ESE-830 Next-generation Photovoltaics 3 CHs

Course Description

1. Nowadays sustained, effective and rapid, mitigation of greenhouse gas is critical to avoid dangerous climate change. In this scenario, photoelectric conversion - the direct conversion of light from the sun to electricity- denotes the largest single untapped low-carbon energy source for our planet. Therefore it is important to train our students developing their understanding in not only the existing photovoltaic (PV) technologies but also to explore the next generation solar cell technologies. After the successful commercialization of 1st generation (silicon wafer based) solar cells in the mid of twentieth century, thin film technologies were introduced as cost effective alternatives achieving pretty comparable efficiencies. Since last two decades researchers instigated thinking about how this novel technology might grow with time. Nonetheless it was realized that post-2020, there would be pressure on PV industry to upsurge performance beyond this level. As a matter of fact, a developed PV industry would drive towards ever-increasing power conversion efficiency further reducing the cost of the solar cells! Hence another generation of solar cells came into existence with high potential of efficiency enhancement beyond the one achieved by existing technologies and several innovative concepts are being introduced today. Keeping in mind the demands of PV industry and the everyday developing solar cell technologies, there arise a need for the development of a new course on next-generation solar cells.

Course Objectives

2. In this course, we will develop a vital understanding of how the innovative nanostructured solar cells convert light to electricity, how these solar cells are fabricated, how the device performance is evaluated, and how the PV technologies are being developed. After an overview of potential of solar light conversion on earth, as compared to other renewable technologies and the fossil fuels, a brief outline will be included for the existing PV technologies**.** The students will acquire knowledge on the processes that take place during solar cell operation: light absorption, carrier thermalization, charge transport, charge separation, charge recombination and charge

extraction. Moreover each such process will be elaborated for a variety of emerging solar cell technologies based on innovative nanostructured/photoactive materials. Using the knowledge of nanomaterials physics, charge generation mechanism and transport kinetics, and the cell structure engineering, the students will be able to not only fabricate but also to assess and critique the drawbacks and potential of the modern photovoltaic technologies, including multi-junction/tandem solar cells, bulk heterojunctions (organic), Graetzel cells, nanostructure-based, hybrid perovskite, and other third generation PVs. Post-Grad students, and also the Ph.D scholars, can apply this knowledge towards a solar energy project of their choice. Other activities may be incorporated into the course, including lab scale training on solar cell fabrication or a tour of some PV-related institute/ industry.

Course Outcomes

3. Understand the working mechanisms and advanced concepts of next generation photovoltaics. Acquire the knowledge of several fabrication and characterization techniques to be employed for nanostructured/photoactive solar energy materials. Design and fabricate the new generation solar cells with low cost and long-term stability. Employ the IV and JV characterizations on these light harvesting devices.

Detailed Contents with suggested contact hours

No.	Topics	Book	CHs
1.	a. **Solar Energy Resource and the Solar Cells** (1) Historical perspective (2) Overview of world energy challenges and competing energy technologies (3) Resources and availability: Options for capturing solar energy (4) The sun, blackbody radiation, atmospheric absorption, solar spectra (AM0, AM1, AM1.5)	SW & MG	2

	(5) Core concepts of a Solar Cell: semiconductors, P-N junction, photo-diode.		
2.	b. **Existing Photovoltaic Technologies** (1) Crystalline Si Solar cells and Technologies: Monocrystalline, Polycrystalline (2) Thin Film Solar Cells and Technologies: Amorphous silicon, Cadmium Telluride, CIGS. (3) Need of Advanced Generation Solar Cells	PW	4
3.	c. **New Concepts in Photovoltaics: Developing Technologies** (1) High Performance (2) Low cost (3) New Market Possibilities	TW, MG & AAA	3
4.	d. **Nanostructured Materials for Solar Cells: Common Characteristics** (1) Quantum Effects (2) Concept of Excitons (3) Bandgap Tuning (4) Photoluminescence effects **Synthesis Techniques** (1) Wet-Chemical (2) CVDs (3) PVDs (4) Other Nano Powder based Techniques	TS & EL	9
5.	e. **Exploring Light Harvesting Properties of Nanostructured/Photoactive Materials using various**	TS	4

	Characterization Techniques: (1) Optical (2) Structural (3) Morphological (4) Electrical (5) Electrochemical		
6.	f. **Fabrication and Characterization of Emerging PVs** (1) Organic Photovoltaics (OPVs) (2) Hybrid Photovoltaics (3) DSSCs (4) Quantum Dot Solar cells (QDSCs) (5) Perovskite Solar Cells (PSCs) (6) and others	MG	18
7.	**Laboratory Demonstrations/Visits of:** g. Few of the synthesis and characterization techniques employed for nanostructured/photoactive materials Fabrication of some selected solar cell types		3
8.	h. **Economic Breakdown of Technology:** (7) Materials, manufacturing, installation. (8) Life cycle analysis, (9) Energy pay-back time, (10) Growth of PV market,	MG & AAA	2
Total			45

Recommended Reading (including Textbooks and Reference books).

1	Physics of Solar Cells: From Principles to New Concepts (2007)	Peter Wurfel	PW
2	Nanostructured Materials: Electrochemical Energy Production and Storage (2009)	Edson Roberto Leite	EL
3	Nanostructured Materials for Solar Energy Conversion (2006)	Tetsuo Soga	TS

4	Optical Properties and Spectroscopy of Nanomaterials (2009)	Jin Zhng Zhang	JZ
5	Dye-Sensitized Solar Cells (2010)	K. Kalyanasundaram	KK
6	Third Generation Photovoltaics: Advanced Solar Energy Conversion (2006)	Martin A. Green	MG
7	Next Generation of Photovoltaics: New Concepts (2012)	Ana Bel´en Crist´obal L´opez Antonio Mart´ı Vega Antonio Luque L´opez	AAA
8	Applied Photovoltaics (2007)	S.R. Wenham M.A. Green M.E. Watt R. Corkish	SW