

## Research Area F 'Nano-Energy'

### Project F1 'Organic Solar Cells'

#### F1.1 'New Concepts for Hybrid Solar Cells' (H. Kalt, U. Lemmer)

- [F1.1:1] \* ‡ H.J. Zhou, J. Fallert, J. Sartor, R.J.B. Dietz, C. Klingshirn, H. Kalt, D. Weissenberger, D. Gerthsen, H.B. Zeng, and W.P. Cai, *Ordered n-type ZnO nanorod arrays*, Appl. Phys. Lett. **92**, 132112 (2008)
- [F1.1:2] ‡ H.Zeng, W. Cai, P. Liu, X. Xu, H. Zhou, C. Klingshirn, and H. Kalt, *ZnO-based hollow nanoparticles by selective etching: elimination and reconstruction of metal-semiconductor interface, improvement of blue emission and photocatalysis*, ACS Nano **2**, 1661 (2008)
- [F1.1:3] A. Colsmann, F. Stenzel, G. Balthasar, H. Do, and U. Lemmer, *Plasma patterning of Poly(3,4-ethylenedioxythiophene): Poly(styrenesulfonate) anodes for efficient polymer solar cells*, Thin Solid Films **517**, 1750 (2009)
- [F1.1:4] H. Do, M. Reinhard, H. Vogeler, A. Pütz, M.F.G. Klein, W. Schabel, A. Colsmann, and U. Lemmer, *Polymeric anodes from poly(3,4-ethylenedioxythiophene): poly(styrenesulfonate) for 3.5% efficient organic solar cells*, Thin Solid Films **517**, 5900 (2009)
- [F1.1:5] ‡ R. Steim, S.A. Choulis, P. Schilinsky, U. Lemmer, and C.J. Brabec, *Formation and Impact of Hot-Spots on the Performance of Organic Photovoltaic Cells*, Appl. Phys. Lett. **94**, 043304 (2009)
- [F1.1:6] \* B. Schmidt-Hansberg, H. Do, A. Colsmann, U. Lemmer, and W. Schabel, *Drying of thin film polymer solar cells*, Eur. Phys. J. Special Topics **166**, 49 (2009)
- [F1.1:7] \* B. Schmidt-Hansberg, M. Klein, K. Peters, F. Buss, J. Pfeifer, S. Walheim, A. Colsmann, U. Lemmer, P. Scharfer, and W. Schabel, *In situ monitoring the drying kinetics of knife coated polymer-fullerene films for organic solar cells*, J. Appl. Phys. **106**, 124501 (2009)
- [F1.1:8] \* D. Weissenberger, D. Gerthsen, A. Reiser, G.M. Prinz, M. Feneberg, K. Thonke, H. Zhou, J. Sartor, J. Fallert, C. Klingshirn, and H. Kalt, *Influence of the measurement procedure on the field-effect dependent conductivity of ZnO nanorods*, Appl. Phys. Lett. **94**, 042107 (2009)
- [F1.1:9] \* J. Sartor, F. Maier-Flaig, J. Conradt, J. Fallert, H. Kalt, D. Weissenberger, and D. Gerthsen, *Modifying growth conditions of ZnO nanorods for solar cell applications*, phys. stat. sol. (c) **7**, 1583 (2010)
- [F1.1:10] F. Nickel, A. Puetz, M. Reinhard, H. Do, C. Kayser, A. Colsmann, and U. Lemmer, *Cathodes comprising highly conductive poly(3,4-ethylenedioxythiophene):poly(styrenesulfonate) for semi-transparent polymer solar cells*, Organic Electronics **11**, 535 (2010)
- [F1.1:11] S. Kettlitz, S. Valouch, and U. Lemmer, *Organic solar cell degradation probed by the nanosecond photoresponse*, Appl. Phys. A **99**, 805 (2010)
- [F1.1:12] F. Nickel, A. Puetz, M. Reinhard, H. Do, C. Kayser, A. Colsmann, and U. Lemmer, *Cathodes Comprising Highly Conductive Poly(3,4-Ethylenedioxythiophene): Poly(Styrenesulfonate) for Semi-Transparent Polymer Solar Cells*, Organic Electronics **11**, 535 (2010)
- [F1.1:13] S. Kettlitz, S. Valouch, and U. Lemmer, *Organic solar cell degradation probed by the nanosecond photoresponse*, Appl. Phys. A **99**, 805 (2010)
- [F1.1:14] S. Züfle, N. Christ, S.W. Kettlitz, S. Valouch, and U. Lemmer, *Influence of temperature-dependent mobilities on the nanosecond response of organic solar cells and photodetectors*, Appl. Phys. Lett. **97**, 063306 (2010)

- [F1.1:15] C. Klingshirn, J. Fallert, H. Zhou, J. Sartor, C. Thiele, F. Maier-Flaig, and H. Kalt, *65 years of ZnO research - old and very recent results*, phys. stat. sol. (b) **247**, 1424 (2010) (**cover story**)
- [F1.1:16] \* A. Puetz, T. Stubhan, M. Reinhard, O. Loesch, E. Hammarberg, S. Wolf, C. Feldmann, H. Kalt, A. Colsmann, and U. Lemmer, *Organic solar cells incorporating buffer layers from indium doped zinc oxide nanoparticles*, Sol. En. Mat. Sol. Cells **95**, 579 (2011)
- [F1.1:17] \* J. Conradt, J. Sartor, C. Thiele, F. Maier-Flaig, J. Fallert, H. Kalt, R. Schneider, M. Fotouhi, P. Pfundstein, V. Zibat, and D. Gerthsen, *Catalyst-Free Growth of Zinc Oxide Nanorod Arrays on Sputtered Aluminum-Doped Zinc Oxide for Photovoltaic Applications*, J. Phys. Chem. C **115**, 3539 (2011)
- [F1.1:18] N. Christ, S.W. Kettlitz, S. Züfle, S. Valouch, and U. Lemmer, *Nanosecond response of organic solar cells and photodiodes: Role of trap states*, Phys. Rev. B **83**, 195211 (2011)
- [F1.1:19] ‡ M. Sanyal, B. Schmidt-Hansberg, M.F.G. Klein, C. Munuera, A. Vorobiev, A. Colsmann, U. Lemmer, W. Schabel, H. Dosch, and E. Barrena, *Effect of Photovoltaic Polymer/Fullerene Blend Composition Ratio on Microstructure Evolution during Film Solidification Investigated in Real Time by X-ray Diffraction*, Macromolecules **44**, 3795 (2011)
- [F1.1:20] ‡ M. Sanyal, B. Schmidt-Hansberg, M.F.G. Klein, A. Colsmann, C. Munuera, A. Vorobiev, U. Lemmer, W. Schabel, H. Dosch, and E. Barrena, *In-situ x-ray study of drying temperature influence on the structural evolution of bulk heterojunction polymer-fullerene solar cells processed by doctor-blading*, Adv. Energy Mat. **1**, 363 (2011).
- [F1.1:21] A. Colsmann, A. Puetz, A. Bauer, J. Hanisch, E. Ahlswede, and U. Lemmer, *Efficient semi-transparent organic solar cells with good transparency color perception and rendering properties*, Adv. Energy Mat. **1**, 599 (2011)
- [F1.1:22] \* B. Schmidt-Hansberg, M. Baunach, J. Krenn, S. Walheim, U. Lemmer, P. Scharfer, and W. Schabel, *Spatially resolved drying kinetics of multi-component solution cast films for organic electronics*, Chemical and Process Engineering **50**, 509 (2011)
- [F1.1:23] \* M. Reinhard, J. Hanisch, Z.-H. Zhang, E. Ahlswede, A. Colsmann, and U. Lemmer, *Inverted organic solar cells comprising a solution-processed cesium fluoride interlayer*, Appl. Phys. Lett. **98**, 053303 (2011)
- [F1.1:24] \* M.F.G. Klein, E. Müller, M. Pfaff, J. Czolk, M. Reinhard, S. Valouch, U. Lemmer, A. Colsmann, and D. Gerthsen, *Poly(3-hexylselenophene) solar cells: Correlating the optoelectronic device performance and nanomorphology imaged by low-energy scanning transmission electron microscopy*, J. Polymer Sci. B: Polymer Phys. (2011), DOI: 10.1002/polb.22394
- [F1.1:25] ‡ J. Yu, K.H. Lee, Y. Zhang, M.F.G. Klein, A. Colsmann, U. Lemmer, P.L. Burn, S.-C. Lo, and P. Meredith, *A dendronised polymer for bulk heterojunction solar cells*, Polym. Chem. **2**, 266 (2011)
- [F1.1:26] ‡ F.M. Pasker, M.F.G. Klein, M. Sanyal, E. Barrena, U. Lemmer, A. Colsmann, and S. Höger, *Photovoltaic Response to Structural Modifications on a Series of Conjugated Polymers Based on 2-Aryl-2H-benzotriazoles*, J. Polymer Sci. A: Polymer Chem. **49**, 5001 (2011)
- [F1.1:27] ‡ \* B. Schmidt-Hansberg, M. Sanyal, M. Klein, M. Pfaff, N. Schnabel, S. Jaiser, Stefan, A. Vorobiev, E. Müller, A. Colsmann, P. Scharfer, D. Gerthsen, U. Lemmer, E. Barrena, and W. Schabel, *Moving through the phase diagram:*

*morphology formation in solution cast polymer-fullerene-blend films for organic solar cells*, ACS Nano **5**, 8579 (2011)

- [F1.1:28] ‡ B. Schmidt-Hansberg, M. Sanyal, N. Grossiord, Y. Galagan, M. Baunach, M. F.G. Klein, A. Colsmann, P. Scharfer, Uli Lemmer, H. Dosch, J. Michels, E. Barrena, and W. Schabel, *Investigation of non-halogenated solvent mixtures for high throughput fabrication of polymer–fullerene solar cells*, Sol. En. Mat. Sol. Cells **96** 195 (2011)
- [F1.1:29] \* A. Colsmann, M. Reinhard, T.-H. Kwon, C. Kayser, F. Nickel, U. Lemmer, Noel Clark, J. Jasieniak, A. Holmes, and D. Jones, *Inverted semi-transparent organic solar cells with spray coated, surfactant free polymer top-electrodes*, Sol. En. Mat. Sol. Cells (2011), DOI:10.1016/j.solmat.2011.10.016 (2011)
- [F1.1:30] ‡ J.D. Yuen, R. Kumar, J. Seifert, S. Valouch, D. Zakhidov, D. Moses, U. Lemmer, A.J. Heeger, and F. Wudl, *Observations of PDDTT Subject to Thermal Treatment: Correlation between Performance and Order*, J. Am. Chem. Soc. **133**, 19602 (2011)

## F1.2 ,Electronic and Morphological Properties of Organic and Hybrid Solar Cells' (D. Gerthsen / U. Lemmer)

- [F1.2:1] A. Colsmann, J. Junge, C. Kayser, and U. Lemmer, *Organic tandem solar cells comprising polymer and small-molecule subcells*, Appl. Phys. Lett **89**, 203506 (2006)
- [F1.2:2] A. Colsmann, J. Junge, T. Wellinger, C. Kayser, and U. Lemmer, *Optimization of Electron Transport and Cathode Materials for Efficient Organic Solar Cells*, Proc. SPIE 6192, 619220 (2006)
- [F1.2:3] N. Christ, S. Kettlitz, S. Valouch, S. Züfle, C. Gärtner, M. Punke, and U. Lemmer, *Nanosecond Response of Organic Solar Cells and Photodetectors*, J. Appl. Phys. **105**, 104513 (2009)
- [F1.2:4] A. Colsmann, F. Stenzel, G. Balthasar, H. Do, and U. Lemmer, *Plasma patterning of Poly(3,4-ethylenedioxythiophene): Poly(styrenesulfonate) anodes for efficient polymer solar cells*, Thin Solid Films **517**, 1750 (2009)
- [F1.2:5] H. Do, M. Reinhard, H. Vogeler, A. Pütz, M.F.G. Klein, W. Schabel, A. Colsmann, and U. Lemmer, *Polymeric anodes from poly(3,4-ethylenedioxythiophene): poly(styrenesulfonate) for 3.5% efficient organic solar cells*, Thin Solid Films **517**, 5900 (2009)
- [F1.2:6] B. Schmidt-Hansberg, H. Do, A. Colsmann, U. Lemmer, and W. Schabel, *Drying of thin film polymer solar cells*, Eur. Phys. J. Special Topics **166**, 49 (2009)
- [F1.2:7] \* B. Schmidt-Hansberg, M.F.G. Klein, K. Peters, F. Buss, J. Pfeifer, S. Walheim, A. Colsmann, U. Lemmer, P. Scharfer, and W. Schabel, *In situ monitoring the drying kinetics of knife coated polymer-fullerene films for organic solar cells*, J. Appl. Phys. **106**, 124501 (2009)
- [F1.2:8] ‡ R. Steim, S.A. Choulis, P. Schilinsky, U. Lemmer, and C.J. Brabec, *Formation and Impact of Hot-Spots on the Performance of Organic Photovoltaic Cells*, Appl. Phys. Lett. **94**, 043304 (2009)
- [F1.2:9] F. Nickel, A. Puetz, M. Reinhard, H. Do, C. Kayser, A. Colsmann, and U. Lemmer, *Cathodes Comprising Highly Conductive Poly(3,4-Ethylenedioxythiophene):Poly(Styrenesulfonate) for Semi-Transparent Polymer Solar Cells*, Organic Electronics **11**, 535 (2010)
- [F1.2:10] S. Kettlitz, S. Valouch, and U. Lemmer, *Organic solar cell degradation probed by the nanosecond photoresponse*, Appl. Phys. A **99**, 805 (2010)
- [F1.2:11] S. Züfle, N. Christ, S.W. Kettlitz, S. Valouch, and U. Lemmer, *Influence of temperature-dependent mobilities on the nanosecond response of organic solar cells and photodetectors*, Appl. Phys. Lett. **97**, 063306 (2010)
- [F1.2:12] \* A. Puetz, T. Stubhan, M. Reinhard, O. Loesch, E. Hammarberg, S. Wolf, C. Feldmann, H. Kalt, A. Colsmann, and U. Lemmer, *Organic solar cells incorporating buffer layers from indium doped zinc oxide nanoparticles*, Sol. En. Mat. Sol. Cells **95**, 579 (2011)
- [F1.2:13] \* M. Pfaff, E. Müller, M.F.G. Klein, A. Colsmann, U. Lemmer, V. Krzyzanek, R. Reichelt, and D. Gerthsen, *Low-energy electron scattering in carbon-based materials analyzed by scanning transmission electron microscopy and its application to sample thickness determination*, J. Microscopy **243**, 31 (2011)
- [F1.2:14] \* M. Reinhard, J. Hanisch, Z.-H. Zhang, E. Ahlswede, A. Colsmann, and U. Lemmer, *Inverted organic solar cells comprising a solution-processed cesium fluoride interlayer*, Appl. Phys. Lett. **98**, 053303 (2011)
- [F1.2:15] \* B. Schmidt-Hansberg, M. Baunach, J. Krenn, S. Walheim, U. Lemmer, P. Scharfer, and W. Schabel, *Spatially resolved drying kinetics of multi-component*

*solution cast films for organic electronics*, Chemical and Process Engineering **50**, 509 (2011)

- [F1.2:16] \* M.F.G. Klein, E. Müller, M. Pfaff, J. Czolk, M. Reinhard, S. Valouch, U. Lemmer, A. Colsmann, and D. Gerthsen, *Poly(3-hexylselenophene) solar cells: Correlating the optoelectronic device performance and nanomorphology imaged by low-energy scanning transmission electron microscopy*, J. Polymer Sci. B: Polymer Phys. (2011), DOI: 10.1002/polb.22394
- [F1.2:17] A. Colsmann, A. Puetz, A. Bauer, J. Hanisch, E. Ahlswede, and U. Lemmer, *Efficient semi-transparent organic solar cells with good transparency color perception and rendering properties*, Adv. Energy Mat. **1**, 599 (2011)
- [F1.2:18] ‡ M. Sanyal, B. Schmidt-Hansberg, M.F.G. Klein, A. Colsmann, C. Munuera, A. Vorobiev, U. Lemmer, W. Schabel, H. Dosch, and E. Barrena, *In-situ x-ray study of drying temperature influence on the structural evolution of bulk heterojunction polymer-fullerene solar cells processed by doctor-blading*, Adv. Energy Mat. **1**, 363 (2011).
- [F1.2:19] ‡ M. Sanyal, B. Schmidt-Hansberg, M.F.G. Klein, C. Munuera, A. Vorobiev, A. Colsmann, U. Lemmer, W. Schabel, H. Dosch, and E. Barrena, *Effect of Photovoltaic Polymer/Fullerene Blend Composition Ratio on Microstructure Evolution during Film Solidification Investigated in Real Time by X-ray Diffraction*, Macromolecules **44**, 3795 (2011)
- [F1.2:20] N. Christ, S.W. Kettlitz, S. Züfle, S. Valouch, and U. Lemmer, *Nanosecond response of organic solar cells and photodiodes: Role of trap states*, Phys. Rev. B **83**, 195211 (2011)
- [F1.2:21] ‡ J. Yu, K. H. Lee, Y. Zhang, M.F.G. Klein, A. Colsmann, U. Lemmer, P.L. Burn, S.-C. Lo, and P. Meredith, *A dendronised polymer for bulk heterojunction solar cells*, Polym. Chem. **2**, 266 (2011)
- [F1.2:22] ‡ F.M. Pasker, M.F.G. Klein, M. Sanyal, E. Barrena, U. Lemmer, A. Colsmann, and S. Höger, *Photovoltaic Response to Structural Modifications on a Series of Conjugated Polymers Based on 2-Aryl-2H-benzotriazoles*, J. Polymer Sci. A: Polymer Chem. **49**, 5001 (2011)
- [F1.2:23] ‡ \* B. Schmidt-Hansberg, M. Sanyal, M. Klein, M. Pfaff, N. Schnabel, S. Jaiser, Stefan, A. Vorobiev, E. Müller, A. Colsmann, P. Scharfer, D. Gerthsen, U. Lemmer, E. Barrena, and W. Schabel, *Moving through the phase diagram: morphology formation in solution cast polymer-fullerene-blend films for organic solar cells*, ACS Nano **5**, 8579 (2011)
- [F1.2:24] ‡ B. Schmidt-Hansberg, M. Sanyal, N. Grossiord, Y. Galagan, M. Baunach, M. F.G. Klein, A. Colsmann, P. Scharfer, Uli Lemmer, H. Dosch, J. Michels, E. Barrena, and W. Schabel, *Investigation of non-halogenated solvent mixtures for high throughput fabrication of polymer-fullerene solar cells*, Sol. En. Mat. Sol. Cells **96** 195 (2011)
- [F1.2:25] \* A. Colsmann, M. Reinhard, T.-H. Kwon, C. Kayser, F. Nickel, U. Lemmer, Noel Clark, J. Jasieniak, A. Holmes, and D. Jones, *Inverted semi-transparent organic solar cells with spray coated, surfactant free polymer top-electrodes*, Sol. En. Mat. Sol. Cells (2011), DOI:10.1016/j.solmat.2011.10.016 (2011)
- [F1.2:26] ‡ J.D. Yuen, R. Kumar, J. Seifert, S. Valouch, D. Zakhidov, D. Moses, U. Lemmer, A.J. Heeger, and F. Wudl, *Observations of PDDTT Subject to Thermal Treatment: Correlation between Performance and Order*, J. Am. Chem. Soc. **133**, 19602 (2011)

### F1.3 ,Nanoscale Transparent Conductive Oxides‘ (C. Feldmann)

- [F1.3:1] E. Hammarberg, A. Prodi-Schwab, and C. Feldmann, *Microwave-assisted Synthesis of  $In_2O_3:Sn$  (ITO) Nanocrystals in Polyol Media and Transparent, Conductive Layers thereof*, *Thin Solid Films* **516**, 7437 (2008)
- [F1.3:2] E. Hammarberg, Anna Prodi-Schwab, and C. Feldmann, *Microwave-assisted Polyol Synthesis of Aluminium- and Indium-doped ZnO Nanocrystals*, *J. Colloid Interface Sci.* **334**, 29 (2009)
- [F1.3:3] A. Luz and C. Feldmann, *Reversible Photochromatic Effect and Electrochemical Voltage driven by Light-induced  $Bi^0$ -Formation*, *J. Mater. Chem.* **19**, 8107 (2009)
- [F1.3:4] H. Goesmann and C. Feldmann, *Nanoparticulate Functional Materials (Review)*, *Angew. Chem. Int. Ed.* **49**, 1362 (2010)
- [F1.3:5] \* A. Puetz, T. Stubhan, M. Reinhard, O. Loesch, E. Hammarberg, S. Wolf, C. Feldmann, H. Kalt, A. Colsmann, and U. Lemmer, *Organic Solar Cells incorporating Buffer Layers from Indium-doped Zinc Oxide Nanoparticles*, *Sol. En. Mater. Sol. Cells* **95**, 579 (2010)
- [F1.3:6] Y.S. Avadhut, J. Weber, E. Hammarberg, C. Feldmann, I. Schellenberg, R. Pöttgen, and J. Schmedt auf der Günne, *Study of the Defect Structure of  $SnO_2:F$  Nanoparticles by High-Resolution Solid State NMR*, *Chem. Mater.* **23**, 1526 (2010)
- [F1.3:7] J. Ungelenk and C. Feldmann, *Nanoscaled Tin Tungstate – A highly efficient Photocatalyst for Daylight-driven Degradation of Organic Dyes and Its quick and easy Synthesis*, *Appl. Catal. B* **102**, 515 (2010)
- [F1.3:8] P. Schmitt, N. Brem, S. Schunk, and C. Feldmann, *Polyol-mediated Synthesis of Nanoscale Molybdates/Tungstates and Its Properties: Color, Luminescence, Catalysis*, *Adv. Funct. Mater.* **21**, 3037 (2011)
- [F1.3:9] C. Kind and C. Feldmann, *One-pot Synthesis  $In^0$  Nanoparticles with Tuned Particle Size and High Oxidation Stability*, *Chem. Mater.* **23**, 4982 (2011)
- [F1.3:10] \* C. Kind, C. Feldmann, A. Quintilla, and E. Ahlswede, *Citrate-capped  $Cu_{11}In_9$  Nanoparticles and Its Use for Thin-film Manufacturing of CIS Solar Cells*, *Chem. Mater.* **23**, 5269 (2011)
- [F1.3:11] H. Dong and C. Feldmann, *Porous ZnO Platelets via controlled thermal Decomposition of Zinc Glycerolate*, *J. Alloys Comp.* **513**, 125 (2012)
- [F1.3:12] C. Kind and C. Feldmann, *Easy access to  $Cu^0$  nanoparticles and porous copper electrodes with high oxidation stability and high conductivity*, *J. Mater. Chem.* DOI: 10.1039/C1JM12779A (2012)