Passivation of surface states on hematite photoelectrode by ALD grown TiO2 for efficient solar water splitting

General information
State: Published
Organisations: Photonics, Tampere Univ Technol, Tampere University of Technology
Authors: Ali-Löytty, H., Valden, M., Palmolahti, L.
Publication date: 4 Dec 2017
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Event: Paper presented at Joint Annual Meeting of Finnish Synchrotron Radiation User Organisation (FSRUO) and Finnish Structural Biology Network (FinnBox), Turku, Finland.
Research output: Scientific > Paper, poster or abstract

Photo-electrochemical and spectroscopic investigation of ALD grown TiO2: Charge transfer characterization and effect of post annealing at different temperature

Inspired by the photo-electrochemical water oxidation system reported by Fujishima and Honda1, recent work has focused on functionalizing photoactive TiO2 thin films on silicon (Si) semiconductor. Targeting to design an efficient photo-electrochemical device for solar fuel production, finding suitable protection layer material for semiconductors like Si, has recently gained significant attention.

In this work, TiO2 thin films were deposited on highly doped Si substrate by atomic layer deposition (ALD) technique using tetrakis-dimethylamido titanium (TDMAT) and water as a precursors. In order to understand the influence of ALD parameters on TiO2 film performance in photo-electrochemical cell, ALD growth temperature was varied from 150 °C to 225 °C and film thickness from 20 nm to 50 nm. Further efforts were made to analyze the effect of post-annealing treatment in air on ALD films and its influence on photo-electrochemical water oxidation reaction.

The highest applied bias photon-to-current efficiency for Solar Water Splitting (SWS) was obtained in 30 nm ALD TiO2 film grown at 200 °C after post annealing at 475 °C. Annealing at higher temperatures decreased the photo-activity substantially. X-ray photoelectron spectroscopy analysis of TiO2 (2 nm)/Si samples after annealing in air revealed the onset of interfacial SiO2 formation at 450 °C. SiO2 at the TiO2/Si interface act as a charge transfer barrier with detrimental consequence on SWS on TiO2/Si photo-anode.

Structured Metal/Polymer Back Reflectors for III-V Solar Cells

We report on fabrication of microstructured metal/polymer back reflectors for light trapping in III-V solar cells. The asymmetric triangular grating provided the highest diffraction of the light when compared to half sphere and cylinder reflectors.

Passivation of GaInP and AlInP surfaces for III-V solar cells

General information
State: Published
Organisations: Photonics, Research group: ORC
Authors: Raappana, M., Polojärvi, V., Aho, T., Aho, A., Isoaho, R., Tukiainen, A., Guina, M.
Publication date: 27 Sep 2017
Peer-reviewed: Unknown
Enabling High-Efficiency InAs/GaAs Quantum Dot Solar Cells by Epitaxial Lift-Off and Light Management

General information
State: Published
Organisations: Photonics, Politecnico di Torino, University College London
Publication date: 25 Jun 2017
Peer-reviewed: Unknown

Broadband Anti-reflective Coatings for Multi-junction Solar Cells

General information
State: Published
Organisations: Facilities and Infrastructure, Photonics, Research group: ORC
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Bibliographical note
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Research output: Scientific › Paper, poster or abstract

Enhanced harvesting of thin-film quantum dot solar cells through light trapping techniques

General information
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Organisations: Photonics, Thales Alenia Space
Publication date: 26 Apr 2017
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Research output: Scientific › Paper, poster or abstract

31% European InGaP/GaAs/InGaNAS Solar Cells For Space Application
We report a triple junction InGaP/GaAs/InGaNAS solar cell with efficiency of ~31% at AM0, 25 °C fabricated using a combined molecular beam epitaxy (MBE) and metal-organic chemical vapour deposition (MOCVD) processes. The prototype cells comprise of InGaNAS (Indium Gallium Nitride Arsenide) bottom junction grown on a GaAs (Gallium Arsenide) substrate by MBE and middle and top junctions deposited by MOCVD. Repeatable cell characteristics and uniform efficiency pattern over 4-inch wafers were obtained. Combining the advantages offered by MBE and MOCVD opens a new perspective for fabrication of high-efficiency space tandem solar cells with three or more junctions. Results of radiation resistance of the sub-cells are also presented and critically evaluated to achieve high efficiency in EOL conditions.

General information
State: Published
General information
State: Published
Organisations: Photonics, Research group: ORC
Authors: Campesato, R., Tukiainen, A., Aho, A., Gori, G., Isoaho, R., Greco, E., Guina, M.
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Research output: Scientific - peer-review › Conference contribution

Composition and Bandgap determination of MBE-grown GaInNAsSb

General information
State: Published
Organisations: Optoelectronics Research Centre, Research group: Semiconductor Technology and Applications, Department of Materials Science
Authors: Aho, A., Korpijärvi, V., Isoaho, R., Malinen, P., Tukiainen, A., Honkanen, M. H., Guina, M.
Publication date: 2017

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Title of host publication: 19th International Conference on Molecular-Beam Epitaxy
Bibliographical note
Research output: Professional › Conference contribution

Design considerations on GaInNAs solar cells with back surface reflectors
We report on modeling of electrical characteristics of dilute nitride GaInNAs solar cells with specular and diffuse back surface reflectors. The paper concentrates on optimization of the GaInNAs junction thickness and doping level for various reflectors. Usually, it is considered that the doping level of GaInNAs should be clearly below 1×10^{16} cm^{-3} to be usable for active sub-junction material of high-efficiency triple junction solar cells. Here we show that this requirement can be alleviated by using high quality diffuse back surface reflectors and thus GaInNAs with background doping levels even exceeding 1×10^{16} cm^{-3} can be used for junction formation for high-efficiency multijunction solar cells. The reflectance of the back surface reflector is shown to affect the optimal GaInNAs thickness. The higher the reflectance the thinner layers can be used. We also show that the optimal GaInNAs layer thickness is different depending on whether the optimization is done for the short circuit current density or open circuit voltage.

General information
State: Published
Organisations: Photonics
Authors: Tukiainen, A., Aho, A., Aho, T., Poloijärvi, V., Guina, M.
Publication date: 2017
Peer-reviewed: Unknown
Research output: Scientific › Paper, poster or abstract

Dilute Nitride Solar Cells - Technology Developments Towards 50% Efficiency

General information
State: Published
Novel Concepts for High-efficiency lightweight space solar cells

One of the key issues in the design and development of a satellite Photovoltaic Assembly (PVA) is the trade-off to be made between the available volume located to the PVA, its mass and the total amount of power that the solar panels have to guarantee to the spacecraft. The development of high-efficiency, flexible, lightweight solar cells is therefore instrumental to the design of future satellites providing enhanced missions and services. Based on the consolidated development of GaAs-based single junction and lattice matched triple-junction solar cells, several research efforts are being pursued worldwide to further increase the efficiency and reduce mass. Promising approaches include thin-film technologies such as Inverted Metamorphic and Epitaxial Lift-Off (ELO), and the use of nanostructures or highly mismatched alloys grown by MBE. We propose here an alternative path towards the development of lightweight GaAs-based solar cells with the potential to exceed the Shockley-Queisser (SQ) limit of single junction cells. Our approach is based on the synergistic combination of thin-film design, quantum dots (QDs) absorption, and photonic nanostructures. Challenges and opportunities offered by the use of QDs are discussed. A cost-effective and scalable fabrication process including ELO technology and nanoimprint lithography is outlined. Finally, a proof-of-concept design, based on rigorous electromagnetic and physics-based simulations, is presented. Efficiency higher than 30% and weight reduction close to 90% - owing to the substrate removal - makes the proposed device to rank record power-to-weight ratio, with the potential to become a cost-effective, attractive option for next generation space solar cells.

Novel III-V Heterostructures for High Efficiency Solar Cells

Dilute nitride arsenide antimonide compounds offer widely tailorable band-gaps, ranging from 0.8 eV to 1.4 eV, for the development of lattice-matched multijunction solar cells with three or more junctions. Here we report on the performance
of GaInP/GaAs/GaInNAsSb solar cell grown by molecular beam epitaxy. An efficiency of 27% under AM0 conditions is demonstrated. In addition, the cell was measured at different temperatures. The short circuit current density exhibited a temperature coefficient of 0.006 mA/cm²/°C while the corresponding slope for the open circuit voltage was −6.8 mV/°C. Further efficiency improvement, up to 32%, is projected by better current balancing and structural optimization.

General information
State: Published
Ministry of Education publication type: A4 Article in a conference publication
Organisations: Photonics, Research group: ORC
Authors: Aho, A., Isoaho, R., Tukiainen, A., Poloijärvi, V., Raappana, M., Aho, T., Guina, M.
Publication date: 2017

Temperature Dependent Characteristics of GaInP/GaAs/GaInNAsSb Solar Cell Under Simulated AM0 Spectra
We report on the temperature characteristics of GaInP/GaAs/GaInNAsSb triple junction solar cell monolithically grown by molecular beam epitaxy. We have measured the temperature dependent light-biased current-voltage characteristics for simulated AM0 spectral conditions using two simulators: a customized three band source and a Xenon lamp with AM0 filter. The current-voltage characteristics of the cell were measured in temperature range of 25-90°C with both solar simulators. At 25°C the cell demonstrated active area efficiencies of 26.7% and 21.1% when illuminated with the three band simulator and Xenon source, respectively. Significant deviations between the measurements were observed as the cell demonstrated approximately 30% lower short-circuit current density when illuminated with the Xenon source compared to the measurement made with the three band simulator and Xenon source, respectively. Significant deviations between the measurements were observed as the cell demonstrated approximately 30% lower short-circuit current density when illuminated with the Xenon source compared to the measurement made with the three band simulator. The temperature coefficients for the cell characteristics were determined from the temperature dependent current-voltage data. For the three band simulator, the temperature coefficients for short-circuit current density and open-circuit voltage of the cell were found to be 5.3 μA/cm²/°C and -6.8 mV/°C, respectively, and are in agreement with results reported for GaInP/GaAs/Ge solar cells. Illumination with filtered Xenon lamp leads to significantly higher temperature coefficient for short-circuit current density. The conversion efficiency of the cell decreased with a slope of -0.068 abs.-%/°C when illuminated with the three band simulator.

General information
State: Published
Organisations: Photonics
Authors: Isoaho, R., Aho, A., Tukiainen, A., Guina, M.
Publication date: 2017
Peer-reviewed: Unknown
Event:
Research output: Scientific › Paper, poster or abstract

The role of (FeCrSi)2(MoNb)-type Laves phase on the formation of Mn-rich protective oxide scale on ferritic stainless steel
Microalloying of stainless steel with reactive elements increases oxidation resistance but makes the alloy prone to microstructural changes. XPS results reveal changes in the initial oxidation mechanism on Ti-Nb stabilized ferritic stainless steel (EN 1.4521) after 120 h heat treatment at 650 °C. Age-precipitation of (FeCrSi)2(MoNb)-type Laves phase resulted in less pronounced surface segregation and oxidation of microalloying elements. Si oxidizes preferentially at the Laves precipitate locations via outward diffusion forming diffusion barrier for the other scale forming elements. Most significantly the diffusion of Mn and the formation of low volatile (Mn,Cr)3O4 spinel oxide at the surface was strongly suppressed.

General information
Enhancement of Photocurrent in GaInNAs Solar Cells using Ag/Cu Double-Layer Back Reflector

General information
State: E-pub ahead of print
Ministry of Education publication type: A1 Journal article-refereed
Organisations: Optoelectronics Research Centre, Research group: Semiconductor Technology and Applications, Research group: Nanophotonics
Authors: Aho, T., Aho, A., Tukiainen, A., Polojärvi, V., Salminen, T., Raappana, M., Guina, M.
Publication date: 22 Dec 2016
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Scopus rating (2012): SJR 2.554 SNIP 1.754 CiteScore 3.76
Scopus rating (2011): SJR 2.805 SNIP 1.94 CiteScore 4.04

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Scopus rating (2010): SJR 2.926 SNIP 1.789
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Original language: English
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Enhancement of photocurrent in GaInNAs solar cells using AgCu double-layer back reflector
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Research output: Scientific › Article

Thermal Modification of ALD Grown Titanium Oxide Ultra Thin Film for Photoanode Applications

General information
State: Published
Organisations: Optoelectronics Research Centre, Research group: Surface Science
Authors: Hannula, M. K., Lahtonen, K. T., Isotalo, T. J., Saari, J. S., Valden, M. O.
Publication date: 15 Dec 2016
Peer-reviewed: Unknown
Event: Paper presented at Symposium on Future Prospects for Photonics, Tampere, Finland.
ASJC Scopus subject areas: Renewable Energy, Sustainability and the Environment, Surfaces, Coatings and Films, Surfaces and Interfaces, Atomic and Molecular Physics, and Optics
Keywords: Titanium dioxide, titanium silicide, Atomic layer deposition (ALD), photoemission electron microscopy, PEEM, hydrogen energy
Research output: Scientific › Paper, poster or abstract

Ambient-Pressure XPS of Electrochemical Interfaces for Solar Fuel Production

General information
State: Published
Organisations: Optoelectronics Research Centre, Research group: Surface Science
Authors: Ali-Löytty, H. J.
Publication date: 1 Dec 2016
Peer-reviewed: Unknown
Research output: Scientific › Paper, poster or abstract

Modeling and experimental verification of magneto-mechanical energy harvesting device based on construction steel
The concept of energy harvesting through ambient vibrations has seen significant rise in academic interest as it allows wireless or portable systems to be autonomous and self-sufficient in terms of energy requirement. Ambient sources of vibration involve vibrations from bridges, skyscrapers, rail tracks, machines, motors, shafts and body of cars or ships etc. Thus, the harvested energy depends on the nature and amplitude of vibration available. The concept in discussion focuses on magneto-strictive energy harvesting technique due to its higher energy density as compared to piezoelectric. The project aims at the development of a stress dependent reluctance network model to determine the effect of mechanical stress on magnetization curves and for simulating the energy conversion process, as well as measurement of the power density observable from the test material. Construction steel has been utilized for energy harvesting application because of its practical applications in bridges, buildings and rail tracks etc.
Fabrication of topographically microstructured titanium silicide interface for advanced photonic applications

We present a widely scalable, high temperature post-growth annealing method for converting ultra-thin films of TiO$_2$ grown by atomic layer deposition to topographically microstructured titanium silicide (TiSi). The photoemission electron microscopy results reveal that the transformation from TiO$_2$ to TiSi at 950 °C proceeds via island formation. Inside the islands, TiO$_2$ reduction and Si diffusion play important roles in the formation of the highly topographically microstructured TiSi interface with laterally nonuniform barrier height contact. This is advantageous for efficient charge transfer in Si-based heterostructures for photovoltaic and photoelectrochemical applications.
Optically Enhanced GaInNAs Solar Cell

General information
State: Published
Organisations: Optoelectronics Research Centre, Research group: Semiconductor Technology and Applications
Authors: Aho, T. A., Aho, A., Tukiainen, A., Polojärvi, V., Raappana, M., Guina, M.
Publication date: 20 Jun 2016
Peer-reviewed: Unknown
Research output: Scientific › Paper, poster or abstract

Ambient-Pressure XPS Study of a Ni-Fe Electrocatalyst for the Oxygen Evolution Reaction

Chemical analysis of solid-liquid interfaces under electrochemical conditions has recently become feasible due to the development of new synchrotron radiation techniques. Here we report the use of "tender" X-ray ambient-pressure X-ray photoelectron spectroscopy (APXPS) to characterize a thin film of Ni-Fe oxyhydroxide electrodeposited on Au as the working electrode at different applied potentials in 0.1 M KOH as the electrolyte. Our results show that the as-prepared 7 nm thick Ni-Fe (50% Fe) film contains Fe and Ni in both their metallic as well as oxidized states, and undergoes further oxidation when the sample is subjected to electrochemical oxidation-reduction cycles. Metallic Fe is oxidized to Fe" and metallic Ni to Ni". This work shows that it is possible to monitor the chemical nature of the Ni-Fe catalyst as a function of potential when the corresponding current densities are small. This allows for operando measurements just above the onset of OER; however, current densities as they are desired in photoelectrochemical devices (∼1-10 mA cm⁻²) could not be achieved in this work, due to ohmic losses in the thin electrolyte film. We use a two-dimensional model to describe the spatial distribution of the electrochemical potential, current density, and pH as a function of the position above the electrolyte meniscus, to provide guidance toward enabling the acquisition of operando APXPS at high current density. The shifts in binding energy of water with applied potential predicted by the model are in good agreement with the experimental values.

General information
State: Published
Organisation type: A1 Journal article-refereed
Organisations: Optoelectronics Research Centre, Research group: Surface Science, SUNCAT Center for Interface Science and Catalysis, SLAC National Accelerator Laboratory, Department of Chemical and Biomolecular Engineering, Berkeley, Materials Sciences Division, Lawrence Berkeley National Laboratory, Materials and Corrosion Engineering, Exponent, Inc., Polymer Science and Materials Chemistry
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Scopus rating (2014): SJR 2.027 SNIP 1.448 CiteScore 5.08
Scopus rating (2013): SJR 2.134 SNIP 1.439 CiteScore 5.14
Scopus rating (2012): SJR 2.514 SNIP 1.46 CiteScore 4.98
Scopus rating (2011): SJR 2.32 SNIP 1.457 CiteScore 4.92
Scopus rating (2010): SJR 2.438 SNIP 1.356
Scopus rating (2009): SJR 2.128 SNIP 1.417
Scopus rating (2008): SJR 1.856 SNIP 1.033
Terpyridine-substituted perylenes containing cyclic anhydrides in the peri position were synthesized. The anhydride group served as an anchor for assembly of the terpyridyl-crowned chromophores as monomolecular layers on metal oxide surfaces. Further coordination with Zn2+ ions allowed for layer-by-layer formation of supramolecular assemblies of perylene imides on the solid substrates. With properly selected anchor and linker molecules it was possible to build high quality structures of greater than ten successive layers by a simple and straightforward procedure. The prepared films were stable and had a broad spectral coverage and high absorbance. To demonstrate their potential use, the synthesized dyes were employed in solid-state dye-sensitized solar cells, and electron injection from the perylene antennas to titanium dioxide was observed.
Dilute Nitride Four-Junction Solar Cell

General information
State: Published
Organisations: Optoelectronics Research Centre, Research group: Semiconductor Technology and Applications, Optoelectronics Research Centre, Tampere University of Technology
Publication date: 2016
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Event: Research output: Scientific › Paper, poster or abstract

Dilute Nitride Multijunction Cells: Recent progress and Future Outlook

General information
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Publication date: 2016
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Event: Paper presented at Optics and Photonics days, Tampere, Finland.
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Dilute nitride solar cells fabricated by combined MBE-MOCVD epitaxy

General information
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Organisations: Optoelectronics Research Centre, Research group: Semiconductor Technology and Applications
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Electronic versions: CPV-12_Guina_MBE-MOCVD_update
Research output: Scientific › Paper, poster or abstract

Electrical isolation of dilute nitride solar cells by wet etching

General information
State: Published
Organisations: Optoelectronics Research Centre, Research group: Semiconductor Technology and Applications
Publication date: 2016
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Event: Paper presented at Optics and Photonics days, Tampere, Finland.
Research output: Scientific › Paper, poster or abstract

Electrical isolation of high-efficiency dilute nitride multijunction solar cells

General information
State: Published
HCl-based wet etching of III-V dilute nitride materials for multijunction solar cells

General information
State: Published
Organisations: Optoelectronics Research Centre, Research group: Semiconductor Technology and Applications
Authors: Raappana, M., Polojärvi, V., Aho, T., Aho, A., Tukiainen, A., Hytönen, L., Isoaho, R., Guina, M.
Publication date: 2016
Peer-reviewed: Unknown
Research output: Scientific › Paper, poster or abstract

High efficiency dilute nitride solar cells: Simulations meet experiments
Parameter extraction procedure and simulation of dilute nitride solar cells are reported. Using PC1D simulation and fitting to experimental current-voltage and external quantum efficiency data, we retrieve the phenomenological material parameters for GaInNAs solar cells. Based on these, we have constructed a model that can explain the changes in short circuit current and open circuit voltage of n-i-p solar cells subjected to rapid thermal annealing. The model reveals that non-annealed MBE-grown GaInNAs material has an n-type doping that evolves to p-type upon rapid thermal annealing. The change of doping type and the shift of the physical location of the pn-junction were confirmed by Kelvin-probe force microscopy. The PC1D modelling was found to work well also for GaInNAs p-i-n solar cells with opposite polarity. It was also found that the GaInNAs lower doping levels in p-i-n solar cells grown at lowered As/III flux ratios were associated with increased carrier lifetimes.

General information
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Ministry of Education publication type: A1 Journal article-refereed
Organisations: Optoelectronics Research Centre, Research group: Semiconductor Technology and Applications
Authors: Tukiainen, A., Aho, A., Polojärvi, V., Ahorinta, R., Guina, M.
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Scopus rating (2013): SJR 0.143 SNIP 0.191 CiteScore 0.54
Scopus rating (2012): SJR 0.122 SNIP 0.228 CiteScore 0.57
Scopus rating (2011): SJR 0.105 SNIP 1.56
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ASJC Scopus subject areas: Environmental Engineering, Energy(all), Physics and Astronomy(all), Materials Science(all)
DOIs:
High-efficiency III-V solar cells: From drawing board to real devices

The record solar cell conversion efficiency of 46% at concentrated sunlight has been demonstrated by direct bonding technique [1]. Regardless of the high efficiencies obtained using the direct wafer bonding technique, the conventional monolithic approach used in commercial solar cell production has several benefits, including production technology and cost-related factors. And yet, there is a high unused potential, particularly in new materials that can be grown lattice-matched onto GaAs or Ge substrates. For example, by utilizing dilute nitride materials in multijunction solar cell structures with more than three junctions and by carefully optimizing structural elements and manufacturing technology, efficiencies exceeding 50% is a realistic target [2]. Here we review our theoretical and experimental work carried out on development of various parts of high-efficiency multijunction solar cells based on GaInNAsSb-based materials, i.e., dilute nitrides. First of all, we have developed a molecular beam epitaxy process for GaInNAsSb sub-junction with very high external quantum efficiency exceeding 90%. This building block is essential for achieving high conversion efficiency for GaInP/GaAs/GaInNAsSb triple-junction solar cells. Secondly, the use of a variety of electro-optical simulation tools such as Crosslight APSYS, Silvaco TCAD, PC1D, Es-sential MacLeod and semi-empirical analytical models combined with experimental work on numerous test samples have helped in fabricating ultra-low specific resistivity tunnel junctions and high-quality sub-junctions based on conventional III-V materials such as GaInP and GaAs to be integrated with the dilute nitride sub-junction. Thirdly, we have also extracted important material specific physical parameters such as carrier lifetimes, mobilities and concentrations for dilute nitrides by matching the simulations to experimental solar cell device characteristics [3]. The extracted parameters are used for refining the simulation models which provide deeper understanding of the device physics. The work done so far has led to a rapid increase in conversion efficiency of our GaInP/GaAs/GaInNAsSb triple-junction solar cells – at a pace of ~5 % points/year since 2012. High-efficiency solar cells with efficiencies of 29% and 31% at one sun (AM0 and AM1.5G, respectively) and 36–39% under concentrated sunlight (at ~70 suns) have already been demonstrated [4,5]. Additionally, the effects of various optical and structural design elements related to fabrication of real III-V multijunction solar cells will be critically reviewed. Especially, we will concentrate on the pros and cons of backside reflector structure architectures – including various planar reflector types and Lambertian scatterers – and nanostructured antireflection coatings [6] which are currently widely employed for solar cell photon management. The consequences of adding such elements to the fabrication process and impact on improving the conversion efficiency towards >50% efficiency are assessed.

Increasing the quantum efficiency of GaInNAs solar cells by advanced optical design

Optimizing iron alloy catalyst materials for photoelectrochemical water splitting: Passivation of FeCr alloy surface by water vapour using near-ambient-pressure photoelectron spectroscopy
X-ray photoelectron spectroscopy of electrochemical interfaces for solar fuel production

General information
State: Published
Organisations: Optoelectronics Research Centre, Research group: Surface Science
Authors: Ali-Löytty, H., Valden, M.
Number of pages: 1
Publication date: 2016
Event: Paper presented at Physics days 2016, Oulu, Finland.
Research output: Scientific \ Paper, poster or abstract

Single-source multibattery solar charger: Case study and implementation issues
In this paper, design process and functionality of a portable single-panel dual-battery solar charger prototype are presented, achieving energy density of 571 Wh kg\(^{-1}\) during a typical 3-day infantry mission. The device may instantaneously charge up to two Li-ion MR-2791 batteries, supporting plug-and-play operation. The system consists of a lightweight custom solar panel, based on 20\% efficient monocrystalline photovoltaics, and an intelligent power processing module. The panel contains eight transparent polymer-encapsulated and camouflage series-connected six solar cell packs with antiparallel diodes, allowing partial shading operation. The power processing module consists of two synchronous current-mode-controlled buck converters, digital signal processor, and a microcontroller, supporting both maximum power point tracking of the solar panel with partial shading detection and multimode charging of Li-ion packs while instantaneously communicating with the batteries. Power management algorithmic design is presented, based on ensuring system stability while supporting the required operation modes. System implementation stages and underlying issues are thoroughly discussed, and utilized hardware components are presented in detail. Experimental results of system testing under real outdoor conditions are presented to demonstrate the device functionality and energy yield capabilities.

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Organisations: Department of Electrical Engineering, Research area: Power engineering, Smart Energy Systems (SES), Hybrid Energy Sources Laboratory
Authors: Gadelovits, S., Sitbon, M., Suntio, T., Kuperman, A.
Number of pages: 13
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Scopus rating (2014): SJR 3.279 SNIP 3.874 CiteScore 7.7
Scopus rating (2013): SJR 3.974 SNIP 5.653 CiteScore 8.93
Scopus rating (2012): SJR 3.478 SNIP 5.082 CiteScore 6.81
Scopus rating (2011): SJR 3.251 SNIP 5.999 CiteScore 6.81
Scopus rating (2010): SJR 3.749 SNIP 4.317
Scopus rating (2009): SJR 3.18 SNIP 3.256
Scopus rating (2008): SJR 2.537 SNIP 2.473
Scopus rating (2007): SJR 1.711 SNIP 2.124
Scopus rating (2006): SJR 1.55 SNIP 2.881
Scopus rating (2005): SJR 1.774 SNIP 3.07
Scopus rating (2004): SJR 0.852 SNIP 1.671
Scopus rating (2003): SJR 0.763 SNIP 1.489
Dilute Nitride Multijunction Solar Cells Grown by Molecular Beam Epitaxy

Solar cells generate green energy directly from sunlight. The energy conversion efficiency of solar cells depends strongly on materials used as absorbers and the cell architecture. Currently, the best solar cells convert sunlight energy to electricity with an efficiency of up to 46%. This thesis focuses on the development of dilute-nitride materials and related solar cells, which are one of the most promising approaches for achieving even higher efficiencies. Applications for these cells include concentrated photovoltaic and space power systems. In particular, the thesis focuses on developing solar cell materials based on GaInNAsSb, which can provide efficient light absorption and energy conversion for a photon energy range of 0.8 eV- 1eV, typically challenging for conventional III-V semiconductors. The GaInNAsSb semiconductor materials were synthesized by molecular beam epitaxy.

The experimental work of this thesis explored the dependence of the fabrication parameters on the GaInNAsSb material and solar cell properties. It was observed that for many of the growth parameters even a slight change of the value can have a significant effect on the solar cell performance. A N incorporation model was developed to help the iteration process for growth parameter tuning. For optimized growth conditions, nearly ideal current generation for GaInNAsSb based material was achieved. Based on external quantum efficiency measurements it was possible to collect up to ~90% of the photons in the spectral range of the GaInNAsSb junction. In addition, an excellent fill factor of 0.7 and voltages in the range of 0.5 V for a 1 eV GaInNAsSb junction were measured.

Simulation based on a state-of-the-art GaInP/GaAs double junction cell, a commercial GaInP/GaAs/Ge triple junction cell and GaInNAsSb single junction cells studied in this thesis, revealed that a GaInP/GaAs/GaInNAsSb/Ge cell at the one sun concentration can have 1.7 percentage points higher efficiency than GaInP/GaAs/GaInNAsSb cell. In addition, the estimated efficiency of a four junction cell at 300 suns would be 3.6 percentage points higher than for a GaInP/GaAs/GaInNAsSb cell. The optimized single junction GaInNAsSb cell was experimentally tested into a GaInP/GaAs/GaInNAsSb cell in this work. The one sun efficiency of the cell under AM1.5G spectral conditions was 31% and the efficiency of the cell at 70 suns concentration was 37-39%. The one sun result is 91% of the projected efficiency. The results under concentrated conditions are expected to be improved by optimizing of the cell top grid design, layer structure and interfaces. As future concepts are concerned, a nanopatterned moth eye antireflection coating was fabricated on top of the GaInP/GaAs/GaInNAs cell, which was then compared to a cell that had a traditional two layer TiO2/SiO2 coating. The moth eye nanostructure had a low average reflection of 2% in the spectral range of 400-1700 nm, being less than half of the reflectance of the TiO2/SiO2 coating. For future work, the absorption loss for the nanostructure coating at wavelengths below 500 nm needs to be reduced.

General information
State: Published
Ministry of Education publication type: G5 Doctoral dissertation (article)
Organisations: Optoelectronics Research Centre, Research group: Semiconductor Technology and Applications
Authors: Aho, A.
Number of pages: 80
Publication date: 14 Nov 2015

Publication information
Publisher: Tampere University of Technology
Original language: English

Publication series
Name: Tampere University of Technology. Publication
Effects of thinning and heating for TiO$_2$/AlInP junctions

TiO$_2$/AlInP junctions are used to construct the antireflection coatings for solar cells and to passivate III-V nanostructure surfaces. The thickness of AlInP epilayer affects light absorption and appropriate Al composition determining further the energy barrier for carriers. We report on reducing the AlInP thickness by dry etching down to 10 nm without introducing harmful defect states at TiO$_2$/AlInP interface and AlInP/GaInP interface below, according to photoluminescence. Synchrotron-radiation photoelectron spectroscopy reveals that increased oxidation of phosphorus is not harmful to TiO$_2$/AlInP and that post heating of the material enhances AlInP oxidation and group III element segregation resulting in decreased material homogeneity.
Improved adaptive input voltage control of a solar array interfacing current mode controlled boost power stage

Nonlinear characteristics of photovoltaic generators were recently shown to significantly influence the dynamics of interfacing power stages. Moreover, since the dynamic resistance of photovoltaic generators is both operating point and environmental variables dependent, the combined dynamics exhibits these dependencies as well, burdening control challenge. Typically, linear time invariant input voltage loop controllers (e.g. Proportional-Integral-Derivative) are utilized in photovoltaic applications, designed according to nominal operating conditions. Nevertheless, since actual dynamics is seldom nominal, closed loop performance of such systems varies as well. In this paper, adaptive control method is proposed, allowing to estimate photovoltaic generator resistance online and utilize it to modify the controller parameters such that closed loop performance remains nominal throughout the whole operation range. Unlike previously proposed method, utilizing double-grid-frequency component for estimation purposes and suffering from various drawbacks such as operation point dependence and applicability to single-phase grid connected systems only, the proposed method is based on harmonic current injection and is independent on operating point and system topology.

General information

State: Published
Ministry of Education publication type: A1 Journal article-refereed
Organisations: Department of Electrical Engineering, Research area: Power engineering, Smart Energy Systems (SES), Dept. of Electrical Engineering and Electronics, Ariel University
Authors: Sitbon, M., Schacham, S., Suntio, T., Kuperman, A.
Number of pages: 7
Pages: 369-375
Publication date: 1 Jul 2015
Peer-reviewed: Yes

Publication information

Journal: Energy Conversion and Management
Volume: 98
ISSN (Print): 0196-8904
Ratings:
Scopus rating (2016): CiteScore 6.04 SJR 2.287 SNIP 2.065
Scopus rating (2015): SJR 2.09 SNIP 2.092 CiteScore 5.24
Scopus rating (2014): SJR 1.854 SNIP 2.835 CiteScore 5.35
Scopus rating (2013): SJR 1.669 SNIP 2.558 CiteScore 4.49
Scopus rating (2012): SJR 1.732 SNIP 2.277 CiteScore 3.72
Scopus rating (2011): SJR 1.292 SNIP 1.846 CiteScore 3.03
Scopus rating (2010): SJR 1.372 SNIP 1.75
Scopus rating (2009): SJR 1.339 SNIP 1.797
Scopus rating (2008): SJR 1.508 SNIP 1.905
Scopus rating (2007): SJR 1.196 SNIP 1.811
Scopus rating (2006): SJR 1.327 SNIP 1.816
Scopus rating (2005): SJR 1.577 SNIP 1.799
Scopus rating (2004): SJR 1.049 SNIP 1.466
Scopus rating (2003): SJR 0.903 SNIP 1.321
Scopus rating (2002): SJR 1.089 SNIP 1.463
Scopus rating (2001): SJR 0.81 SNIP 0.855
Scopus rating (2000): SJR 0.576 SNIP 0.688
Scopus rating (1999): SJR 0.515 SNIP 0.724
Original language: English
Keywords: Adaptive control, Dynamic resistance, Photovoltaic generators
DOIs:
10.1016/j.enconman.2015.03.100
GaInNAs Solar Cell with Back Surface Reflector

General information
State: Published
Ministry of Education publication type: A4 Article in a conference publication
Organisations: Optoelectronics Research Centre, Research group: Semiconductor Technology and Applications, Frontier Photonics
Authors: Aho, T., Aho, A., Tukiainen, A., Polojärvi, V., Penttinen, J., Raappana, M., Guina, M.
Number of pages: 4
Publication date: 14 Jun 2015

Host publication information
Title of host publication: 42nd IEEE Photovoltaic Specialists Conference (PVSC), 2015
Publisher: IEEE

Publication series
Name: Conference record of the IEEE photovoltaic specialists conference
Publisher: Institute of Electrical and Electronics Engineers
ISSN (Print): 0160-8371
DOIs: 10.1109/PVSC.2015.7356356
Research output: Scientific - peer-review › Conference contribution

Comprehensive dynamic analysis of photovoltaic generator interfacing DC-DC boost power stage
In transformer-less grid-connected renewable energy systems, interfacing of photovoltaic (PV) generators is typically implemented by means of DC-DC boost-power-stage converter, mainly because of its voltage-boosting capability. In order to track the maximum power point of a PV generator, input voltage of the converter is usually feedback controlled, forcing the converter to operate as a current-sourced rather than voltage-sourced converter. Nevertheless, PV generator interfacing power stage is commonly assumed to possess the same dynamic properties as corresponding voltage-sourced power stage. Investigations presented in this study reveal explicitly that the dynamics of PV generator interfacing DC-DC boost power stage resembles conventional buck power stage behaviour with duty-cycle independent resonance and additional right-half-plane zeros. In addition, the duty cycle has to be decreased for increasing the corresponding output variables (i.e. input voltage and output current). Extended experimental results are given to support the theoretical findings.

General information
State: Published
Ministry of Education publication type: A1 Journal article-refereed
Organisations: Department of Electrical Engineering, Research area: Power engineering, Smart Energy Systems (SES), Ariel Univ, Dept Elect Engn & Elect, Hybrid Energy Sources Lab
Authors: Viinamäki, J., Jokipii, J., Messo, T., Suntio, T., Sitbon, M., Kuperman, A.
Number of pages: 9
Pages: 306-314
Publication date: May 2015
Peer-reviewed: Yes

Publication information
Journal: IET Renewable Power Generation
Volume: 9
Issue number: 4
ISSN (Print): 1752-1416
Ratings:
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Scopus rating (2015): SJR 1.054 SNIP 1.64 CiteScore 3.13
Scopus rating (2014): SJR 1.375 SNIP 2.338 CiteScore 3.56
Scopus rating (2013): SJR 1.814 SNIP 2.78 CiteScore 4.96
Scopus rating (2012): SJR 1.5 SNIP 2.854 CiteScore 4.64
Scopus rating (2011): SJR 1.374 SNIP 2.474 CiteScore 4.43
Scopus rating (2010): SJR 1.893 SNIP 2.631
Matlab/Simulink modeling to study the effect of partially shaded condition on photovoltaic array's maximum power point

General information
State: Published
Ministry of Education publication type: A1 Journal article-refereed
Organisations: Department of Electrical Engineering, Research area: Power engineering, Islamic University of Gaza
Authors: Matter, K., El-Khozondar, H., El-Khozondar, R., Suntio, T.
Number of pages: 7
Pages: 697-703
Publication date: May 2015
Peer-reviewed: Yes

Publication information
Journal: International Research Journal of Engineering and Technology
Volume: 02
Issue number: 02
ISSN (Print): 2395-0072
Original language: English
Research output: Scientific - peer-review › Article

Dynamics of photovoltaic-generator-interfacing voltage-controlled buck power stage
This paper investigates the dynamic properties of the photovoltaic-generator-interfacing voltage-controlled buck power stage operating in both the maximum and limited power point tracking modes. The photovoltaic generator (PVG) is known to possess both current- and voltage-source properties with respect to its maximum power point. While voltage-fed operation is conventional, current-fed action is nontrivial and is thoroughly analyzed in this paper. The photovoltaic-generator-interfacing converter is formed by adding a capacitor at conventional voltage-fed converter input terminals, turning it into a current-fed power stage. During the maximum power point tracking phase, converter input voltage is regulated, possessing nontrivial dynamics. The situation is burdened further when output-voltage control should be alternatively realized to limit the voltage of the converter terminating the energy storage element. It is shown that both the photovoltaic generator and the terminating energy storage greatly affect the combined system dynamics. Parallel as well as cascaded control arrangements are proposed to support dual-mode system operation. Extended experimental results are shown to enforce presented theory and reveal nontrivial dynamics-related issues.

General information
State: Published
Ministry of Education publication type: A1 Journal article-refereed
Organisations: Department of Electrical Engineering, Research area: Power engineering, Smart Energy Systems (SES), Hybrid Energy Sources RandD Laboratory, Ariel University, ABB Oy, Drives
Authors: Sitbon, M., Leppäaho, J., Suntio, T., Kuperman, A.
Number of pages: 8
Pages: 633-640
Publication date: 1 Mar 2015
Peer-reviewed: Yes

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Volume: 5
III-N/Bu-V based high efficiency solar cells: recent developments ad future prospects

General information
State: Published
Organisations: Optoelectronics Research Centre, Research group: Semiconductor Technology and Applications
Authors: Guina, M.
Publication date: 2015
Peer-reviewed: Unknown

Bibliographical note
xpresentation
"Invited talk"
Research output: Scientific › Paper, poster or abstract

MBE GROWN GaInNAsSb MULTIJUNCTION SOLAR CELLS: PATH TOWARDS 50% EFFICIENCY

General information
State: Published
Ministry of Education publication type: D3 Professional conference proceedings
Organisations: Optoelectronics Research Centre, Research group: Semiconductor Technology and Applications
Authors: Aho, A. J., Polojärvi, V. V., Aho, T. A., Raappana, M. J. S., Tukiainen, A. K., Guina, M. D.
Publication date: 2015

Host publication information
Title of host publication: 18th European Molecular Beam Epitaxy Workshop. Canazei, Italy
ASJC Scopus subject areas: Energy(all)
Links:

Bibliographical note
xpresentation
Research output: Professional › Conference contribution

Optical properties and thermionic emission in solar cells with InAs quantum dots embedded within GaNAs and GaInNAs
The optical properties of p-i-n solar cells comprised of InAs quantum dots embedded within GaNAs and GaInNAs quantum wells are reported. Strain compensating and mediating GaNAs and GaInNAs layers shift the photoluminescence emission as well as absorption edge of the quantum dots to longer wavelengths. GaNAs and GaInNAs quantum wells contribute also to extending the absorption edge. In addition, the use of GaNAs and GaInNAs layers enhances the thermal escape of electrons from QDs by introducing steps for electrons to the GaAs conduction band.

General information
State: Published
Temperature coefficients for GaInP/GaAs/GaInNAsSb solar cells
We report the temperature coefficients for MBE-grown GaInP/GaAs/GaInNAsSb multijunction solar cells and the corresponding single junction sub-cells. Temperature-dependent current-voltage measurements were carried out using a solar simulator equipped with a 1000W Xenon lamp and a three-band AM1.5D simulator. The triple-junction cell exhibited an efficiency of 31% at AM1.5G illumination and an efficiency of 37-39% at 70x real sun concentration. The external quantum efficiency was also measured at different temperatures. The temperature coefficients up to 80°C, for the open circuit voltage, the short circuit current density, and the conversion efficiency were determined to be -7.5mV/°C, 0.040mA/cm²/°C, and -0.09%/°C, respectively.
Effect of plasma treated Ag/indium tin oxide anode modification on stability of polymer solar cells

General information
State: Published
Ministry of Education publication type: A1 Journal article-refereed
Organisations: Optoelectronics Research Centre, Research group: Surface Science, Frontier Photonics
Authors: Augustine, B., Sliz, R., Lahtonen, K., Valden, M., Myllylä, R., Fabritius, T.
Number of pages: 5
Pages: 330-334
Publication date: 2014
Peer-reviewed: Yes

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Volume: 128
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Scopus rating (2015): SJR 1.869 SNIP 1.896 CiteScore 5.16
Scopus rating (2014): SJR 2.204 SNIP 2.396 CiteScore 5.87
Scopus rating (2013): SJR 2.174 SNIP 2.582 CiteScore 5.58
Scopus rating (2012): SJR 2.435 SNIP 2.707 CiteScore 5.25
Scopus rating (2011): SJR 2.175 SNIP 2.638 CiteScore 5.16
Scopus rating (2010): SJR 2.524 SNIP 2.121
Scopus rating (2009): SJR 1.991 SNIP 1.977
Scopus rating (2008): SJR 1.654 SNIP 1.458
Scopus rating (2007): SJR 1.359 SNIP 1.488
Scopus rating (2006): SJR 1.447 SNIP 1.799
Scopus rating (2005): SJR 1.141 SNIP 1.619
Scopus rating (2004): SJR 0.932 SNIP 1.178
Scopus rating (2003): SJR 0.992 SNIP 1.34
Scopus rating (2002): SJR 1.042 SNIP 1.114
Scopus rating (2001): SJR 0.896 SNIP 1.235
Scopus rating (2000): SJR 0.828 SNIP 0.986
Scopus rating (1999): SJR 0.701 SNIP 0.75
Original language: English
DOIs:
10.1016/j.solmat.2014.05.043

Bibliographical note
Contribution: organisation=orc,FACT1=1
Portfolio EDEND: 2014-09-10
Publisher name: Elsevier BV
Source: researchoutputwizard
Influence of surface hydroxylation on the oxidation of FeCr in O2 and air

General information
State: Published
Ministry of Education publication type: B2 Part of a book or another research book
Organisations: Optoelectronics Research Centre, Research group: Surface Science
Authors: Hirsimäki, M., Hannula, M., Lahtonen, K., Urpelainen, S., Valden, M.
Number of pages: 2
Pages: 1-2
Publication date: 2014

Host publication information
Title of host publication: Max-Lab Activity Report 2013. Reports 2013 Synchrotron Radiation. Beamline I511-1
Place of publication: Lund, Sweden
Publisher: MAX-LAB
Links:
https://www.maxlab.lu.se/node/1913

Bibliographical note
Contribution: organisation=orc,FACT1=1<br/>Portfolio EDEND: 2014-12-15
Source: researchoutputwizard
Source-ID: 480
Research output: Scientific › Chapter

Surface Modifications and Analysis Methods at Molecular Level

General information
State: Published
Ministry of Education publication type: A4 Article in a conference publication
Organisations: Optoelectronics Research Centre, Research group: Surface Science, Department of Physics, Research group: Ultrafast and intense lasers, Research group: Nanophotonics
Publication date: 2014

Host publication information
Title of host publication: Abstracts of the 28th International Conference on Surface Modification Technologies, SMT28, Tampere University of Technology, Tampere, Finland, June 16-18, 2014
Place of publication: Tampere
Publisher: Tampere University of Technology
Links:

Bibliographical note
xabstract
Research output: Scientific - peer-review › Conference contribution

In Situ XPS Studies of Electrochemically Negatively Polarized Molybdenum Carbide Derived Carbon Double Layer Capacitor Electrode

General information
State: Published
Ministry of Education publication type: A1 Journal article-refereed
Organisations: Optoelectronics Research Centre, Research group: Surface Science, Frontier Photonics
Authors: Tonisoa, A., Kruusma, J., Pärna, R., Kikas, A., Hirsimäki, M., Nommi, E., Lust, E.
Number of pages: 10
Pages: A1084-A1093
Publication date: 2013
Peer-reviewed: Yes
Optimization of interfacial oxidation properties of FeCr SOFC interconnect alloy

General information
State: Published
Ministry of Education publication type: B2 Part of a book or another research book
Organisations: Optoelectronics Research Centre, Research group: Surface Science
Authors: Ali-Löytty, H., Jussila, P., Hirsimäki, M., Valden, M.
Number of pages: 2
Pages: 1-2
Publication date: 2013

Host publication information
Title of host publication: Max-Lab Activity Report 2012. Reports 2012 Synchroton Radiation. Beamline I311-XPS
Place of publication: Lund, Sweden
Publisher: MAX-LAB
Links:
https://www.maxlab.lu.se/cmis/display?id=workspace%3A%2F%2FSpacesStore%2F0f1d8b0b-533a-48e6-a4cf-a85090776f76
https://www.maxlab.lu.se/node/1693

Bibliographical note
Contribution: organisation=orc,FACT1=1<br/>Portfolio EDEND: 2013-11-29
Source: researchoutputwizard
Source-ID: 1912
Research output: Scientific › Chapter