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ACADEMIC PROFILE

Degree	Year	Institution	Marks
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M-Tech(EE)	*2011*	**Tripura University (A Central University)**	*66%*
B.Tech(ECE)	*2008*	BITM,Santiniketan(West Bengal University of Technology)	*7.7(DGPA)*

PROFESSIONAL EXPERIENCE	
RESEARCH EXPERIANCE (Before PHD enrolment 10 months)	***May 2013 – April 2018*** ▪ **Junior** and **Senior Research Fellow (JRF/SRF)** for **DST, GOI** sponsored project entitled as **"Solar Photovoltaic HUB at BESU"**(DRC/DST/CEGESS/HS/043/10-11) attached to the Centre of Excellence for Green Energy and Sensor System, **Bengal Engineering and Science University(BESU) , Shibpur.**

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TEACHING EXPERIECE	***May 2018-Till now*** ▪ ***Now Working as Sr. Assistant Professor under the Department of Electrical and Electronics Engineering in Madanapalle Institute of Technology and Science (UGC, Autonomous)*** ***January' 2012- May 2013*** ▪ Working as **Assistant Professor** under the Department of Electrical Engineering in **Dream Institute of Technology (Approved by AICTE & Affiliated to WBUT)**. ***August' 2011- December'2011*** ▪ Working as **Guest Faculty** in the Department of **M.Tech (Electrical Engineering)**, **Tripura University** (A central University). ***December' 2007 - March' 2009*** ▪ I have one year working experience in ASSURGENT TECHNOLOGY SOLUTIONS PVT LTD as a junior web developer.
ACHIEVEMENT	Fabrication of**India's 1stUltrathinMonocrystalline flexible Silicon Solar Cell**. (Highlighted in IIEST, Shibpur's website). https://www.iiests.ac.in/IIEST/ResHighlightDetails/14
Field of Interest	Solar cell fabrication,Renewable Energy Systems, Semiconductor devices, Instrumentation, Microprocessors, Embedded systems,3rd generation solar cells, thin film solar cells, Surface passivation of C-Si solar cell, Solar tracking systems,Solar radiation assessment.
Technical Skills	▪ Able to operate **PECVD** (Plasma enhance chemical vapor deposition) cluster tool and developed different dielectrics and anti reflecting coatings like silicon nitrite (SiNx), SiO2 and i-layers for solar cell applications. ▪ Able to create front and back metallization of C-Si solar cells with the help of **Screen printer, belt furnace and firing furnace.** ▪ **Developed Microcontroller and Interfacing Lab for UG curriculum.**
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Journal Papers:

1)**Arijit Bardhan Roy,** Kalluri Vinay Kumar, Moumita Saha , "Light management studies by using different surface texturing for thin c-Si solar cells", **Applied Physics A(Springer)** volume 127, 119 (2021), **Impact Factor: 2.5 (SCI)**

2) Arijit Bardhan Roy, Sonali Das, Avra Kundu, Chandan Banerjee and Nillohit Mukherjee, "c-Si/n-ZnO based flexible solar cells with silica nanoparticles as light trapping metamaterial", **PhysicalChemistry Chemical Physics**, 2017, 19,12838, **RSC,Impact Factor: 3.5(SCI)**

3)Arijit Bardhan Roy, Arup Dhar, Mrinmoyee Choudhuri, Sonali Das, S Minhaz Hossain and Avra Kundu, "Black silicon solar cell: analysis optimization and evolution towards a thinner and flexible future", **Nanotechnology** 27 (2016) 305302 (12pp), **IOP publishing**, **Impact Factor:3.4(SCI)**

4) Apurba Baral, Gourab Das, **Arijit Bardhan Roy**, Arindam Kole, Nillohit Mukherjee, Sukanta Bose, "Unique back reflector architecture for advanced optical management in sate of the art single junction superstrate μc-Si:H solar cells", **IEEE Journal of Photovoltaic,**Volume: 10, Issue: 5,10.1109/JPHOTOV.2020.3008263 ,2020, **Impact Factor:3.8(SCI)**

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1) M. Choudhuri, A. Dhar, P. Banerjee, **A. B. Roy**, A. Kundu , Junctionless Ultra-thin c-Si Solar cell with Metamaterial Back Reflector,Third International Conference on Nanotechnology for Better Living, 25-29 may 2016, NIT, Srinagar,India.
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5) Pritam Banerjee, Nabin CMondal,**Arijit Bardhan Roy**, AvraKundu, "Tuning the Resonance Frequency of Metamaterial Nanoparticles: Silver Core and PVP Cladding ," **IEEE Xplore, 978-1-5090-3564-9/16,**2016.
6) Sumit Verma, Pritam Banerjee, Mohan Kumar,**Arijit Bardhan Roy**, Nabin C Mondal, Avra Kundu Sonali Das, "Spherical Silica Micro-Lenses for Enhanced LightAbsorption in Thin Crystalline Silicon Solar Cell", **IEEE Xplore, 978-1-5090-3564-9/16,** 2016.

Patents:

Title	Type	Ref.No	Status
1. **Nanostructured gas sensors for healthcare and medical sector.**	Indian	202141035750	Drafted on (7.8.21)
2. **A novel method for nano-carbon energy-storage material with specific high energy.**	Indian	202141037976	Drafted on (22.8.21)
3. **Vehicle to Grid (V2G) for EV charging energy management system**	Indian	202141051391	Drafted on (9.11.21)
4. **An electric vehicle having renewable and eco-friendly energy resources through solar power.**	Indian	202141057745	Drafted on (12.12.21)

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Book Chapters:

1. Jayasree Roy Sharma, Debolina Saha**, Arijit Bardhan Roy**,Gourab Das, Snehanshu Patra, A K Barua and Sumita Mukhopadhyay, "Application of N-doped ZnO Nanorods in Heterojunction Si Solar Cells", The Physics of Semiconductor Devices, **Springer Nature Switzerland AG**, ISSN no- 1867-4941, https://doi.org/10.1007/978-3-319-97604-4_55, 2019

2. **Arijit Bardhan Roy**, Kalluri Vinay Kumar, Moumita Saha, APPLICATION AND UTILIZATION OF HIGH ASPECT RATIO ANTI REFLECTIVE Si NANO STRUCTURE EMBEDDED OPTICAL SENSOR FOR IOT APPLICATIONS, Internet of Things and Data Mining for Modern Engineering and Healthcare Applications, **CRC Press**, 2022 (Accepted)

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2	NCES (Introduction to Research)	NPTEL	8 weeks (Dec, 2020)	Do
3	AI For Everyone	Coursera	5.20.20	Do
4	AstroTech: The Science and Technology behind Astronomical Discovery	Coursera	05/23/2020	Do
5	Electric Power Systems	Coursera	05/31/2020	Do
6	From the Big Bang to Dark Energy	Coursera	07/01/2020	Do
7	COVID-19: Operational Planning Guidelines and COVID-19 Partners Platform to support country preparedness and response	WHO (World health organization)	17.5.2020	Do
8	Infection Prevention and Control (IPC) for Novel Coronavirus (COVID-19)	WHO (World health organization)	19.05.2020	Do
9	Simulation Exercise Management:	WHO (World health	21.05.2020	Do

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Materials Science & Processing

T.C. : SOLAR ENERGY MATERIALS AND APPLICATIONS

Light management studies by using different surface texturing for thin c-Si solar cells

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Received: 24 March 2020 / Accepted: 10 December 2020

Abstract

To realize the high-efficiency solar cell, surface texturing method is one of the well-liked and potential way for the last few decades. Though different research groups have adopted several types of nanostructured anti-reflective geometries for front surface texturing of solar cell but till today which type of dimension will be fruitful to get maximum efficiency of the cell is yet to be exposed. In this work, we are trying to give a comparative study of different types of nanostructure geometries like circle, ellipse, trapezoidal and triangle (or cone) made by same material silicon and try to investigate their potential to give minimum reflectance for better cultivation of electron–hole pair into the junction of the cell. Through this study, it was validated that the triangle or cone structures have the competence to satisfy maximum criteria like low reflectance, Omni-directionality with better harvesting of electron–hole pair into the junction of the solar cell without compromising its material and processing cost. Further these types of structures (cone or triangle) have the potentiality to enhance the efficiency (more than 27% compared to other structures) of solar cell with noticeable increment of short-circuit current of the device. Finally, we fabricated the optimized nanotriangle (or nanocone) geometry through nanosphere lithography technique to realize the structure in real world and found the same optical occurrence which was already explored in our simulation studies.

Keywords Surface texturing · Thin c-Si solar cell · Anti-reflective geometry · Nanocone · Nanotriangle · Nanosphere lithography

1 Introduction

In this present era, majority of the (about 80%) world's energy needs will be fulfilled by fossil fuels to meet the increasing energy demands [1]. As the conventional reserves are very limited in this planet, therefore, overall fossil fuel consumption has been increased approximately 51% from 1995 to 2015 and the usage will increase by about 18% more in 2015–35 [2]. So the continuous usage of fossil fuels will create rigorous environmental problems for our planet in future. To overcome these issues, we have to choose alternative clean energy sources like hydro, solar, wind, biomass, ocean, and geothermal, etc. to protect our enviroment as well as to reduce the dependency on conventional energy [3]. Recently, the diverse groups of researchers are presenting different new and renewable enrgy sources but to mantain the equilibrium between production cost with supply of power is very crucial. In the present age, solar PV technology is the most promising way to meet the current energy demand in a clean and sustainable way.

To improve the efficiency of solar cells, photon harvesting near to the junction is one of the most significant factors. But generally, it will not happen because more than 30–40% of the sunlight will be reflected from the surface and 70–60% absorbed by the solar cell. By reducing reflectance for a wide range of visible spectrum (wavelength of 300–1100 nm), the loss will be reduced by making non-reflective nanostructures on top surface of the solar cell. So, increasing the photon injection into the silicon solar cell without compromising its material and processing cost is the foremost criteria to achieve high-efficiency solar cell. In order to decrease the reflection loss into the solar cell, the most popular method is to

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c-Si/n-ZnO-based flexible solar cells with silica nanoparticles as a light trapping metamaterial

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Herein, we report the fabrication of flexible solar cells based on a crystalline p-Si/n-ZnO heterostructure for the first time. An enhancement of ∼52% in the base efficiency was achieved by the application of spherical SiO_2 nanoparticles as light trapping structures on the top. The use of ZnO not only offers a facile route of synthesis, but also provides an additional advantage of large band bending, leading to notable open circuit voltage and formation of an intermediate ultra-thin barrier layer of Zn_2SiO_4 for minimized carrier recombination. The spherical silica nanoparticles act as nanoresonators, causing absorption hot-spots in the thin silicon absorber, along with the capability of providing wide-angle light-collection. Simulation showed, for the higher angle of incidence, that the silica nanoparticles have the ability to bend light on the same side of the normal to the incident wave-front, thereby acting as a negative index metamaterial (NIM). The flexibility and cost-effectiveness of this device can make it important for the next-generation photovoltaics and roll-to-roll electronics.

1. Introduction

Nowadays, various types of solar cells such as organic, inorganic–organic hybrids, DSSCs, and perovskites are being investigated by researchers; however, conventional c-Si solar cells with and without structural modifications still dominate the photovoltaic technology due to their high efficiency and better stability as compared to those of others.[1–5] There are still some challenges in the conventional 180 μm c-Si solar cell technology, which may act as a barrier for establishing photovoltaic systems as a prime power source in the renewable energy sector. The major drawback of the conventional c-Si solar cell is its high capital cost, thicker absorber layer, and incompatibility with the next-generation flexible electronics. Thus, it is very essential to fabricate stable and flexible c-Si solar cells by a facile synthetic route for compatibility with roll-to-roll processing. For this reason, to achieve low-cost and efficient solar cells, we have to scale down the c-Si wafer thickness, which will allow lower material usage along with flexibility. Shockley reported that an approximately 30 μm Si wafer is sufficient for fabricating high efficiency single-junction c-Si-based solar cells.[6,7] However, to date, the PV industries have shown minimum interest in developing thin c-Si-based solar cells on a large scale. Therefore, it is high time to focus on the c-Si cell fabrication processes that will minimize material consumption without compromising the efficiency. During the past couple of years, there has been a boom in Si-based hybrid heterojunction solar cells, especially for heterojunctions made up with organic hole-transporting materials, as reported by J. He *et al.*[8–10] According to their report, this type of solar cells can achieve conversion efficiency as high as 16.2%.[8] Moreover, it has been theoretically proven that the use of ZnO as an active n-layer as well as an antireflection coating can help to achieve the conversion efficiency of ∼19%.[11] Therefore, in this study, we aimed at introducing a pathway of fabricating thin c-Si/ZnO-based hybrid and flexible solar cells using a 30 μm wafer and SiO_2 nanoparticles (NPs), as light trappers, as a pilot scheme. In the near future, this may lead to large scale production of cost-effective solar cells.

ZnO is an n-type semiconductor with unique properties such as piezoelectric, pyroelectric, optoelectronic, and ultraviolet lasing. It is also a promising material as an antireflecting coating (ARC) and a window layer for solar cell applications.[11–16] In this study, we introduced ZnO for multi-functionality like the n-type counterpart with p-Si to form a heterojunction as well as an ARC material. Spherical SiO_2 nanoparticles are also known to act as Mie resonators, which help to favorably couple light inside the device. Further, note that the refractive index of ZnO is less than that of c-Si but greater than that of both air and silica. This composite layer helps in grading the refractive index mismatch between air and silicon, resulting in more photon injection and subsequent electron–hole pair generation. The wide band-gap

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Black silicon solar cell: analysis optimization and evolution towards a thinner and flexible future

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Abstract

Analysis and optimization of silicon nano-structured geometry (black silicon) for photovoltaic applications has been reported. It is seen that a unique class of geometry: micro-nanostructure has the potential to find a balance between the conflicting interests of reduced reflection for wide angles of incidence, reduced surface area enhancement due to the nano-structuring of the substrate and reduced material wastage due to the etching of the silicon substrate to realize the geometry itself. It is established that even optimally designed micro-nanostructures would not be useful for conventional wafer based approaches. The work presents computational studies on how such micro-nanostructures are more potent for future ultra-thin monocrystalline silicon absorbers. For such ultra-thin absorbers, the optimally designed micro-nanostructures provide additional advantages of advanced light management capabilities as it behaves as a lossy 2D photonic crystal making the physically thin absorber optically thick along with the ability to collect photo-generated carriers orthogonal to the direction of light (radial junction) for unified photon–electron harvesting. Most significantly, the work answers the key question on how thin the monocrystalline solar absorber should be so that optimum micro-nanostructure would be able to harness the incident photons ensuring proper collection so as to reach the well-known Shockley–Queisser limit of solar cells. Flexible ultra-thin monocrystalline silicon solar cells have been fabricated using nanosphere lithography and MacEtch technique along with a synergistic association of crystalline and amorphous silicon technologies to demonstrate its physical and technological flexibilities. The outcomes are relevant so that nanotechnology may be seamlessly integrated into the technology roadmap of monocrystalline silicon solar cells as the silicon thickness should be significantly reduced without compromising the efficiency within the next decade.

S Online supplementary data available from stacks.iop.org/NANO/27/305302/mmedia

Keywords: black silicon, solar cell, micro-nanostructure, flexible, ultra-thin, monocrystalline substrates, nanosphere lithography

(Some figures may appear in colour only in the online journal)

1. Introduction

Black silicon (b-Si)—as the name implies—absorbs almost every incident photon in the visible spectrum and therefore

[4] Equal contribution.

Stacked Back Reflector Architecture for Advanced Optical Management in State-of-the-Art Single-Junction μc-Si:H Solar Cells

Apurba Baral, Gourab Das, Arijit Bardhan Roy, Arindam Kole, Nillohit Mukherjee, and Sukanta Bose

***Abstract*—The present work deals with an advanced technology for efficient light management through back reflection in thin silicon based solar cells, in particular, single-junction microcrystalline silicon (μc-Si:H) solar cells. Semiconductor nanoparticles (Ag_2S NPs) have been chosen to design the back reflector layer (BRL) by embedding them within two thin layers of indium tin oxide (ITO). Owing to its nominal parasitic light absorption over a broad wavelength region (300–1100 nm), the Ag_2S NPs can reflect back a notable amount of light that were supposed to get transmitted through the relatively less thick ($\sim$2 μm) active microcrystalline Si layer, and hence, can function like nanomirrors. Encapsulation of the Ag_2S NPs between the ITO layers provides chemical and physical stability to the nanomirrors. By placing such BRL at the back of this p-i-n based superstrate structure, a significant amount of light (>90%), mainly in the red and near infrared (NIR) region, was found to reflect back to the cell and this resulted in a state-of-the-art photoconversion efficiency of 9.36% for single-junction μc-Si:H solar cells. The reported value is one of the best in the class. As the main light absorption zone for μc-Si:H falls in the red and NIR region (bandgap energy of μc-Si:H is 1.1–1.2 eV), such back reflections become worthy. The experimentally observed facts have also been validated through theoretical simulations.**

***Index Terms*—Advanced optical management, back reflection, microcrystalline silicon (μc-Si:H), nanomirror, solar cells, theoretical validation.**

I. Introduction

THE importance of solar photovoltaics (SPV) among all other available renewable energy technology is well known in the community to address the global energy demand in a greener way. Successful utilization of SPV depends on some critical factors like use of the material, fabrication/production cost, payback time, longevity, and reliability of the proposed technology, to name a few. As crystalline silicon (c-Si) based SPV can well satisfy these points, it is the most popular technology from the point of view of real life applications, till date. However, the thickness of the individual cells ($\sim$150 μm) used in c-Si-based conventional single-junction devices consumes a lot of the material and hence, enhances the cost of the device. To address this problem, the researchers have developed solar cells based on hydrogenated amorphous silicon (a-Si:H) and microcrystalline silicon (μc-Si:H) with relatively less thickness of the active layer [1]. These technologies also involve lesser thermal budget than the conventional c-Si-based technology, and hence, can be designated as more green. These thin-film silicon solar cells (TFSSCs) have the potential to provide large scale solar electricity, however, proper optical management must be done in order to trap more light in the thinner (<2 μm) active layer of either a-Si:H or μc-Si:H cells. Such thickness (i.e., <2 μm) of active layer is too small to absorb photons with longer wavelengths, mainly greater than 600 nm [1]. On the other hand, the thickness of the absorber layer of TFSSCs must be kept as thin as possible to reduce the light-induced degradation (LID), and hence, the only way to maximize light absorption within the cell (over the red and near infrared (NIR) region [1]) is by doing some optical engineering, preferably, by placing a back reflector layer (BRL) at the bottom of a superstrate (p-i-n) TFSSC.

Now, because of some other intrinsic technical disadvantages associated with a-Si:H solar cells like higher LID factor in strong light condition, longevity, and low power output, the applications of them in real life have been minimized. On the other hand, microcrystalline silicon, i.e., μc-Si:H has the intrinsic optical and electrical properties almost like c-Si and the cells can be produced with the smaller thickness ($\sim$2 μm) following a relatively easy flow line and obviously with lesser cost and thermal budget. The power output in μc-Si:H cells is also better than the a-Si:H cells and the former has a lesser LID factor also. Considering these facts, μc-Si:H solar cells are drawing the attention of the researchers in recent days. However, as mentioned earlier, proper optical management must be done in this case also for extracting better power output from the cell. In a TFSSC with p-i-n structure, the thickness of the "p" and "n" layers with their doping parameters controls the open-circuit voltage (V_{oc}) and short-circuit current density (J_{sc}), whereas the thickness of the "i" layer controls the J_{sc}. To achieve better power

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ORIGINAL PAPER

Design Analysis of Heterojunction Solar Cells with Aligned AZO Nanorods Embedded in p-type Si wafer

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Abstract

Higher price-per-watt of silicon (Si) solar cells is still the main bottleneck in their widespread use for power generation due to their expensive manufacturing process. The n-type zinc oxide (n-ZnO) and p-type Si (p-Si) based single heterojunction solar cell is one of the several methods being tried to replace conventional Si single homojunction solar cell technology. In this work, we have explored the possibility of producing photovoltaic materials by employing RF sputtering and hydrothermal technologies. Conductivity of ZnO nanorods has been increased by aluminium (Al) doping. The advantages of using Al doped ZnO (AZO) nanorods (NRs) have been investigated. The integrated reflectance (IR) has been found to be only ~2.86%. Hence, the short circuit current density (J_{sc}) has been increased by minimizing the reflection loss of solar cells. AZO NR array have been developed over several large area (3″ × 3″) textured p-Si wafers to confirm the repeatability. The maximum efficiency of AZO NRs/Si solar cell of 0.8 cm^2 area has been found to be 6.25% for textured p-type Si wafer which is much higher than reported hitherto for this type of solar cell. A simple, low temperature, low cost procedure is thus being proposed, which has the potential of attaining lower cost of production of heterojunction silicon solar cells.

Keywords AZO nanorods · Silicon · Heterojunction solar cell · Antireflection coating

1 Introduction

Zinc oxide (ZnO) as a functional oxide semiconductor material has drawn the attention of the semiconductor industry due to its extensive applicability in short wavelength optoelectronic devices [1–3]. Besides its strong UV photoresponse, capability of operating at high temperature and in harsh environment is particularly choice of interest of many researchers. ZnO films show promising electrical and optical properties in combination with low cost alternatives. With a wide direct bandgap (3.37 eV), ZnO is a low resistivity material, highly transparent in the IR region and absorbs near ultraviolet. These properties of ZnO allow it to be used as a window layer and simultaneously heterojunction partner for heterojunction Si solar cells [4–7], because the key point of heterojunction Si solar cells is the displacement of highly recombination-active contacts from the crystalline surface by insertion of a film with wide band gap semiconductor. With the help of a wide band gap semiconductor, heterojunction Si solar cells physically separate the metal contacts from the active layer; thereby avoid recombination losses. To reach the full device potential, the hetero-interface state density should be minimal [8]. Practically, high band gap semiconductors of only a few nanometers of thickness are potential candidates for this. Their band gaps are wider than those of crystalline silicon (c-Si) and these films can be doped relatively easily, either n- or p-type, allowing for the fabrication (lithography-free) of contacts with record-low values for the saturation-current density. ZnO is an extremely able candidate for this. Application of ZnO in heterojunction Si solar cells offers some advantages such as an excellent blue light response, simple processing steps, low processing temperatures, and non toxicity virtue. Using ZnO over c-Si provides a window for photon transfer which gives a higher built in potential to increase

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