Oral presentations for Session 2.3.6 | Thursday, 27 October | Room 3810A / 3810B

Session Chair:
Olindo ISABELLA (Delft University Of Technology, Netherlands)

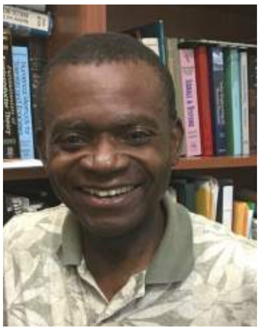
2.3.6a (16:00 – 16:15)
Prof Matthew Tan
CEC Energy Pte Ltd, Singapore

Elimination of LID with Innovative New Hydrogenation Technology Facilitates Increased PERC Cell Efficiencies Through the Use of Lower Resistivity p-Type Cz Wafers

M. TAN[1], S. WENHAM[2], C. CHONG[2]
[1] CEC Energy Pte Ltd, Singapore
[2] University of New South Wales (UNSW), Australia

Abstract
Light-induced degradation (LID) due to B-O defects has plagued p-type Cz wafers for decades, necessitating the use of higher resistivity wafers than optimal In PERC cells, the higher than optimal wafer resistivity leads to increased lateral resistive losses and more resistive rear point contacts. In this work, CEC Energy and UNSW exploit the use of atomic hydrogen to passivate defects, particularly B-O defects, within p-type Cz silicon solar cells. Innovative new technology has been developed to control the charge state of interstitial atomic hydrogen atoms within the silicon lattice, which in turn has facilitated improvements in both the diffusivity and reactivity of the hydrogen atoms. A new prototype industrial tool for the implementation of this technology has been developed and appears to have solved LID in p-type Cz wafers, now allowing more heavily and optimally doped wafers to be used in PERC cell manufacturing.

Biography
A/ Prof Matthew Tan is currently the CEO of CEC Energy Pte Ltd. CEC Energy is a tripartite partnership entity with Prof Stuart Wenham and A/ Prof Chong Chee Mun who are from the UNSW PV team. They have teamed up to fast track the latest solar energy related innovations from UNSW. A/Prof Tan brings a wealth of business and engineering related experience to CEC Energy as he was previously the CEO of an environmental engineering company (10 years) where he has been involved in the extensive implementation of engineering solutions in the region.



2.3.6b (16:15 – 16:30)
Prof Abasifreke Ebong
UNC Charlotte, United States

Understanding the Influence of Tellurium Oxide in Front Ag Paste for Contacting Silicon Solar Cells with Homogeneous High Sheet Resistance Emitter

N. BEZAWADA[1], A. EBONG[2], K. BATCHU[2] et al.
[1] University of North Carolina Charlotte, United States
[2] UNC Charlotte, United States

Abstract
In recent times FF of >81% has been routinely achieved on conventional screen-printed silicon solar cell with efficiency of >19.6%, indicating the front silver paste, printing and co-firing are optimal. The high FF is due to lower total series resistance, because of lower contact and gridline resistances. This paper investigates TeO2, one of the Ag paste additives, to understand its role in low contact and gridline resistances for screen-printed Si solar cell. It is concluded that TeO2 aids the reduction of molten glass frit viscosity during contact co-firing, which in turn leads to uniform flow of molten glass frit, both in the gridline bulk and interface of gridline and SiNx. This is followed by uniform wetting and etching of SiNx and consequently large contact area of metal to Si. Thus the current transport mechanism from Si to gridline can be said to be both direct and tunneling.

Biography
Professor Ebong obtained his PhD degree from the University of New South Wales in Australia under the supervision of Prof. Martin Green, Stuart Wenham and Christian Hunsberg in 1995. He is a Professor and Graduate Program Director at the University of North Carolina at Charlotte, where he teaches solar cell course, electronics etc. His main research area is on low-cost and high efficiency silicon solar cells. He has contributed immensely to the Photovoltaic field for more than 26 years in journal and conference papers as well as pioneering understanding of screen-printed contacts to high sheet resistance emitters.

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2.3.6c (16:30 – 16:45)
Dr Felix Haase
Institute for Solar Energy Research Hamelin (ISFH), Germany

Printable Liquid Silicon for Local Doping of Solar Cells

F. HAASE[1], B. LIM[2], A. MERKLE et al.
[1] Institute for Solar Energy Research Hamelin (ISFH), Germany
[2] Solar Energy Research Institute of Singapore (SERIS), Singapore

Abstract
We demonstrate the application of a liquid-processable doped silicon precursor as an ultrapure doping source for the fabrication of interdigitated back contact solar cells. We integrate phosphorus as well as boron doped liquid silicon in our n-type interdigitated back contact cell process based on laser-structuring. The cell with the phosphorus back surface field from liquid silicon has an efficiency of 20.9 % and the cell with the boron emitter from liquid silicon has an efficiency of 21.9 %. On passivated test samples we measured saturation current densities of 34 fA/cm^2 on 108 Ohm/sq phosphorus doped layers and 18 fA/cm^2 on 140 Ohm/sq on boron doped layers.

Biography
Felix Haase received his PhD degree in Physics in 2013 for the development and characterization of IBC thin-film monocrystalline silicon solar cells processed by the porous silicon process. Afterwards he was analyzing cell cracks and their impact on the module power at ISFH in Hamelin. Now, he is leading a joint project devoling IBC solar cells with passivating contacts and a joint project developing solar cells with printable doping sources for solar cells in the Emerging solar cell technologies group.

2.3.6d (16:45 – 17:00)
Dr Woojun Yoon
U.S. Naval Research Laboratory, United States

Metal Oxides as Full-area Rear Contacts for High-efficiency Crystalline Si Solar Cells

W. YOON[1], J. MOORE[2], D. SCHEIMAN[1] et al.
[1] U.S. Naval Research Laboratory, United States
[2] The George Washington University, United States

Abstract
Thin layers of metal oxides were investigated as full-area rear contacts for high-efficiency crystalline Si solar cells. Numerical simulation was performed for the n- and p-PERT cell structures using TiO2 and MoOx full-area rear contacts, respectively, focusing on the material properties of each structure that appeared to most affect the cell performance. N-type cells with TiO2 contacts were found to be strongly influenced by the back surface recombination velocity (BSRV) at the Si/TiO2 interface, while the performance of the p-type cell with MoOx contacts was found to be most sensitive to the electron affinity of the MoOx. The overall passivation quality of both metal oxides layers was experimentally determined to be around ~100 cm/s. The iVoc of 651 mV was attained from the p-PERT cells with MoOx contacts. Finally the standard cell performance of the n- and p-PERT cell featuring with these metal oxide full-area rear contacts will be presented.

Biography
Dr. Woojun Yoon received his M.S. and Ph.D. in Electrical Engineering from the Ohio State University in 2006 and 2009, respectively, and is currently an Electrical Engineer at the U.S. Naval Research Laboratory (NRL). His current research efforts focus on ultra-thin crystalline Si solar cells, advanced surface passivation and novel structures based on selective contact to Si. Currently he is s a senior member of the IEEE.

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2.3.6e (17:00 – 17:15)
Ms Erin Looney
Massachusetts Institute of Technology, United States

Tabula Rasa: Mitigating Performance Limiting Oxygen Precipitates Though Rapid High Temperature Processing

E. LOONEY[1], M. JENSEN[1], A. YOUSSEF[1] et al.
[1] Massachusetts Institute of Technology, United States

Abstract
Efficiency is one of the main levers to overcoming the cost barriers preventing rapid adoption of solar technologies to terawatt scale capacity. Process optimization can mitigate defects that limit bulk material performance, thereby increasing efficiency and driving down these costs. Oxygen related defects present one of the main impurities in industrial solar materials today. Tabula rasa is a proposed oxygen mitigation technique involving a short high temperature step to quickly dissolve oxygen precipitates. By implementing tabula rasa on materials with known oxygen content and precipitate density, the dependence of oxygen dissolution on annealing time and temperature is explored. Interstitial oxygen content is measured before and after tabula rasa to track macroscale oxygen concentration movement and calculate the dissolution time constant for oxygen precipitates in silicon.

Biography
Erin Looney is a graduate student in Mechanical Engineering who graduated with a B.S. in Mechanical Engineering and a B.A. in History from the University of Alabama in Huntsville in 2015. Her research is focused on furthering the PV labs work on device and process modeling for silicon based solar industry applications. She has completed two internships at General Electric and Ball Aerospace Corporation.

2.3.6f (17:15 – 17:30)
Dr. Fen Lin
Solar Energy Research Institute of Singapore, Singapore

Interface Related Light Induced Degradation in Monocrystalline Silicon Wafer Solar Cells

F. LIN[1], M. TOH[1], T. MAUNG[1] et al.
[1] Solar Energy Research Institute of Singapore, Singapore

Abstract
Light induced degradation (LID) in silicon wafer solar cells has now been well recognized and extensively studied in the photovoltaics community. This effect is generally ascribed to boron-oxygen (B-O) complexes in the bulk silicon wafer. However, there is still a large discrepancy in literature regarding the degradation effects on the interfaces/surfaces upon light illumination. In this paper, we will investigate the interface/surface component of LID in monocrystalline silicon wafer solar cells. The degradation and thermal recovery of carrier lifetime samples with different substrate types and various passivation dielectrics will be carefully studied and compared, in order to understand the underlying mechanisms for interface/surface related LID. The impact of the interface/surface related LID on the overall solar cell device performance will also be analyzed.

Biography
Dr. LIN Fen (Serena) has 12 years of experience in cutting edge technologies in both Photovoltaic and Optoelectronic industry. She joined Solar Energy Research Institute of Singapore (SERIS) in 2008 and currently serves as a senior research scientist, principal investigator and project manager in SERIS. Her job responsibility includes project management on industrial and semi-industrial projects on silicon wafer solar cells as well as high-efficiency tandem solar cells. She has extensive experience in the area of surface passivation, fabrication and characterization of high-efficiency solar cells. She obtained her PhD degree in Optoelectronics from National University of Singapore and Bachelor degree from Zhejiang University.

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2.3.6g (17:30 – 17:45)
Dr Hyunju Lee
Toyota Technological Institute, Japan

Excellent Surface Passivation of Crystalline Silicon by AlxMg1-xOy and Its Tunable Interface Properties

H. LEE[1], F. NISHIMURA[2], T. KAMIOKA[1] et al.
[1] Toyota Technological Institute, Japan
[2] University of Hyogo, Japan

Abstract
A new class of passivation materials, ternary AlxMg1-xOy is developed and its surface passivation and interface properties on crystalline silicon are investigated in this study. Super-cycle plasma-enhanced atomic layer deposition (PEALD) is employed to fabricate AlxMg1-xOy thin films and found to effectively engineer interface properties, i.e., surface passivation quality of the thin films on c-Si. The results of RBS, ERDA, and HAXPES studies reveal that Mg ions can be homogeneously doped into AlOx and an accumulation of Mg ions at the Si/AlOx interface seems to reduce negative fixed charges. Our study also shows that the developed AlxMg1-xOy thin films can provide excellent surface passivation on both p- and n-type c-Si and an extremely low upper-limit effective surface recombination velocity Seff,max of ~1.8 cm/s can be obtained from AlxMg1-xOy passivation on p-type Si wafers after post deposition annealing.

Biography
I received the M.Sc. degree in chemistry and the Ph.D. degree in materials science and engineering from the Korea University, Seoul, Korea, in 1998 and 2010, respectively. From 2010 to 2015, I held a postdoctoral position at Meiji University, Kawasaki, Japan and National Institute for Materials Science, Tsukuba, Japan. I have been a research scientist at Toyota Technological Institute, Nagoya, Japan since 2015. My research interests include the development of dielectric surface passivation for crystalline silicon solar cells and advanced solar cells based on silicon wafers.

2.3.6h (17:45 – 18:00)
Prof Keisuke Ohdaira
Japan Advanced Institute of Science and Technology, Japan

Catalytic Phosphorus and Boron Doping to Amorphous Silicon Films

K. OHDAIRA[1], J. SETO[1], H. MATSUMURA[1]
[1] Japan Advanced Institute of Science and Technology, Japan

Abstract
We investigate a novel method to dope phosphorus (P) or boron (B) atoms onto hydrogenated amorphous silicon (a-Si:H) films using P- or B-related radicals generated by the catalytic cracking of PH3 or B2H6 molecules (Cat-doping). The conductivity of a-Si:H films can be effectively increased by the Cat-doping of P and B atoms, and more significant enhancement in the conductivity is observed after Cat-doping at higher catalyzer temperature. P and B atoms introduced in a-Si:H films by Cat-doping exist within 10–15 nm from the surface of a-Si:H films, indicating the formation of shallow P and B-doped layers. We also confirm that the passivation quality of underlying a-Si films can be maintained if we carefully choose the condition of B and P Cat-doping. These results suggest the applicability of B and P Cat-doping to the fabrication process of silicon heterojunction (SHJ) solar cells.

Biography
Keisuke Ohdaira received a Bachelor of Engineering in the University of Tokyo in 1998, and a Ph.D. in Applied Physics from the same university under Prof. Yasuhiro Shiraki in 2004. He then moved to Tohoku University and worked as a post-doctoral researcher between 2004 and 2005. On September in 2005, he joined the School of Materials Science at the Japan Advanced Institute of Science and Technology as an Assistant Professor, and was promoted to an Associate Professor at the same institute in 2012. Current research topics are related to silicon-based solar cells including surface passivation of crystalline silicon using thin films formed by catalytic chemical vapor deposition (Cat-CVD), formation of polycrystalline silicon films by flash lamp annealing, and potential induced degradation of n-type crystalline silicon solar cell modules.