A Review on Potential Applications of Thin Films Photovoltaic Cells using Nanotechnology

M. Aravind
UG Student
Department of Electronics and Communication Engineering
Saveetha School Of Engineering, Saveetha University,
Chennai, India

M. Akilan
UG Student
Department of Electronics and Communication Engineering
Saveetha School Of Engineering, Saveetha University,
Chennai, India

B. N. Ajai Vikash
UG Student
Department of Electronics and Communication Engineering
Saveetha School Of Engineering, Saveetha University,
Chennai, India

P. Bobby Keerthan
UG Student
Department of Electronics and Communication Engineering
Saveetha School Of Engineering, Saveetha University,
Chennai, India

A. Deepak
Associate Professor
Department of Electronics and Communication Engineering
Saveetha School Of Engineering, Saveetha University, Chennai, India

Abstract

This paper reviews about the Potential applications of thin film Photovoltaic (PV) Cells with a common goal of producing high power efficiency of the solar cells by reducing the size of silicon wafers. A new field of nanotechnology has opened up and promising possibilities to reduces the heating effect in the material with thin film PV cells. We discuss about the light trapping effect for cell efficiency using the high surface area in 3-D hierarchical ZnO nanostructures. CdTe thin films were made using a layer-by-layer deposition process consisting of spin coating colloidal CdTe Nano crystals followed by a sintering step.

Keywords: CIGS, CdTe, CdSe, heterojunction, nanocrystal, photovoltaic (PV), ZnO, Thin Film, Nano-tech solar cells

I. INTRODUCTION

Renewable energies are considered as a vital source globally. Photovoltaic cells convert the solar energy into electricity. By using thin film PV cells the efficiency of power can be increased. Since silicon wafers has layers of silicon they have less efficiency to produce power. The growing energy demand and the depletion of conventional energy sources along with global warming threats has motivated researchers to design the most efficient photovoltaic (PV) cells. A PV cell that used sunlight to generate clean electric power was first designed and fabricated by Bell Laboratories in 1955[1,6]. To achieve an overall PV efficiency of at least 15%, six thin film nanotechnologies methodologies were proposed [2]. Colloidal inorganic nanocrystals provide an excellent opportunity for the development of large area thin-film absorbers for photovoltaic (PVs) [5, 7]. Thin film is a more cost-effective solution and uses a cheap support onto which the active component is applied as a thin coating. As a result much less material is required and costs are decreased.

II. THIN FILM SOLAR CELL TECHNOLOGY

A. Amorphous Silicon (a-Si) / Silicon heterojunction cells

It is one of the earliest technologies. This is entirely different from crystalline silicon in the fact that silicon atoms are not located at accurate distances from each other. This causes the electron to move in random direction and has higher band gap (1.7 eV) than crystalline silicon (1.1 eV) [4, 8]. Fabrication of silicon heterojunction cell at low temperatures <150^0c.thin .By hot-wire chemical vapour deposition thin layers of hydrogenated silicon solar cells are deposited, are used as emitter. Further improvement can be made in (a-si: H) by back contacts of both p and n type silicon wafers and employed them in double heterojunction solar cell which has an efficiency of 18.2% .These contacts are deposited and carried out at low temperature <250^0c. Which replaces the diffused field contacts used in single heterojunction solar cell [1, 9]?

B. CIGS technology

Thin film CIGS technology is very optimistic for achieving high power efficiency at a profitable fee. Non vacuum process is used to fabricate CIGS solar cell on both rigid and flexible substrate. An aqueous precursor metal-oxide suspension made from nano particles of Cu, Ia, and Ga oxides is coated onto a Molybdenum(mo) foil or a non-conducting substrate which improves cell efficiency to 8.9 % on polyimide, 13.0 % on Mo foil, and 13.6 % on glass substrate[10,11]. The recorded efficiency of ZnO / CdS thin film solar cells is 19.2% due to higher open-circuit photo voltage and short - circuit photocurrent density [12]. The performance of thin film GaAs solar cell is increased by adding a gold mirror back contact which reduces the thickness of the film and gives an efficiency of 24.5% [1].

C. Enhanced light trapping by metal nano-particles

The process of Enhanced light trapping by metal nano- particles is performed using surface plasmonic effect, which increases the absorption of light over a broad spectral range by increase of light scattering and electric field strengthening [13,14]. The introduction of the metal nano particles in heterojunction with thin film solar cell shows increase in the absorption of light .short-circuit current density, and energy conversion efficiency [2].

D. Sintering CdTe Nanocrystals synthesis

CdTe and CdSe nanocrystals are synthesized by this procedure [16, 17]. Colloidal CdTe nanomaterials are particularly suitable for the application of thin film PV cell due to its effective bandwidth of 1.45eV. Due to the colloidal nature of this material it is harmonious with solution processing methods like spin dip and spray coating. To perform this solution process a sintering process is required to remove the bulk of the organic ligands and to increase the size of CdTe While wide band gap oxides such as ZnO or TiO2 have been the n-type buffer materials for most heterojunction cells based on colloidal nanocrystals, alternative buffer materials remains unknown particularly for sintered CdTe-based solar cells. CdTe/CdSe heterojunction devices based on colloidal nanocrystals produces of ~2% with an open-circuit voltage of 500 ± 20 mV [18]. Progress has been made in improving the power conversion efficiencies of heterojunction solar cells [4].

E. 3-D Hierarchical ZnO nanostructures

ZnO nanostructures are deposited in an aqueous solution. It is done by electrochemical process on the ITO glass substrate at low temperature. For the growth of ZnO film zinc nitrate hydrate is dissolved into 100 ml of deionized water and 100ml of methanol at room temperature. Methanol is used to increase the growth rate of ZnO. It is then heated at 70 ^{o}C. At 65^{o}C nano walls were grown [15]. The 3-D Hierarchical ZnO nanostructures are synthesized by two methods. In the first method the ZnO nanowires are placed on an ITO glass substrate. Second, the asynthesized nanostructures are annealed at 350°C in air.
The hierarchical ZnO nanobushes were obtained by using the annealed nanowires this process was performed at 95^{o}C with a negative DC potential voltage of -2.5V [3].

F. Organic solar cells and Polymer solar cells

The working principle of organic solar cells involves using organic thin film consisting of an electron donor and acceptor pair. Absorption of light promotes the donor onto the exited state, which continuously undergoes electron transfer reaction to transfer one electron to the acceptor molecule, leaving a hole in the donor molecule. The photo-generated charges are then transported and collected at the opposite electrodes to be utilized, before they recombine. Typically the cell has a glass front, a transparent Indium Tin Oxide (ITO) contact layer, a conducting polymer, a photoactive polymer and finally the back contact layer. Since ITO glass substrate is very expensive Carbon Nanotube films are used as the transparent contact layer [19, 20]. They can be made of lower-cost materials [5].

III. CONCLUSION

In recent years, the crystalline silicon played a major role in the production of solar cell. Solar energy losses are typically caused by optical losses because of reflections, carrier losses as a result of poor interface or material quality, heat loss, optical power loss because of wasing the large volume of infra-red light. To enhance energy conversion efficiency, research and development has been motivated on hybrid PV cells utilizing nanotechnologies, especially using quantum dots, nanotubes, and hot carriers. We also present the cost-effective approach to synthesize a ZnO core-shell nanostructures by combining a low temperature electrochemical process with an atomic layer deposition technique, This indicates the core-shell nanostructure are promising for fabricating advanced solar cells. We have demonstrated efficient solar cells based on inverted CdSe/CdTe heterojunction prepared using solution processed nanocrystal thin films followed by a sintering process, the performance was limited due to reduced absorption in the sintered CdTe layer brought about by the CdSe.

REFERENCES

[1] T. K. Manna and S. M. Mahajan, "Nanotechnology in the Development of Photovoltaic Cells", Proc. International Conference on Clean Electrical Power, pp. 379-386, 2007.
[2] Jia-Min Shieh *, Chang-Hong Shen, Ting-Jen Hsueh, Wen-Hsien Huang, Bau-Tong Dai, andFu-Liang Yang NationalNanoDevice Laboratories,"Potential Application of Thin-film Nanotechnologies in Third-Generation Si Solar Cells",2010
[3] Keyue wu, Jingbiao Cui, Department of Physics and Astronomy, University of Arkansas at Litte Rock, Little Rock, Arkansas 72204, USA; 2School of Physics and Material Science, Anhui University,"Fabrication of ahierarchical ZnO/TiO2 Core-Shell Nanostructures for Advanced Photovoltaic Devices",2011
[4] Woojun Yoon, Member, IEEE, Troy K. Townsend, Matthew P. Lumb, Joseph G. Tischler, and Edward E. Foos ,"Sintered CdTeNanocrystal Thin Films:Determination of Optical Constants and Application in Novel Inverted Heterojunction Solar Cells",2014
[5] L. El Chaar, Senior Member, IEEE, L. A. Lamont, Member, IEEE, and N. Elzein, Member, IEEE" PV Technology Industry Update",2010.
[6] Green, M. A.: Silicon Photovoltaic Modules: A Brief History of the First 50 Years, Progress in Photovoltaics: Research and Applications, 2005, vol.13, pp. 447- 455.
[7] J. Tang, K. W. Kemp, S. Hoogland, K. S. Jeong, H. Liu, L. Levina,M. Furukawa, X. Wang, R. Debnath, D. Cha, K. W. Chou, A. Fischer,A. Amassian, J. B. Asbury, and E. H. Sargent, "Colloidal-quantum-dot Photovoltaic's using atomic-ligands passivation," Nat. Mater., vol. 10, pp. 765–771, 2011.
[8] T. Markvart, Solar Electricity, 2nd Edition, Wiley, 2001.
[9] Page, M. R.; Iwaniczko, E.; Xu, Y.; Wang, Q.; Yan, Y.; Roybal, L.; Branz, H. M.; Wang, T. H.: Well-Passivated aSi:H Back Contacts for Double-Heterojunction Silicon Solar Cells, IEEE 4th World Conference on Photovoltaic Energy Conversion (WCPEC -4), Waikoloa, Hawaii, May 7 - 12,2006.
[10] Kapur, V. K.; Bansal, A.; Le, P.; Asensio, O. I.:Nonvacuum Processing of CuIn1-xGaxSe2 Solar Cells on Rigid and Flexible Substrates Using Nanoparticle Precursor Inks, Science Direct, Thin Solid Films 431 - 432, 2003, pp. 53 - 57.
[11] Kapur, V. K.; Bansal, A.; Asensio, O. I.; Le, P.; Shigeoka, N. K.: Fabrication of CIGS Solar Cells via Printing of Nanoparticle Precursor Inks, DOE Solar Program Review Meeting 2004.
[12] Ramanathan, K.; Contreras, M. A.; Perkins, C. L.; Asher, S.; Hasoon, F. S.; Keane, J.; Young, D.; Romero, M.; Metzger, W.; Noufi, R.; Ward, J.; Duda, A.: Properties of 19.2% Efficiency ZnO / CdS / CuInGaSe2 Thin-film Solar Cells, Progress in Photovoltaics: Research and Applications, 2003, vol. 11, pp. 225-230.
[13] D. Derkacs, S. H. Lim, P. Matheu, W. Mar, and E. T. Yub, Appl. Phys. Lett. 89, p.093103 (2006).
[14] V. E. Ferry, M. A. Verschuuren, Hongbo B. T. Li, E. Verhagen, R. J.Walters, Ruud E. I. Schropp, H. A.Atwater, and A. Polman, Opt. Express, 18, p.A237 (2010).
[15] J. B. Cui and U. J. Gibson, "Enhanced Nucleation, Growth Rate, and Dopant Incorporation in ZnO Nanowires," Journal of Physical Chemistry B, vol. 109, pp.22074-22077, 2005.
[16] J. Jasieniak, B. I. MacDonald, S. E. Watkins, and P.Mulvaney, "Solution processed sintered nanocrystal solar cells via layer-by-layer assembly," Nano. Lett., vol. 11, pp. 2856–2864, Jul. 13, 2011.
[17] W. W. Yu and X. Peng, "Formation of high-quality CdS and other II–VI semiconductor nanocrystals in noncoordinating solvents: Tunable reactivity of monomers," Angewandte Chemie Int. Ed., vol. 41, pp. 2368–2371, 2002.
[18] W. Yoon, E. E. Foos, M. P. Lumb, and J. G. Tischler, "Solution processing of CdTe nanocrystals for thin-film solar cells," in Proc. IEEE 38th Photovoltaic Spec. Conf., 2012, pp. 002621–002624.
[19] M. W. Rowell, M. A. Topinka, M. D. McGehee, H. Prall, G. Dennler, N.S. Sariciftci, L. Hu, and G. Gruner, "Organic Solar Cells with Carbon Nanotube Network Electrodes",Appl. Phys. Letters 88, pp. 235061235063, 2006
[20] PV news, Greentech Media and Promotheus Institute, 03/2008 issue http://www.pvtech.org/news/_a/concentrating_solar_power_a_200_billion_business_through_2020/