	YES	1,70%		2009	Blankenburg et al.
Gravure	P3HT/PCBM	PC	Inert	ITO	NO	1,68%	0,03cm²	2009	Ding et al.
Screen/ Knife /Slot die	P3MHOCT	PET	Ambient	ITO	YES	0,84%	15cm²	2009	Krebs et al.
Slot die /Screen	P3HT/PCBM	PEN	Ambient	ZnOx PDOT	YES	0,30%	15cm²	2009	Krebs et al.

Characterization

Morphology characterization

Microscopic characterization of Baydots® (5nm diameter) / P3HT films.

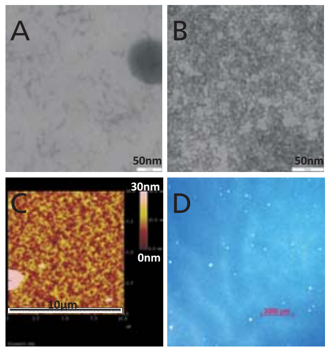
(A) TEM low particle concentration: shows the agglomeration of individual nanoparticles at low particle concentration.

(B) TEM high particle concentration: displays the particle distribution in a film with realistic Baydots®-concentration.

(C) AFM high particle concentration: shows no pinholes, AFM pictures are related to domain size

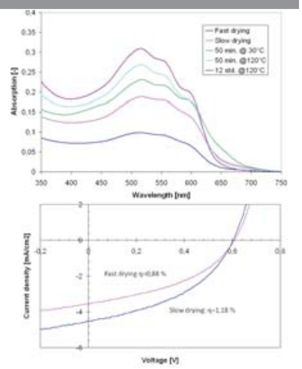
(D) Light microscope reveals thickness variations in the mm range at realistic particle concentration.

➡ No difference between spin coating and doctor blading



Electro-optical charcterisation

- Absorption increases with decreased drying speed and annealing time and temperature. This is caused by further crystallization of the polymer.
- Voltage-current plots show the behavior of the solar cell. Short current density and Efficiency are a function of the drying conditions.
- Hybrid solar cells have been produced with a roll to roll compatible method yielding efficiencies of up to 1.18%.
- Further increase in efficiency is expected through the application of low bandgap polymers and rod shaped particles.



Summary

- A slot die coater for organic electronic films has been developed and successfully tested
- Experimental setup allows independent variation process parameters.
- A coating and drying plant enables investigation on pilot scale
- Drying kinetics determines film morphology, film properties and cell efficiency
- Hybrid solar cells have been produced with roll to roll compatible method yielding 1.2% efficiency

Blankenburg, Lars, et al. 2009. Reel-to-reel wet coating as an efficient up-scaling technique for the production of bulk- heterojunction polymer solar cells. Solar Energy Materials and Solar Cells, 2009.
Günes, Serap and Sariciftci, N. Serdar. 2008. Hybrid solar cells. Inorganica Chimica Acta. 2008, 581-588.
Kistler, Stephan F. and Schweizer, Peter M. 1997. Liquid Film Coating. London : Chapman and Hall.
Park, Sung Heum, et al. 2009. Bulk heterojunction solar cells with internal quantum efficiency approaching 100%. Nature Photonics. April 2009, 297-303.
Peet, Jeffrey, et al. 2009. The Role of Processing in the Fabrication and Optimization of Platic Solar Cells, Advanced Materials, 1521-1527.
Schmidt-Hansberg et al. 2009. In situ monitoring the drying kinetics of knife coated polymer-fullerene films for organic solar cells. Journal of Applied Physics. 2009.

Acknowledgements:
This project is financially supported by the Bundesministerium für Bildung und Forschung and Bayer Technology Services.

Dipl.-Ing. Lukas Wengeler
Institute of Thermal Process Engineering
Chair Thin Film Technology
Kaiserstr. 12, 76131 Karlsruhe

Tel.: +49 721 / 608 7152 (KIT Campus South)
Fax: +49 721 / 608 3490
E-Mail: Lukas.Wengeler@kit.edu
Homepage: www.tft.kit.edu

TFT Thin Film Technology