Department of Sustainable Energy Engineering
Indian Institute of Technology Kanpur

Proposal for Course Modification

Course Title		**Solar Photovoltaics**
Number		SEE-613
Credits(L-T-P[C])		3-0-0-9
Departments proposing the course	:	Sustainable Energy Engineering
Name of the Proposer(s)	:	Rajeev Jindal and Sudarshan Narayanan
Offered for	:	PG Students of SEE and other departments or programs, 3/4th year UG students
Status of the course	:	PG Elective / UG Elective
Prerequisite(s) for the course	:	Consent of Instructor / SEE-602 / completion of any other course on introductory solid-state physics and semiconductors
Other faculty members interested in teaching	:	Ashish Garg, Srinivas Karthik Yadavalli
Other Departments/Programmes whose students are expected to take up the courses	:	MSE, MSP, PHY, EE, ME, CHE, CHM

Course Objectives

The course aims to help students understand the physics and application of solar photovoltaics, which is the fastest growing source for renewable energy generation. The course reviews the basic semiconductor physics of photovoltaic materials and various structures in which these devices can function. It also covers the various generations of solar cells, including the device structure, manufacturing, and application aspects. Finally, it delves into the various stages of cell to module to system development, associated operational issues, and their potential solutions.

Expected Learning Outcomes

The students will be able to understand the working principle of solar photovoltaics, its dependence on radiation, material processing, device fabrication, etc. The students will be able to learn how to characterize the solar cells and how to utilize them in the end application. They will also be able to understand the practical issues concerning degradation, and other field issues. The course should help the students who are willing to learn about this field, and guide them in appropriately identifying topics of interest for future research.

Course outline

Introduction to solar cells: Solar spectrum, the concept of airmass, history of solar cells, economics, status, emerging technologies, and recent development.

P-N junctions: Energy band diagram, Operation of p-n junction in forward and reverse bias, depletion width, drift-diffusion currents, I-V characteristics of P-N junction in dark and under illumination.

Characterization of solar cell devices: Open circuit voltage, short circuit current, fill factor, efficiency, quantum efficiency, equivalent circuit of the solar cell, series and shunt resistances, diffusion length, and the effect of recombination processes.

A brief overview of different types of solar cells: First-generation technologies: primarily Si-based, Second-generation technologies (low cost): thin films (a-Si, CdTe, CIGS), Third generation (high efficiency and low cost): Organic solar cells, multi-junction, Perovskite solar cells, Comparative Performance, PV Processing with emphasis on migration from solar cells to modules to systems, present status and outlook.

Field Application: Enhancing capacity utilization factor (tracking), optical performance, effect of dust and possible mitigation strategies, system design, and related software. Module recycling and concept of material circularity.

Lecture-wise breakup

Topics	**No. of lectures (approximate)**
Introduction to Solar cells / Introduction and motivation, including solar policy in India	2
Solar radiation and angles	2
Basics of Semiconductors, Recap of Semiconductors with emphasis on R-G Centers	4
Work-function and Junctions a) Metal–semiconductor interface b) Semiconductor i. P-N ii. P-i-N iii. P-N heterojunction	6
Characterization of solar cell devices	5
Brief overview of different types of solar cells a) First-generation technologies: Primarily Si-based and GaAs (Including Si cell manufacturing aspects and issues) b) Second-generation technologies: thin films (a-Si, CdTe, CIGS) c) Third generation: Organic solar cells, Perovskite solar cells d) Multi-junction and tandem solar cells	11
Enhancing solar cell / module performance: • Light management • Trackers	3
Solar cells to modules to systems and related software	3
Field issues, module recycling, material sustainability	3

Textbooks, reference books, suggested readings, and any other references:

- Robert F. Pierret, Semiconductor Device Fundamentals, Pearson

- Jenny A. Nelson, The Physics of Solar Cells, World Scientific Publishing Company
- Luque and Hegedus, Handbook of Photovoltaic Science and Engineering, John Wiley Publications
- S.M. Sze, Physics of Semiconductor Devices, Wiley
- Ben G. Streetman, Solid State Electronic Devices, Prentice Hall India
- Reviews and journal articles

Course Proposed By	Recommended/ Not recommended	This course is approved/ Not approved
 (Rajeev Jindal)  (Sudarshan Narayanan)	Convenor, DPGC (SEE)	Chairman, SPGC

Lecture wise breakup

Topics	@ of lectures (approximate)
Introduction to Solar cells	3
Basics of Semiconductors	5
Optoelectronic processes in solar cells	8
P-h' junction	5
Device characterization of solar cells	5
First generation solar cells	5
Second-generation solar cells	5
Third generation solar cells	5
Total number of lectures	41

Textbooks, reference books, suggested readings and any other references

- Safa O. Kasap, Optoelectronics & Photonics: Principles & Practices: International Edition, Pearson Education Limited
- Robert F. Pierret, Semiconductor Device Fundamentals, Pearson
- Jenny A. Nelson, The Physics of Solar Cells, World Scientific Publishing Company
- Ben G. Streetinan, Solid State Electronic Devices, Prentice Hall India
- Charles Kittel, Introduction to Solid State Physics, Wiley
- Reviews and journal articles

Course proposed by	Recommended/ Not recommended	This course is approved/ not approved
(Kanwar Singh Nalwa)	Convener, DPGC (SEE)	Chairman, SPGC