MRS/E-MRS Joint Chapter of Hasselt University, Institute for Materials Research (IMO-IMOMEC), Belgium

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2019 Mini Symposium Series: Photovoltaics II

Wednesday 14th August 2019 at 14.00h
Room 'Zon', Energyville I, Thor Campus, Genk

High-efficiency perovskite solar cells: From fundamental approaches to evaporated upscaling

Program

14.00h-14.45h	Prof. dr. Annalisa Bruno, Nanyang University (Singapore)
15.00h-15.45h	Dr. Martin Stolterfohlt, Potsdam University (Germany)
16.00h-17.00h	Closing reception

MRS MATERIALS RESEARCH SOCIETY E-MRS

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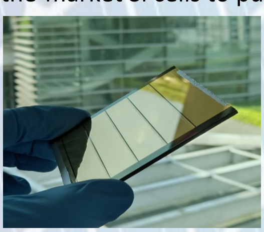
Towards large area metal halide perovskite based solar cells

Dr. Annalisa Bruno
Energy Research Institute, Nanyang Technological University, Singapore

Biography Annalisa Bruno received her B.S., M.S. and Ph.D. Degrees in Physics and Applied Physics from University of Naples Federico II, Italy, where she also worked as a post doc in the Chemical Engineering Department. After, she joined the Chemistry Department of Imperial College London as a Post Doctoral Research Associate, In 2011 Annalisa become Senior Staff Scientist at Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) and hold and then as Long Term Visiting Staff position in Imperial College for few more years. Since 2014 she is also a Senior Scientist at the Energy Research Institute at Nanyang Technological University (ERI@N). During her scientific career she has also been visiting researcher at Lund University, Lawrence Berkeley National Laboratory and Strathclyde University Glasgow, UK. Her research interests range from hybrid halide perovskite optical and electrical proprieties to their implementation in solar cells and tandem devices.

Abstract Metal-halide perovskites are one of the most promising active materials for photovoltaic and light-emitting technologies, due to their excellent optoelectronics properties and fabrication versatility. For perovskite solar cells (SCs), despite their astonishing improvements in terms of efficiency and stability, the scalability and reproducibility remain the major challenges to be tackled before their possible introduction to the existing photovoltaic market. In this talk, I will present an overview of the most promising current research directions at Energy Research Institute @NTU (ERI@N) on metal halide perovskite for PV and light emitting applications. The activities range from fundamental research to device development and implementation in line with the market needs. Fundamental studies focus on understanding optical and charge transport properties in novel halide perovskite materials and new strategies to improve their stability in devices. On the other hand, current technological challenges include the development of tandem solar cells which couple the perovskites with state-of-the-market Si cells to push the efficiency beyond the Shockley-Queisser limit (>30%) and the scale-up towards large area SCs.



I will also present our recent results in high efficient, large area, planar solar cells with prepared by thermal evaporation. The co-evaporated perovskite thin films are of high quality, pinhole-free and highly uniform, as demonstrated by the high reproducibility, low surface roughness and the long carrier lifetime. Furthermore the uniformity of the coated perovskite film allows us to demonstrate the first mini-modules with active area larger than 20 cm^2 with efficiency exceeding 18%. Our work represent an important step towards the development of high quality and reproducible large area thin films, the main requirements the commercialization of the technology.

Selected Publications

[1] N Yantara, A Bruno*, A Iqbal, N FJamaludin, C Soci, S Mhaisalkar, N Mathews Designing efficient energy funneling kinetics in Ruddlesden-Popper perovskites for high performance light emitting diodes, Adv. Mater. 2018, 30, 1800818.
[2] XY Chin, A Perumal, A Bruno, N Yantara, S Veldhuis, L Martinez-Sarti, B. Chandran, V. S. Chirvony, S-Z A. Lo, J. So, C. Soci, M. Grätzel, H.J. Bolink, N. Mathews, S. Mhaisalkar, Self-assembled Hierarchical Nanostructured Perovskites Enable Highly Efficient LEDs via Energy Cascade, Energy & Environmental Science, DOI:10.1039/C8EE00293B (2018).
[3] A. Bruno*, D.Cortecchia, X.Y. Chin, K. Fu, P. P. Boix, S. Mhaisalkar, C. Soci, MAPbI3 Photovoltaic Cells down to cryogenic temperatures, Adv. Energy Materials (2017) Adv. Energy Mater. 7, 1700265(2017).
[4] XY Chin, D Cortecchia, J Yin, A Bruno, C Soci, Lead iodide perovskite light-emitting field-effect transistor, Nat.Comm. 6, Article number: 7383, (2015).
[5] I. Neogi+, A. Bruno+*, D. Bahulayan, T. W. Goh, B. Ghosh, R. Ganguly, D. Cortecchia, T. C. Sum, C. Soci, N. Mathews, S. G. Mhaisalkar, Broadband Emitting 2D-Hybrid Organic Inorganic Perovskite Based on Cyclohexane-bis (methylamonium) Cation, ChemSusChem 10,3765 , (2017).
[6] MD Birowosuto, D Cortecchia, W Drozdowski, K Brylew, W Lachmanski, A Bruno, C Soci, X-ray Scintillation in Lead Halide Perovskite Crystals, Scientific Report, 6, (2016).

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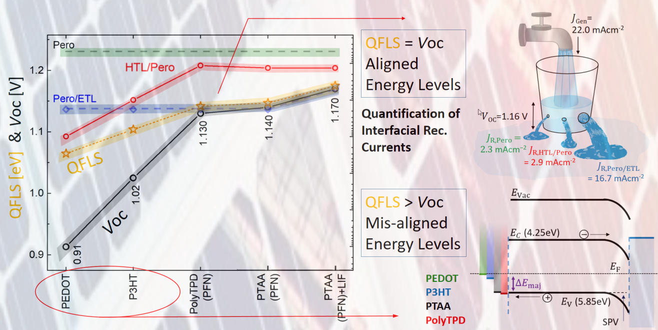
The impact of energy alignment and interfacial recombination on the internal and external open-circuit voltage of perovskite solar cells

Dr. Martin Stolterfohlt
Institute of Physics and Astronomy, University Potsdam, Germany

Biography Martin Stolterfoht is a Habilitand and postdoctoral researcher in the Soft Matter Physics group at the University of Potsdam, Germany. He completed his master degree in physics at the University of Graz in 2012 and obtained his Ph.D. at the University of Queensland Australia in 2016 before moving to Potsdam. His research is focused on providing a fundamental description of thin film solar cell operation and charge recombination processes from picoseconds to steady-state through electro-optical measurements and numerical modeling. He also aims at improving perovskite single and multijunction solar cells through identification and suppression of recombination losses.

Abstract As perovskite solar cells continue to improve at a rapid pace, more fundamental insights into the remaining open-circuit voltage (V_{OC}) losses are required in order to unlock power conversion efficiencies (PCEs) of ~30%. Several studies highlight that the perovskite absorber exhibits an opto-electronic quality that is comparable to GaAs in terms of external fluorescence, therefore potentially allowing PCEs close to the radiative limits. However, the high internal potential in the absorber layer can often not be directly translated into an equal potential at the metal electrodes. Here, we reveal the reasons for the discrepancy by decoupling the main V_{OC} losses in the bulk, perovskite/charge transport layer (CTL) interfaces and/or metal contacts using photoluminescence measurements [1]. The study comprises different perovskite compositions and several, commonly used CTLs including high efficiency devices (21.4 %). Undoubtedly, by introducing additional recombination centres at the interfaces, the CTLs have the most striking impact on the device V_{OC}. Interestingly, the *VOC* equals the internal quasi-Fermi level splitting (QFLS) only in high efficiency cells while in poor performing devices, the *VOC* is substantially lower than the internal QFLS. Using ultraviolet photoelectron spectroscopy (UPS) and differential charging capacitance experiments, we show that this is due to an energy level mis-alignment at the *p*-interface. The findings are corroborated by rigorous device simulations which outline important considerations to maximize the *VOC*. We conclude that energy level matching is of primary importance to achieve the implied V_{OC} of the perovskite/CTL stack, followed by suppression of defect recombination at the interfaces and in the absorber layer.



Selected Publications

[1] Stolterfoht, M., Caprioglio, P., Wolff, C. M., Márquez Prieto, J. A., Nordmann, J., Zhang, S., Rothhardt, D., Hörmann, U., Amir, Y., Redinger, A., Kegelmann, L., Zu, F., Albrecht, S., Koch, N., Kirchartz, T., Saliba, M., Unold, T. & Neher, D. The impact of energy alignment and interfacial recombination on the open-circuit voltage of perovskite solar cells. *Energy Environ. Sci.* (2019). doi:10.1039/C9EE02020A

[2] Zhang, S., Hosseini, S. M., Gunder, R., Petsiuk, A., Caprioglio, P., Wolff, C. M., Shoaee, S., Meredith, P., Schorr, S., Unold, T., Burn, P. L., Neher, D. & Stolterfoht, M. The Role of Bulk and Interface Recombination in High-Efficiency Low-Dimensional Perovskite Solar Cells. *Adv. Mater.* 1901090 (2019). doi:10.1002/adma.201901090

[3] Würfel, U., Perdigón-Toro, L., Kurpiers, J., Wolff, C. M., Caprioglio, P., Rech, J. J., Zhu, J., Zhan, X., You, W., Shoaee, S., Neher, D. & Stolterfoht, M. Recombination between Photogenerated and Electrode-Induced Charges Dominates the Fill Factor Losses in Optimized Organic Solar Cells. *J. Phys. Chem. Lett.* 10, 3473–3480 (2019).

[4] Caprioglio, P., Stolterfoht, M., Wolff, C. M., Unold, T., Rech, B., Albrecht, S. & Neher, D. On the Relation between the Open Circuit Voltage and quasi-Fermi Level Splitting in Efficient Perovskite Solar Cells. *Adv. Energy Mater.* (2019). doi:aenm.201901631R1

[5] Stolterfoht, M., Wolff, C. M., Márquez, J. A., Zhang, S., Hages, C. J., Rothhardt, D., Albrecht, S., Burn, P. L., Meredith, P., Unold, T. & Neher, D. Visualization and suppression of interfacial recombination for high-efficiency large-area pin perovskite solar cells. *Nat. Energy* 3, 847–854 (2018).