Module Handbook Photovoltaics Northumbria

Fakultät 5: Mathematik und Naturwissenschaften Institut für Physik *Subject:* European Master in Renewable Energy Summer Term 2017	*Category:* - Master Module *Degree award:* - Master
Emphases: -	*Sections:* -
Module reference number/Title: **pre351 - Photovoltaic Cell and Module Technology**	
Duration: 1 semester *Cycle:* once a year *Type of module:* mandatory *Level:* MM (master module) *This module should be taken in* 2nd semester	*Type of program:* - Lectures, Laboratories *Language:* English *Attainable credit points:* 10,00 CP *Workload:* 200 hours *Required attendance:* 54 hours
Person responsible for the programme: Professor N. Pearsall	*Person responsible for this module:* Dr. I. Forbes
Alternative person(s) responsible for this module: Dr. V. Barrioz	*Examiner(s):* Another member of staff from the Department (not teaching on the module) and the external examiner (from another UK University) appointed for the course.

Objective of the module / skills:

After completing the module, the student will

- have a critical understanding of the physical principles relating to the operation and design of photovoltaic cells.
- be able to compare and analyse the design and operation of the main types of photovoltaic cells.
- have a critical understanding of the effect of material purity and crystallinity on the device performance.
- be able to compare and evaluate different methods for the fabrication of photovoltaic cells in terms of device properties and manufacturing issues.
- have a critical understanding of the principles of operation and design of photovoltaic modules.
- be able to compare and evaluate methods for the fabrication of photovoltaic modules, including performance and manufacturing issues.

Content of the module:

1. Physics of Solar Cell Devices:

- Solar spectrum, solar constant and air mass.
- Important semiconductors. Important solar cell devices.
- Drude theory. Breakdown of classical theory. Quantum theories of conduction: E-k curves, energy bandgap and effective masses, direct and indirect transitions.
- Carrier statistics in equilibrium - intrinsic and extrinsic behaviour.
- Carrier transport, mobilities and diffusion coefficients, scattering mechanisms. Hall effect.
- Non-equilibrium behaviour: direct, indirect and surface recombination, carrier lifetime and diffusion length.
- Current density and continuity equations, examples of solutions.
- Optical and thermal properties of semiconductors. Antireflection coatings. p-n junction in equilibrium: built in voltage, depletion region and depletion capacitance. Derivation of I-V characteristics in the dark.
- Spectral response. Ideal diode under illumination: open circuit voltage, short circuit current, solar conversion efficiency, fill factor.
- Variations of photocurrent and open circuit voltage with incident light intensity. Optimum energy bandgap of a solar cell.
- Loss mechanisms. Introduction to tandem/ multijunction concepts.
- Real diodes: recombination and generation in the depletion region, effects of series and leakage resistance on ideal behaviour. Schottky diodes and Ohmic contacts. Interface states.
- Heterojunctions: Anderson model, current transport models, heterojunction window effect.
- Effects of temperature and radiation on solar cell performance.

2. Solar Cell Fabrication Technologies
- Introduction: Important semiconductors and solar cell devices.
- Important semiconductor parameters. Effects of lattice vibrations, impurity atoms and other crystal imperfections on these parameters.
- Purification of silicon: chemical, zone refining and gettering. Segregation coefficient.
- Crystal growth: Bridgmann methods, Czochralski method and Floating Zone Methods.
- Advanced epitaxial growth methods: MBE, MOCVD, LPE AND VPE.
- Low cost thin film deposition methods: thermal evaporation methods, sputtering methods and wet chemical methods, e.g electrodeposition, autocatalytic deposition, spray pyrolysis and screen printing.
- Compensation doping: alloying, solid state diffusion and ion implantation. Dielectric deposition - thermal oxidation of silicon, LPCVD and PECVD silicon oxide and nitrides.
- Photolithography. Etching - wet and dry methods.
- Overview of characterisation techniques for semiconductor materials and cells.
- Overview of design of silicon, III-V and thin film solar cells for terrestrial and space applications and the design and fabrication of photovoltaic modules made from these cells.

Suggested reading:

S.M. Sze and Kwok K. Ng: Physics of Semiconductor Devices, Wiley, 2006

Lewis Fraas and Larry Partain (eds): Solar Cells and Their Applications, Second Edition, Wiley, 2010.

Journals of „Solar Energy Materials and Solar Cells" and „Progress in Photovoltaics“.

Proceedings of IEEE Photovoltaic Specialist Conferences.

Proceedings of European Photovoltaic Solar Energy Conferences.

Comments:	*Helpful previous knowledge:*

- *Weblink:* - *Prerequisites for admission:* -	Core module of European Master on Solar Energy *Associated with the module(s):* -

Maximum number of students / selection criteria: - *Types of examinations:* Written exam (60%, 3 hours) Laboratory Reports (40%) *Examination periods:* At the end of the semester *Registration procedure:* -

Fakultät 5: Mathematik und Naturwissenschaften Institut für Physik *Subject:* European Master in Renewable Energy Summer Term 2017	*Category:* - Master Module *Degree award:* - Master
Emphases: -	*Sections:* -

Module reference number/Title:

pre352 - Advanced Photovoltaic Cell Design

Duration: 1 semester *Cycle:* once a year *Type of module:* mandatory *Level:* MM (master module) *This module should be taken in* 2nd semester	*Type of program:* - Lectures, seminars *Language:* English *Attainable credit points:* 5,00 CP *Workload:* 100 hours *Required attendance:* 24 hours
Person responsible for the programme: Prof. N. Pearsall	*Person responsible for this module:* Dr. R.Fu
Alternative person(s) responsible for this module: -	*Examiner(s):* -

Objective of the module / skills:

After completing the module, the student will be able to

- Critically appraise the choice of semiconductors used and the design and fabrication methods used to produce an advanced PV device.
- Critically appraise the characterisation methods used with semiconductor materials and with PV devices.
- Perform a literature review on advanced PV devices to a professional standard.
- Present data and information both verbally and in the written form to a professional standard.

Content of the module:

1. Introduction

- Flat plate modules. Concentrator solar cells. Multijunction concepts.
- Overview of types of solar cell developed - status of the technologies.

2. Advanced Devices

- Crystalline Silicon Devices: High efficiency crystalline silicon designs incorporating surface passivation, light trapping and vertical contacts. Cost reduction strategies: ribbon fed growth and thin film silicon devices.
- Polycrystalline silicon.
- III-V Devices: Heteroface cell. Radiation resistance. GaAs, InP and GaSb-based devices. Designs for use under high concentration.
- Space applications. Physics of multijunction cells. Quantum well devices.

- Thermophotovoltaic devices.
- Thin Film Solar Cells: Amorphous silicon. CdTe and chalcopyritebased solar cells. Typical cell structures. Methods of fabrication. Applications. Polymer cells, Gratzel cells.

3. Advanced Characterisation Methods

- Material characterisation: X-ray diffraction, electron and ion beam characterisation methods, optical characterisation, Van der Pauw length.
- Device Characterisation: DLTS, photoluminescence and PAS.
- Solar simulators.
- Measurement of fill-factor, solar conversion efficiency and spectral response.
- I-V-T and C-V-f measurements. Radiation damage

4. Literature Review

This will be undertaken for one of the following topics: crystalline silicon devices, III-V devices or thin film devices.

Suggested reading:

S.M.Sze and Kwok K. Ng: Physics of Semiconductor Devices, Wiley, 2006

Lewis Fraas and Larry Partain (eds): Solar Cells and Their Applications, Second Edition, Wiley, 2010.

Journals of „Solar Energy Materials and Solar Cells" and „Progress in Photovoltaics“.

Proceedings of IEEE Photovoltaic Specialist Conferences.

Proceedings of European Photovoltaic Solar Energy Conferences.

Comments:

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Weblink:

-

Prerequisites for admission:

-

Helpful previous knowledge:

Core module of European Master on Solar Energy

Associated with the module(s):

-

Maximum number of students / selection criteria:

-

Types of examinations:

Written report (literature review): The module assessment is in the form of a review of approximately 3,000 words, chosen by the student from a list of PV device categories.

Examination periods:

At the end of the semester

Registration procedure:

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Fakultät 5: Mathematik und Naturwissenschaften Institut für Physik *Subject:* European Master in Renewable Energy Summer Term 2017	*Category:* - Master Module *Degree award:* - Master
Emphases: -	*Sections:* -

Module reference number/Title:

pre353 – Photovoltaics, Economics, Policy and Environment

Duration: 1 semester *Cycle:* once a year *Type of module:* mandatory *Level:* MM (master module) *This module should be taken in* 2nd semester	*Type of program:* - Lectures, seminars *Language:* English *Attainable credit points:* 5,00 CP *Workload:* 100 hours *Required attendance:* 24 hours
Person responsible for the programme: Prof. N. Pearsall	*Person responsible for this module:* Prof. N. Pearsall
Alternative person(s) responsible for this module: -	*Examiner(s):* -

Objective of the module / skills:

After completing the module, the student will be able to:
- Critically analyse the international policies relating to photovoltaics and other energy technologies focusing on the strategic, environmental and economic implications of these policies
- Perform an economic and/or environmental analysis of a photovoltaic system.

Content of the module:

1. Economic Analysis
- Economic theory - net present value, effect of interest rates, definition of capital and recurrent costs
- Production economics - definition of production costs, economies of scale, projected manufacturing costs
- Subsidies and tariff issues - effect of electricity supply costs on system viability
- Financing mechanisms - review of international financing mechanisms for purchase and operation of systems

2. Policy Issues
- Market development and projections
- Review and appraisal of government policies and market development schemes
- Security of supply
- Climate change issues
- Energy for development - role of photovoltaics

3. Environmental Impact Assessment
- Process definition for module production
- Hazard assessment
- EC environmental directives
- Embodied energy calculations
- Energy payback times and ratios
- Calculation of associated CO_2 and other emissions

Suggested reading:

Journal of "Progress in Photovoltaics"

Proceedings of European Photovoltaic Solar Energy Conferences

Proceedings of IEEE Photovoltaic Specialist Conferences

IEEEXplore database

Environmental data sources

Government literature (including European Commission and international) on renewable energy promotion

IEA Photovoltaic Power Systems Programme reports

Comments:

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Weblink:

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Prerequisites for admission:

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Helpful previous knowledge:

Core module of European Master on Solar Energy

Associated with the module(s):

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Maximum number of students / selection criteria:

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Types of examinations:

Written report (essay, approximately 3,000 words) and Presentation (10 minutes)

Examination periods:

At the end of the semester

Registration procedure:

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Fakultät 5: Mathematik und Naturwissenschaften Institut für Physik *Subject:* European Master in Renewable Energy Summer Term 2017	*Category:* - Master Module *Degree award:* - Master
Emphases: -	*Sections:* -
Module reference number/Title: **pre354 - Photovoltaic System Technology**	
Duration: 1 semester *Cycle:* once a year *Type of module:* mandatory *Level:* MM (master module) *This module should be taken in* 2nd semester	*Type of program:* - Lectures, seminars *Language:* English *Attainable credit points:* 10,00 CP *Workload:* 200 hours *Required attendance:* 48 hours
Person responsible for the programme: Prof. N. Pearsall	*Person responsible for this module:* Prof. N. Pearsall
Alternative person(s) responsible for this module: -	*Examiner(s):* another member of staff from the Department (not teaching on the module) and the external examiner (from another UK University) appointed for the course.
Objective of the module / skills: After completing the module, the student will be able to: - Assess the system requirements for both grid connected and stand alone applications. - Design and develop a PV system by evaluating complex customer needs in relation to an application - Critically evaluate the performance of a PV system in comparison to a theoretical model of such a system, calculating yields and efficiencies - Analyse the main system losses and compare methods for minimising these for various system designs	
Content of the module: 1. Basic systems design - Photovoltaic (PV) arrays, support structures - Electrical Connections and wiring issues - BOS components - Stand alone and grid connected systems - System sizing 2. Stand-alone systems - Applications	

- Performance assessment and sizing
- Standards and regulations

3. Grid connected systems - electrical
- Inverter systems and electrical supply issues
- Grid connection regulations
- Harmonic content, reactive power, and wiring issues

4. Grid connected systems - large scale
- Design of large scale systems
- Case studies

5. Grid connected systems - building integrated
- System design and sizing
- Energy in buildings and building components
- Installation and operation
- Case studies

6. Concentrator systems
- Design of concentrator systems
- Operation and maintenance

7. Monitoring and performance analysis
- Monitoring specifications
- Yield and performance ratio, and MTBF
- Operational issues and maintenance

8. Standards and regulations
- Standards for construction and operation
- Regulations governing system design and operation
- Health and safety issues

9. Space systems
- Array configurations
- Quality control and assessment
- Design of systems
- BOL and EOL design tradeoffs

Suggested reading:

Messenger, R., & Ventre, J.:. Photovoltaic Systems Engineering, 3rd edition, Taylor & Francis, 2010.

Wenham, S.: Applied Photovoltaics, 3rd edn., Earthscan, 2011.

Journals:
- Progress in Photovoltaics
- Renewable Energy
- Various IEEE journals relating to electrical engineering

Databases and Websites
- IEA PV Power Systems Programme (www.iea-pvps.org)
- European Photovoltaic Industries Association (http://www.epia.org/home/)
- PVGIS web site (http://re.jrc.ec.europa.eu/pvgis/)

Other Resources
- Measurement data from system trials
- PVSyst software

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Weblink:
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Prerequisites for admission:
-</td><td>Helpful previous knowledge:
Core module of European Master on Solar Energy
Associated with the module(s):
-</td></tr>
<tr><td colspan="2">Maximum number of students / selection criteria:
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Types of examinations:
Written exam (60%, 3 hours)
Written report (40%, design assignment): Feasibility report, maximum of 10 pages plus technical appendices
Examination periods:
At the end of the semester
Registration procedure:
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