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Physics, Simulation, and Photonic Engineering of Photovoltaic Devices IV

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1 Plasmonics for Sub-Wavelength Light Trapping
Seth M. Hubbard, Rochester Institute of Technology (United States)
Alexandre Freundlich, University of Houston (United States)

Introduction

The conference on Physics, Simulation, and Photonic Engineering of Photovoltaic Devices, the fourth of its kind, held 3–6 February 2014 in the Moscone Center in San Francisco, was once again a success and attracted a lively crowd. The conference was divided in 11 sessions (including one joint with the conference on Physics and Simulation of Optoelectronic Devices XXIII) and a poster session, totaling 46 contributions in the following topics: Plasmonics for Sub-Wavelength Light Trapping, Advanced Light Management for Si Cells, Advanced Light Management for III-V and Multi-Junction Cells, Innovative Concentrator Design, Growth of III-V Alloys and Nanostructures, Characterization and Transport Properties, Solar Cell Simulation (Joint Session with Conferences 9357 and 9358), Hybrid and Nanowire Materials for Solar Energy Conversion, and three sessions on Advanced Photovoltaic Concepts: IBSC, Hot Carriers, and Photon Conversion and Spectral Shaping. All these topics are well represented in this volume.

Several presentations on subwavelength light trapping confirmed that the field is not only a source of fundamental concepts as was shown by S. Collin (LPN, France) with a new paradigm based on multi-resonant absorption and K. X. Wang (Stanford, United States) with the condition for perfect antireflection by optical resonance at dielectric interface on the possibility to go beyond the Yablonovitch limit on light trapping, but also an emerging engineering concept, as shown by the numerical surface texture optimization presented by V. Ganapati (MIT, United States) and Z. W. Pei (NCHU, Taiwan) exploring the effective absorption length of Si nanohole arrays. More conventional light trapping, but nevertheless still a very active and practical research direction, was also presented, and especially, the paper presented by A. Smets (U. Delft, Netherlands) could summarize how far the field has gone with the example of thin film silicon solar cells, while further examples were given by Yunae Cho (Ewha Womans Univ. Korea), Hui-Hsin Hsiao (NTU, Taiwan), and B. Roberts (U. Michigan, United States). W. Wang (U. Huston, United States) and P. Y. Yu (NCTU, Taiwan) gave examples related to III-V with, respectively, the design and development of back reflectors and the use of selective filters. Finally, light trapping combined with the remarkable improvement of photovoltaic materials has the consequence that photon recycling is becoming an important issue, as outlined by A. W. Walker (ISE, Germany) and H. Akiyama (U. Tokyo) when characterizing multijunction cells. The level of performance achieved makes power converters using PV devices practically implementable as was presented by K. Hinzer (U. Ottawa, Canada). In the concentrator design session, the progresses made with a demonstration of a 5x5 cm^2 self-tracking solar concentrator were presented by Volker Zagolla (EPFL, Switzerland).

Achieving a high level of performance depends not only on excellent light trapping, but also on perfectly controlled material growth. This aspect was well

represented by several contributions on dilute nitride materials that are important for a full coverage of the solar spectrum: O. Durand (FOTON, France) presented on the monolithic integration of GaAsPN dilute-nitride compounds on silicon substrates; Y.K. Sin (Aerospace Corp., United States) presented "Time-resolved PL and TEM studies of MOVPE-grown bulk dilute nitride and bismide quantum well heterostructure," and A.D. Utrilla (UPM, Spain) presented on stacked GaAs(Sb)(N)-capped InAs/GaAs quantum dots, for their use in nanostructured devices. M. A. Slocum (RIT, United States) presented a n-i-p-i structure that mitigates the losses when materials have an intrinsically low performance, as for instance after degradation by space radiation. Alternatively, very thin silicon cells can also be used to this effect, as shown by K. Fedoseyev (CFD Research Corp., United States). These aspects were completed by a session on materials and device characterization, studying carrier capture and escape (Seth Hubbard, RIT, United States) or defect metastability by TRPL (G. El Hajje, IRDEP, France) and on the investigation of carrier collection in multi-quantum well solar cells by luminescence spectra analysis by Amaury Delamarre, (The Univ. of Tokyo, Japan). Finally, a session on device modeling presented how progress can be made towards innovative architectures, whether nanostructured devices (A. Di Carlo, Tor Vergata, Italy), using transport in QDots (A. Berbezier, Julich, Germany) or thinned devices (R. E. Welser, Magnolia Inc., United States).

The last day was devoted to new photovoltaic conversion concepts, exploring the possibility of enhanced photovoltaic conversion performance, beyond Schockley Queisser. A first session discussed the intermediate band solar cell concept. Much of the session was turned toward understanding the intricate multiphoton processes, and the competition with thermal escape, as in the talk on broadband photocurrent spectroscopy on InAs quantum dot solar cell by Ryo Tamaki (The Univ. of Tokyo, Japan); as well as the presentation on characterization of a AlAsSb/InAlAs heterojunction emitter design for InAs/AlAsSb quantum-dot intermediate-band solar cell by Zachary S. Bittner, (RIT, United States); and on the possibility of suppression of thermal carrier escape and enhanced two-step photon absorption in quantum-dot intermediate-band solar cells by Shigeo Asahi, (Kobe Univ., Japan).

A second session presented progresses and new directions in hot carrier solar cells. First, evidence of hot carriers at elevated temperatures in InAs/$AlAs_{0.84}$ $Sb_{0.16}$ quantum wells was shown by Ian R. Sellers (Univ. of Oklahoma, United States), a promising new material system working under rather low illumination intensities. Then, an important emerging approach based on the excitation of hot electrons in metals that was abundantly discussed by several contributions. Notably, James A. R. Dimmock, (Sharp Labs. of Europe Ltd., United Kingdom) showed hot carriers thermonionic emission from Cr into GaAs, while Scott K. Cushing, (West Virginia Univ., United States) studied experimentally and theoretically injection of hot electrons from plasmon excitation in metals. Golam I. Hossain, (Univ. of California, Santa Cruz, United States) closed the session with a detailed fundamental study

of the phenomena. All papers gave an overview of the field with its potential and limitations.

The last session devoted to photon conversion processes, using selective emitters, showing how these could be used for radiative cooling of solar cells (Linxiao Zhu, Stanford Univ., United States), thereby increasing the power yield of solar cells, or for a more efficient use of the solar spectrum either with thermal emitters as with GaSb thermophotovoltaics featuring on chip developments (Nassim Rahimi, Virginia Polytechnic Institute and State Univ., United States) or photothermal emitters as in thermally enhanced photoluminescence, as presented by Assaf Manor (Technion-IIT, Israel).

The scientific committee, and especially some of its most active members, are to be thanked for helping shaping an exceptional program, and we are also grateful to the invited speakers that made outstanding presentations. We are glad that most of the presentations made at the symposium can be found in the present volume.

In the field of photovoltaics, this conference is like no other, with its strong side on theory and simulation, whether on materials, photovoltaic devices or photonics. It is also a place where physics and engineering mingle well. The reader will check that the present volume of collected papers reflects these aspects.

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