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Increasing Efficiency of PV Cells using Nanotechnology

Dr Ruchika Chahal

Abstract:

Nanotechnology based PV cells have 80% efficiency which is beyond the capabilities of current photovoltaic technologies, whose performance currently approaches only 43%. An integrated, multidisciplinary, experimental and theoretical effort is now required to drive transformational changes in the way solar cells are conceived, designed, implemented, and manufactured. Nanotechnology can promisingly help us to reach these goals. In particular, significant increases in photovoltaic efficiency and reductions in cost may be realized through engineered devices that exploit spatial and compositional in homogeneities such as surfaces, interfaces, and Nanostructures.

Keywords: Nanotechnology, photovoltaic cells

Introduction: Nanotechnology for Solar Energy Collection and Conversion help achieve that goal. New multifunctional techniques combining Nan scale spatial resolution with ultrafast time resolution are needed to measure fundamental carrier dynamics in individual 3D Nanoscale structures and in Nanostructure arrays. New electromagnetic measurement probe photo induced carrier generation; carrier scattering processes that lead to energy relaxation, trapping, and recombination; as well as carrier transport and localization in individual Nanostructures and heterogeneous assemblies of Nanostructures (such as organic materials, Nano wires, and quantum dots) are needed. Overall improvement in cost/performance of Nanotechnology-enabled photo voltaics may involve a balance between cost- reduction and efficiency and stability improvements. All costs should be considered, including long-term for manufacturing of Nanotechnology-based materials and devices. Wherever possible, earth-abundant materials should be used. In addition, the unique environmental impact (cost) of the Nanomaterials used in these devices needs to also be considered.

Litrature Review: Nanotechnology can contribute to the improvement of PV device efficiency in a number of ways, including but not limited to the following:

Enhanced light coupling:Efficiency of PV Cells can be increased byincreasing the light incidenton the active light sensitive material will improve the efficiency of PV devices.

Nanostructured antireflection coatings can miracalously reduce loss of reflection, and light capture can be improved by exploiting photonic crystals, plasmonic guiding, and other Nanoscale coupling structures.Economicallymanufacturing such structures into multilayer heterostructure devices is an important and interesting area of research.

Engineered interfaces: Appropriately engineered interfaces can enhance the collection and trapping of light, control the flow of photocarriers, and play a major role in a number of technologies. However, interfaces can be a source of interdiffusion, defects, and impurities that degrade performance. Improving the carrier dynamics at interfaces is critical, as is the ability to control interfaces between dissimilar materials. There is evidence that integration of carbon Nanotubes and other Nanowires into the solar cell junction interface as a bonding agent has the potential to improve multijunction solar light transmission and energy conversion efficiency.

Bandgap engineering: Many current-generation photovoltaic devices utilize a single energy bandgap that cannot perfectly match the energies of sunlight photons.Some energy is absorbed but is lost to heat and is not converted to electricity. New structures must be designed and fabricated that exploit multiple junctions, multi-exciton generation, multiple energy levels, hot- carrier junctions and intermediate band solar cells (IBSC) and other techniques/ phenomena to maximally convert light energy to electricity. Better theoretical and experimental understanding and control of quantum confinement is required and the development of semiconductor Nanostructures such as quantum dots, quantum rods, quantum wiresas well as carbon Nanotubes to enhance generation . Develop improved measurement and characterization techniques to support Higher Efficiency and Advanced Manufacturing.

The promise of new high efficiency photovoltaic devices incorporating Nanotechnology will not be commercially realized until scalable low-cost fabrication and manufacturing technologies are developed.Well- ordered Nano-scale arrays capable of efficiently generating and transporting carriers which will be required to maximize photon absorption and minimize electron- hole recombination. Current laboratory-scale fabrication and manufacturing methods to realize such Nano-architectures, including self assembly, nucleation and growth, growth and etch, are cost prohibitive today on the large scale required to meet the nation's renewable energy goals. Development of fabrication methods that are economical and scalable to mass-production is required. Using Nanocoatings or Atomic Layer Deposition (ALD) approaches are applicable and potentially scalable technologies.We can also consider of manufacturing techniques that maximize use of readily available materials and minimize need for recycling and end of life-time waste issues. Improve the stability and longevity of Nanotechnology-based photovoltaic devices Some novel photovoltaic devices that have been proposed utilize Nanostructured materials that offer promise of improved efficiency and/or reduced manufacturing cost compared to conventional single, multi-, or micro crystalline devices, but some may also have limited useful lifetimes under exposure to radiation (i.e., sunlight including UV) and other environmental factors (e.g., temperature variations, oxygen, moisture, dirt, etc.). Understanding why degradation occurs is a first step in developing solutions to prevent such degradation. There is a need for new approaches to improving the stability and lifetimes, or new approaches for renewing these materials in situ after they have been deployed in photovoltaic arrays.

Outcomes:Expected Outcomes Laboratory demonstration of next-generation photovoltaics that close the gap halfway between current best laboratory and theoretical maximum efficiencies by 2020. Multi- junction concentrating photovoltaic (CPV) devices with improvements such as Nanostructured antireflection coatings will reach efficiencies of 53percent. Copper Indium Gallium Diselenide (CIGS) and CdTe devices with better engineered interfaces and fine-tuned band gap engineering at the Nanoscale will reach efficiencies 24% and 23%, respectively . Single junction silicon devices withimprovements as such better band gap engineering will reach efficiencies of 28%.

NNI Signature Initiative: Photovoltaic devices applications with Nano- engineered improvements are unattended, zero-maintenance operations with high reliability along space.They have non- concentrated efficiencies up to 47% with 25 years lifetime.This will save manpower

Fabrication and manufacturing technologiesby 2020 close the performance gap halfway between best laboratory PV devices nano PV modules in a cost-effective manner.

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