

Newsletter

First Semester 2015



Kestcells: Introduction

Kestcells (FP7-MC-ITN GA 316488) is an FP7-Marie Curie funded project with a total budget of 3.7M €, that has the objective of creating an Initial Training Network for the structured interdisciplinary training of researchers in advanced thin film photovoltaic (PV) technologies.

Scientifically the first 30 months the project has allowed a significant scientific progress gaining a deeper understanding of the fundamental properties of kesterites. In particular, new insights in the fundamental properties of the materials have been obtained including order-disorder effects, cationic distribution and its relation with compositional parameters, the development of a phonon confinement model for the evaluation of layers quality and the determination of fundamental optical parameters. Additionally, new processes especially suited for the synthesis of these materials have been developed, including physical vapor deposition methods (reactive sputtering, co-evaporation, sequential processes) and chemical routes (spray pyrolysis and doctor blade). Besides, the optimization of kesterite based p-n junction, the development of light scattering based methods suitable for processes control and the presentation of a theoretical model for the analysis of kesterite devices have been successfully attained. With the know-how developed so far in the consortium, devices with efficiencies higher than 10% have been achieved by some partners.

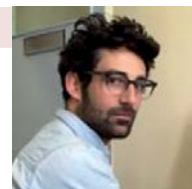
In parallel, the project has paved the way to an intense campaign of dissemination and outreach activities to share with the society the results of this field of research. Regarding outreach activities, the project has developed an eye-catching project website which has received by the end of February 2015 more than 60,000 visits; a high impact press campaign with publications in more than 40 general media; a brochure with the main scientific contributions of the project participants, which is regularly distributed in scientific congress and workshops. Moreover, the dissemination activities completed so far include 63 contributions at international conferences, and 11 papers published in peer-reviewed journals.

Coordinated by:

As part of these outreach activities during the months of November and December the Consortium has organized an International Open Day, with the main objective to raise awareness of the research in thin films photovoltaic technologies. The event has been led by Early Stage Researchers (ESR) as a key task of their multidisciplinary training within KESTCELLS. This initiative has been participated by six prestigious research centres around Europe and it was specially designed to provide a general overview of the work carried out in research centers to young and undergraduate students, encouraging a new generation of Europeans to develop an active scientific career.

ESR 2.1 Jose Marquez Prieto – PhD student at Northumbria University

Jose studied Chemistry at the University of Sevilla where he specialised in Chemical Engineering. In the frame of the Erasmus program, he studied one year in Erlangen, Germany, working in developing anodization processes of aluminium for commercial purposes. After finishing his Degree, he undertook an internship in Abengoa Solar NT, during which he became interested in solar energy. At Abengoa, he worked in the Thin Film group of the Soland R&D Centre. In this internship, he was directly involved in projects related to CIGS technology which were coordinated by Abengoa, in collaboration with the Institute of Materials Science of Seville and the University of Zaragoza, where he was developing chemical bath deposition processes for CdS and Zn(O,S) buffer layers. Currently, he is developing his PhD under supervision of Dr Ian Forbes at Northumbria University. The main topic of his PhD is the development of sputtering techniques for the CZT(S,Se) absorber for Thin Film Solar Cells. The main activities during the PhD have been focused in developing the growth processes of CZTSe by sputtering and post-reactive annealing in Se atmosphere. He has deeply studied the influence of composition in the physical, structural and chemical properties of CZTSe as well as its influence in the optoelectronic properties of pure selenide kesterite solar cells. After optimisation of composition and growth conditions of the absorber, the current solar cells processed achieved efficiencies over 8%.



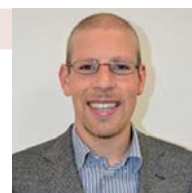
ERS 3.1 Tetiana Olar – PhD student at Helmholtz-Zentrum Berlin

A joint Master in Nanoscience was received at University of Basque Country, Spain and at Taras Shevchenko National University of Kyiv, Ukraine. The multidisciplinary training was given in physics, chemistry, engineering and complementary subjects. The thesis was focused on glass transition phenomena in polystyrene thin films tackled by fast calorimetry. The individual research project “Implementation of solar cells” of WP3 has the goal to examine junction formations on CTZS absorbers for CZTS based heterojunctions. Secondly, the development of adapted buffer layers and transparent conductive oxides are objectives, including the investigation of surface and interface properties and assessment of current transport. In order to reach the mentioned aims systematic combinations of absorbers with different buffer materials will be investigated on the basis of theoretical considerations. Photoelectron spectroscopy is the main tool to determine the band-line-up and to characterize interfaces of each combination of window-buffer-absorber-back contact layers. Taking into account the obtained results, the systematic surface and interface modification will be performed to improve the band-line-up. And of course, analysis of CTZS(Se)/buffer interface properties should be taken into account.



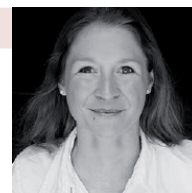
ESR 3.2-Stephan Haass – PhD student at EMPA

Stefan studied physics (Diplom) at the Karlsruhe Institute of Technology and during his 12 month diploma thesis investigated the surface and grain boundary properties of CIGS in collaboration with ZSW, Stuttgart. Afterwards he worked at ULVAC, Japan 6 months on the development of thin film deposition equipment for solar cell fabrication. Since August 2013 Stefan is a PhD student at Empa, Switzerland and early-stage researcher in the KESTCELLS project. His task is the development of optimal kesterite based heterojunction solar cells, including finding suitable back contact materials, optimization of the absorber layer as well as interfaces and alternative buffer layers. Therefore many advanced skills in the field of thin film deposition and characterizations have been developed, which helped him to produce a kesterite solar cell with an efficiency of 11.2% using a solution approach.



ESR 4.1 Lisa Risch – PhD student at NEXCIS

She obtained her Master degree in Physics from the Freie Universität Berlin in 2013. Within the framework of the Erasmus students exchange program she spent one year in Granada, Spain during her studies. Thanks to the collaboration between the Freie Universität and the Helmholtz-Zentrum Berlin she was offered the opportunity to carry out her Bachelor thesis in the group of Solar Energy Research at the Helmholtz Zentrum. She continued working at the Helmholtz Zentrum as students research assistant and then decided to undertake her Master's thesis there. The Master thesis' central topic was the characterization of TCO/CuInSe₂-interfaces under the influence of high deposition temperatures. This implied surface analysis and depth profiling using different X-ray spectroscopy methods, partly undertaken at the electron storage ring BESSY-II. Within the KESTCELLS project, her tasks are the characterization of kesterite solar cells and the identification of suitable methods for quality control in industrial fabrication processes. So far, she has mainly focused on Photoluminescence and Raman Spectroscopy, two techniques that are particularly suitable for fast and non-destructive quality assessment.



ESR 4.2 Stephan van Duren – PhD student at Helmholtz-Zentrum Berlin

At Utrecht University he received a bachelor degree in Physics. He gained interest in renewable energies and decided to obtain a Master in Energy Science. During this education he gained knowledge about the physical and chemical background of a wide range of renewable energies. His main interest became photovoltaics. In this field, he performed his master research and studied plasmonic effects in metal nanostructured solar cells. Currently, he participates in the Kestcells project and his main topic of his PhD is focused on development of optical techniques for in-situ process control and monitoring. He analysed and worked with different (vacuum) techniques for absorber fabrication. Analysis included the impact of process parameters, such as temperature, on compositional and morphological absorber homogeneity. Reflectometry as a tool for in-situ phase identification/evolution was studied. For this purpose an optical setup was designed and built. Secondary phases and absorbers with different composition were studied in- and ex-situ at different temperatures. This was supplemented with compositional, structural and morphological analysis and simulations of reflection spectra. Further in-situ studies of different secondary phases and CZTS absorbers are currently investigated with Raman spectroscopy.



ER 6.1 Rémi Aninat – Abengoa Solar New Technologies

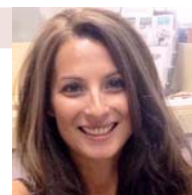
His background education is in physics, he obtained in 2008 a Masters degree in “Engineering of micro- and nano-technologies” from the University Joseph Fourier in Grenoble (France), completed in 2012 a PhD thesis in photovoltaics in the Northumbria University (Newcastle Upon Tyne, UK) entitled “ Study of Cu(In,Al)Se₂ thin films prepared by selenisation of sputtered metallic precursors for applications in solar cells”, followed by a postdoc in the CRP Gabriel Lippmann (Luxembourg) focusing on reactive sputtering and characterisation of titanium nitride-based hard coatings for machining applications. He joined the Kestcells project in September 2014, within the company Abengoa, based in Seville, Spain. The main objective of his project is to carry out a feasibility study on the industrial scale up and transferability of the fabrication by physical vapour deposition (PVD) of kesterite-based thin film solar cells. In a first stage, assisted by the tools of Failure Mode Effect Analysis (FMEA), he will assess the most promising fabrication routes for scale up, the principal failures that typically occur in state-of-the-art kesterite absorber layers and their impact on the scalability.





ER 6.2 Mariana Amuntencei – NEXCIS

Mariana is an electrochemist with an extended experience in laboratory, R&D and manufacturing environments. Her professional experience is mainly related to metal electro-deposition as well as metal recycling from industrial chemistries. Her technical interest is orientated towards improvement of industrial processes in microelectronics and solar fields.



She holds a PhD in materials science that she obtained from Paris VI University. Her PhD work was focused on copper deposition into complex nanoscale interconnections features on resistive 300 mm diameters silicon wafers for microelectronics application. This work was part of collaboration between CEA-Leti and ST Microelectronics (France). She then developed new complex materials as precursor for positive electrode of Li-ion batteries in the framework of collaboration between Renault and CEA-Liten in Grenoble (France).

In 2012, she joined Areva Solar (USA) for nickel alloy electrodeposition process improvement in the high volume manufacturing of concentrated solar power generators.

Within the KESTCELLS project (NEXCIS, in France), she is in charge of developing and implementing industrial waste management methods required for an environmentally friendly manufacturing process.

Training

In the Frame of the project a series of Seminars will be given by each partner, specially designed for each researcher. These seminars are open to all members of the local institutions as well as to all the members of the Network. In addition the Network will organize five thematic workshops where the researcher will discuss his research and the advances of their theses. Herewith you will find the training program of the years 2014-2015

February 2014

- Effect of Na on CIGSe thin films and devices. Flexible solar cells. Possible extrapolation to $\text{Cu}_2\text{ZnSn}(\text{S},\text{Se})_4$ Universidad Autonoma Madrid (UAM)

March 2014

- Spectroscopic Ellipsometry: applications for thin film solar cells. Aix Marseille Université (AMU)
- Electrical Characterisation of Interfaces. Northumbria University.
- Raman spectroscopy: practical approach. Institut Recerca Energia de Catalunya (IREC)

May 2014

- Photo Electron Spectroscopy. Helmholtz-Zentrum Berlin (HZB)
- Ion matter interaction and ion beam analysis. Universidad Autonoma Madrid (UAM)

June 2014

- Growth and characterization of $\text{Cu}_2\text{Zn}(\text{Sn},\text{Ge},\text{Si})(\text{S},\text{Se})_4$. Universidad Autonoma Madrid (UAM)
- Supramolecular Photochemistry: from basic concepts to energy conversion. Aix Marseille Université (AMU)
- Luminescence Techniques for Solar Cells Characterization. NEXCIS

July 2014

- State of the art in Kesterites. Institut Recerca Energia de Catalunya (IREC)
- Advanced characterization of chalcogenide thin film solar cells. Eidgenössische Materialprüfungs- und Forschungsanstalt (EMPA)
- Black Silicon Photovoltaics. Aix Marseille Université (AMU)



December 2014

- X-ray absorption spectroscopy and its application to chalcopyrite and kesterite materials. Freie Universität Berlin (FUB).
- Management of European Projects. Institut Recerca Energia de Catalunya (IREC)
- Time-resolved photoluminescence spectroscopy of thin film solar cells. Eidgenössische Materialprüfungs- und Forschungsanstalt (EMPA)
- Low-cost approaches for CZTS solar cell manufacturing. NEXCIS

January 2015

- Clues towards identifying limits and improving kesterite solar cells. NEXCIS.

February 2015

- Laser applications for photovoltaics. Institut Recerca Energia de Catalunya (IREC)
- Characterization techniques for chalcogenide thin film solar cells. Institut Recerca Energia de Catalunya (IREC)
- “Zn-based alternative buffer layers – a challenge worthwhile?”. Eidgenössische Materialprüfungs- und Forschungsanstalt (EMPA)

March 2015

- Dye sensitized solar cells. Institut Recerca Energia de Catalunya (IREC)
- Perovskite solar cells. Institut Recerca Energia de Catalunya (IREC)

News

The Project co-organized along with the project INDUCIS (FP7-MC-IAPP-GA-285897) the workshop “Thin film future technologies: What beyond 2020? New scenarios for industry-academia interactions” in the frame of the IXth Barcelona Energy Challenges Conference.

Kestcells will participate in the 2nd Nanotechnology for the Next Generation High Efficiency Photovoltaics Spring International School & Workshop. The main aim is to review the state of the art and existing challenges related to the implementation of new nanotechnology based concepts for solving the main problems in the development of cost efficient and sustainable PV. The workshop will analyse and highlight the potential of these new nanotechnology concepts for successful industrial implementation into new competitive PV technologies for the EU industry. Kestcells is organizing the session on earth abundant materials for photovoltaics, where Prof. Susanne Siebentritt (University of Luxembourg) and Dr. Teodor K. Todorov (IBM) will give key note talks reviewing the last advancements in this field and the future challenges.

Papers

- H. Xie, Y.Sánchez, S. López-Marino, M. Espíndola-Rodríguez, J. López-García, M. Neuschitzer, D. Sylla, A. Fairbrother, A. Pérez-Rodríguez and E. Saucedo. Impact of Sn(S,Se) secondary phases in Cu₂ZnSn(S,Se)₄ solar cells: a chemical route for their selective removal and absorber surface passivation, ACS-Applied Surfaces and Interfaces, DOI:10.1021/am502609c.
- S. Lopez-Marino, M. Neuschitzer, Y. Sánchez, A. Fairbrother, M. Espíndola-Rodríguez, J. López-García, M. Placidi, L. Calvo-Barrio, A. Pérez-Rodríguez and E. Saucedo. Earth-abundant absorber based solar cells onto low weight stainless steel substrate, Solar Energy Materials and Solar Cells, DOI:10.1016/j.solmat.2014.07.030.
- M. Dimitrievska, H. Xie, A. Fairbrother, X. Fontané, G. Gurieva, E. Saucedo, A.o Pérez-Rodríguez, S. Schorr and V. Izquierdo-Roca. Multiwavelength excitation Raman scattering of Cu₂ZnSn(S_xSe_{1-x})₄ (0 ≤ x ≤ 1) polycrystalline thin films: Vibrational properties of sulfoselenide solid solutions, Applied Physics Letters, DOI:10.1063/1.4891333.



- A. Fairbrother, L. Fourdrinier, X. Fontané, V. Izquierdo-Roca, M. Dimitrievska, F. Maseri, A. Pérez-Rodríguez and E. Saucedo. Precursor Stack Ordering Effects in Cu₂ZnSnSe₄ Thin Films Prepared by Rapid Thermal Processing, *Journal of Physical Chemistry C*, DOI:10.1021/jp503699r.
- G. Rey, A. Redinger, J. Sendler, T. P. Weiss, M. Thevenin, M. Guennou, B. El Adib, and S. Siebentritt. The band gap of Cu₂ZnSnSe₄: effect of order-disorder, *Applied Physics Letters*, DOI:10.1063/1.4896315.
- Y. Ren, J. J. Scragg, T. Ericson, T. Kubart and C. Platzer-Björkman. Reactively sputtered films in the CuxS-ZnS-SnSy system: from metastability to equilibrium, *Thin Solid Films*.
- J. Márquez-Prieto and I. Forbes. Evolution of phases in two-stage vacuum processed thin film Cu₂ZnSnSe₄ absorber layers, *Materials Research Innovations*, DOI:10.1179/1433075X14Y.0000000248.
- M. Dimitrievska, A. Fairbrother, A. Pérez-Rodríguez, E. Saucedo, V. Izquierdo-Roca, Raman scattering crystalline assessment of polycrystalline Cu₂ZnSnS₄ thin films for sustainable photovoltaic technologies: Phonon confinement model, *Acta Materialia*, Vol. 70, 15 May 2014, Pages 272-280, ISSN 1359-6454, <http://dx.doi.org/10.1016/j.actamat.2014.02.035>.
- M. Dimitrievska, A. Fairbrother, X. Fontané, T. Jawhari, V. Izquierdo-Roca, E. Saucedo, A. Pérez-Rodríguez, Multiwavelength excitation Raman scattering study of polycrystalline kesterite Cu₂ZnSnS₄ thin films, *Applied Physics Letters*, Vol. 104/Issue 2, 13 Jan 2014, <http://dx.doi.org/10.1063/1.4861593>
- R. Caballero, E. Garcia-Llamas, J.M. Merino, M. León, I. Babichuk, V. Dzhagan, V. Strelchuk, M. Valakh, Non-stoichiometry effect and disorder in Cu₂ZnSnS₄ thin films obtained by flash evaporation: Raman scattering investigation, *Acta Materialia*, Volume 65, 15 February 2014, Pages 412-417, ISSN 1359-6454, <http://dx.doi.org/10.1016/j.actamat.2013.11.010>.
- A. Redinger, R. Djemour, T. P. Weiss, J. Sendler and S. Siebentritt, Molecular beam epitaxy of Cu₂ZnSnSe₄ thin films grown on GaAs(001), *Proceeding of the Photovoltaic Specialists Conference (PVSC)*, 2013 IEEE 39th, 16-21 June 2013, Tampa, FL, USA, pp.0420 – 0425, DOI: 10.1109/PVSC.2013.6744181.
- M. Neuschitzer, Y. Sanchez, S. López-Marino, H. Xie, A. Fairbrother, M. Placidi, S. Haass, V. Izquierdo-Roca, A. Perez-Rodriguez and E. Saucedo, Optimization of CdS buffer layer for high-performance Cu₂ZnSnSe₄ solar cells and the effects of light soaking: elimination of crossover and red kink, *Progress in Photovoltaics Research and Applications*, 2015, DOI: 10.1002/pip.2589.
- J Márquez-Prieto,, Y Ren, RW Miles, N Pearsall, and I Forbes, The influence of precursor Cu content and two-stage processing conditions on the microstructure of Cu₂ZnSnSe₄, (In press) *Thin Solid Films* (2014)