Oral presentations for Session 1.4.1 | Thursday, 27 October | Room 3911

Session Chair:
Armin ABERLE (SERIS, Singapore)
Vinodh SHANMUGAM (SERIS, Singapore)

1.4.1a Invited Talk (16:00 – 16:15)
Prof Tom Markvart
University of Southampton, United Kingdom

Photon Management: from Planck To Solar Cells and Beyond

T. MARKVART[1]
[1] **University of Southampton, United Kingdom**

Abstract
The manipulation of light provides an attractive option to enhance the output of a solar cell. Optical concentration, antireflection coatings and textured surfaces with light trapping are just a few examples of technologies in routine use today. Recent advances in photonics and nanotechnology offer a range of additional tools that are being researched for application in the next generation of solar cells. Starting with a brief historical overview, we shall consider several concepts which are under discussion to improve the light capture at the nanoscale, including light injection into thin films by photon tunnelling, light harvesting energy transfer via the near-field dipole interaction, limitations to light trapping in subwavelength layers by diffraction, and the role of photon recycling in the operation of a solar cell.

Biography
Tom Markvart is Professor of Energy Conversion and the Director of the Solar Energy Laboratory at the University of Southampton. Since receiving his undergraduate and doctorate degrees in Mathematical Physics from the University of Birmingham, much of his research has focused on various aspects of photovoltaics, including solar cell degradation in space, stand-alone systems and utility integration issues as well as the fundamentals of photovoltaic conversion. Recent research at the Solar Energy Laboratory centres around theoretical and experimental work towards high-efficiency low-cost future generations of solar cells.

1.4.1b Invited Talk (16:15 – 16:30)
Dr Albert Polman
AMOLF, Netherlands

High-Efficiency Solar Cells by Nanophotonic Design

A. POLMAN[1]
[1] AMOLF, Netherlands

Abstract
We review the electrical characteristics of the record cells of the 16 widely studied photovoltaic materials geometries (efficiencies 10-29%) and compare these to the fundamental limits based on the Shockley-Queisser detailed-balance model. All geometries suffer from incomplete light management. We show how nanostructured dielectric and metallic metasurface and metamaterial architectures can help to control the coupling, trapping and conversion of light in solar cells. Prospects for practical application and large-area fabrication, for which achieving high efficiency is a key factor, are discussed for all materials. Ref.: A. Polman et al., Science 352, 207 (2016)

Biography
Albert Polman is scientific group leader at the FOM Institute AMOLF in Amsterdam, the Netherlands, where he heads the Program "Light management in new photovoltaic materials" and is professor of Photonic materials for photovoltaics at the University of Amsterdam. Polman's group has developed many novel generic concepts of light coupling, light trapping and current collection using nanostructured metasurfaces that can be applied to a broad range of solar cells. Polman has published >250 papers (>20.000 citations) and is co-recipient of the 2012 ENI Renewable Energy Prize.

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1.4.1c (16:30 – 16:45)
Dr Rudi Santbergen
Delft University of Technology, Netherlands

Minimizing Optical Losses In Flat Monolithic Perovskite/c-Si Tandem Solar Cells

R. SANTBERGEN[1], R. MISHIMA[2], T. MEGURO[2] et al.
[1] Delft University of Technology, Netherlands
[2] Kaneka Corporation, Japan

Abstract
In a monolithic perovskite/c-Si tandem device, the perovskite top cell is deposited directly onto the c-Si bottom cell. To avoid fabrication issues, the perovskite top cell has to be deposited onto a flat c-Si bottom cell, i.e. without front-side anti-reflective texture. As expected this leads to large reflection losses in the tandem device. In this work we use optical simulations to identify the origins of these reflection losses and present ways to reduce them systematically.

Biography
Rudi Santbergen studied Applied Physics at Eindhoven University of Technology and did his Ph.D. research at the department of Mechanical Engineering of the same university. There he worked on the topic of the photovoltaic/thermal (PVT) solar collector. As a part of this research he developed an optical model for light-trapping in solar cells. In 2008 he received his Ph.D. degree for his thesis 'Optical Absorption Factor of Solar Cells for PVT Systems'. In 2009 he joined the PVMD group at Delft University to work on improving the optical design of solar cells. Of special interest is the use of plasmonic metal nanostructures that are designed to confine light inside the solar cell. He is also developing advanced optical models for accurate and fast simulation of crystalline silicon and thin-film solar cells. In 2013 he spent 6 months at the Photovoltaic Research Laboratories of Kaneka Corporation in Japan.

1.4.1d (16:45 – 17:00)
Ms Bernice Mae Yu Jeco
The University of Tokyo, Japan

Spatial Distribution of Temperature Dependent luminescence coupling Current in InGaP/GaAs/Ge Triple Junction Solar Cells

B. M. YU JECO[1], T. SOGABE[2], Y. OKADA[1]
[1] The University of Tokyo, Japan
[2] The University of Electro-Communications, Japan

Abstract
In this study, we experimentally investigate the effect of temperature change on luminescence coupling (LC) in InGaP/GaAs/Ge triple junction solar cells. The LC effect between GaAs and Ge subcells was characterized using light I-V characteristics curve and laser beam induced current mapping method with temperatures between 18°C and 90°C. Results have shown notable variations of LC yield with varying temperature. As the temperature decreases, the LC effect at the Ge subcell degrades. Thus at low temperatures, this effect has higher contribution to the current mismatch reduction between GaAs and Ge subcells than at high temperatures.

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1.4.1e (17:00 – 17:15)
Mr Yusuke Shirayanagi
Japan Science and Technology Agency, Japan

Preparation of axial type wire-structure crystalline silicon solar cells

Y. SHIRAYANAGI[1], Y. Yashiki[1], S. KATO[2] et al.
[1] Japan Science and Technology Agency, Japan
[2] Nagoya institute of Technology, Japan

Abstract
An axial type micro-wire crystalline silicon solar cell structure has been studied. In this structure, a number of micro wires (Si-MW) were fabricated on a p-type Si wafer, and an n-layer was formed on the top of each Si-MW to make p-n junction. To form the Si-MW's, a deep reactive ion etcher based on the Bosch process was used. After that, the surface of Si-NW's were filled with Al1-xOx deposited by the ALD, and then the Al1-xOx on the n-layer was removed by the CMP to make electric contact. As a result, we obtain a conversion efficiency of 8.2% in the axial type wire-structure solar cell. We will also discuss the details of photovoltaics performances as compared with a radial type Si-MW solar cell in which the n-layer covers on the entire surface of the p-type Si-MW's.

Biography
He received master's degrees in engineering department from Tokyo Institute of Technology, Japan, in 2010. Since 2010, he has been a researcher at Advanced Technology Research and development, Mitsubishi Electric Corporation. Since 2014, he has also been a researcher at Japan Science and Technology, Japan.

1.4.1f (17:15 - 17:30)
Ms Claire Disney
University of New South Wales, Australia

Parasitic Absorption in Plasmonic Light Trapping Structures for Solar Cells: Do the Performance Benefits Outweigh the Losses?

C. DISNEY[1], S. PILLAI[1], M. GREEN[1]
[1] University of New South Wales, Australia

Abstract
Significant photocurrent enhancement is possible in photovoltaics by using light-trapping structures consisting of arrays of nanostructured metallic features at the cell's rear. These structures have conversely been identified as suffering heightened parasitic absorption into the metal at certain resonant wavelengths. Simulations were undertaken to explore the relationship between enhanced absorption into the solar cell, and parasitic losses in the metal. These simulations revealed that resonant wavelengths associated with high parasitic losses in the metal could also be associated with high absorption enhancement in the solar cell. The mechanisms linking these parasitic losses and absorption enhancements were identified, allowing for correct design to ensure that the light trapping structures will have a positive impact on the overall solar cell performance.

Biography
Claire is completing her PhD in plasmonic light trapping for solar cells at the Australian Centre for Advanced Photovoltaics, University of New South Wales

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1.4.1g (17:30 - 17:45)
Prof Martina Schmid
Helmholtz-Zentrum Berlin, Germany

Nano- and Microconcentration for the Next Generation of Chalcopyrite Solar Cells

M. SCHMID[1], D. SANCHO-MARTINEZ[1], T. KÖHLER[1] et al.
[1] Helmholtz-Zentrum Berlin, Germany

Abstract
Chalcopyrite solar cells have the potential of contributing a significant share to the photovoltaic market. Addressing the limited supply of indium, which will restrain production in the upper GW scale, we fabricate ultra-thin and micrometer-sized absorbers. Losses emerging from the reduction of absorber material are tackled by light concentration on the nano- and microscale. We present dielectric nanostructures giving rise to resonant and waveguiding modes and thus leading to localization of electromagnetic energy in ultra-thin absorber layers. Light concentration on a larger scale is followed in microconcentrator solar cells utilizing concentrator lenses to focus the incident radiation onto the restrained absorber area. For the two concepts first device results proving the enhancement potential are shown and remaining challenges addressed.

Biography
Martina Schmid holds a Diploma in Physics from the University of Augsburg and a PhD from the Freie Universität Berlin, Germany. After postdoctoral stays at the University of Ljubljana and the California Institute of Technology, she started a Helmholtz Young Investigator Group at the Helmholtz-Zentrum Berlin in 2012. Since 2013 she is a Junior Professor at the Freie Universität Berlin. Her research interests are photonics, plasmonics, photovoltaics and renewable energy devices with a special focus on nano- and micro-optical concepts for light guiding and concentration.

1.4.1h (17:45 - 18:00)
Dr Yasuyoshi Kurokawa
Nagoya University, Japan

Effect of Surface Morphology Randomness on Optical Properties of Si-based Photonic Nanostructures

Y. KUROKAWA[1], O. AONUMA[1], T. TAYAGAKI[2] et al.
[1] Nagoya University, Japan
[2] National Institute of Advanced Industrial Science and Technology (AIST), Japan

Abstract
We have fabricated a Si-based photonic nanostructure with submicron sizes using a maskless wet etching of Ge quantum dot (QD) multilayers, and it has been demonstrated that the photonic nanostructures result in the enhanced optical absorption in the near-infrared light owing to light trapping. In this study, optical properties for our fabricated Si-based photonic nanostructures with surface morphology randomness were calculated by the finite-difference time-domain (FDTD) method. As a result, as the degree of the randomness is increasing, the absorption in a near-infrared light range was enhanced, suggesting that the enhancement of optical absorption in the near-infrared light by our fabricated photonic nanostructures is due to the randomness of themselves.

Biography
[Education] Mar. 2009, Doctor of Engineering, Tokyo Institute of Technology, Japan [Professional Experience] Apr. 2015-, Lecturer, Graduate School of Engineering, Nagoya University, Japan Oct. 2011-, PRESTO Research Fellow, Japan Science and Technology Agency, Japan May 2010- Mar. 2015, Assistant professor, Department of Physical Electronics, Tokyo Institute of Technology, Japan [Awards] Nov. 2009, Best Paper Award, 19th International Photovoltaic Science and Engineering Conference, Jeju, Korea. Sep. 2009, Best Poster Award, 24th European Photovoltaic Solar Energy Conference, Hamburg, Germany. [Research Interests] Silicon based nanostructures for the application to photovoltaics, Silicon based thin film solar cells, Chalcopyrite based thin film solar cells