The University Of Sheffield.

Electronic & Electrical Engineering.

EEE6216 ENERGY EFFICIEINT SEMICONDUCTOR DEVICES

Credits: 15

Course Description including Aims

The efficient use of energy is of critical importance to future growth and well-being, providing a mechanism to reduce global emissions and to offset the impact of increasing fuel costs. Semiconductor devices can play can crucial role in this key global challenge, providing options which can both improve energy efficiency and also means for renewable energy generation. The course describes four key sectors where semiconductor devices are making considerable impact on energy efficiency. Current approaches for **Solid state lighting** using light emitting diodes are described which provide an efficient means to light our future living and working environments. A major focus of this sub-module will be the development of gallium nitride materials from research through to the mass-production of lighting systems. The current status of organic LED materials will also be discussed. A second segment discusses modern **Display Technologies** focusing on new and emerging approaches such as LED backlit LCD displays, full LED panels, projection displays and the opportunities for laser displays. Semiconductor approaches for **Energy Generation** are described in a third section. This will focus on the important role of semiconductor in photovoltaics (solar cells), but will also discuss thermal energy recovery and the use of semiconductor devices in photo-electrolysis. A final section describes **Energy Efficient Semiconductor Devices,** looking at various approaches to reduce the power consumption of electrical and photonic devices and systems and also the use of semiconductor detectors in remote thermal and environmental sensing to assist the achievement of energy efficient devices and systems.

Course Objectives

On successful completion of this module the students should be able to:

1. Understand the need for energy efficiency and its context against ever increasing global energy demands.
2. Understand that semiconductor devices can play a crucial role in reducing energy consumption and describe the major areas of future impact.
3. Understand the fundamentals of solid-state lighting, form materials to lighting systems, with particular emphasis on GaN LED technology.
4. Have knowledge of present-day energy efficient display technologies and introduce possible future developments utilizing full-colour LED and laser technology
5. Describe the basic operation of semiconductor solar cells and gain knowledge over different device and system approaches. Understand the importance of semiconductor photovoltaics within in a range of renewable energy options.
6. Understand alternative energy generation methods, such as thermo-photovoltaic and photo electrolysis methods

7. Understand the fundamental issues and present-day technological approaches being taken in electronics and photonics to achieve future energy efficient devices. Understand the potential impact of this within the communications, computer processing and power conversion sectors
8. Gain knowledge of the use of semiconductor detectors for thermal sensing to assist energy efficiency. Develop a wider understanding of the use of a range semiconductor sensors in environmental sensing applications

Detailed Syllabus

- **Introduction:** Global energy demands and environmental challenges, the need for energy efficient electronic and photonic devices, role of semiconductor devices in energy efficiency, key sectors, opportunities and challenges **(2 Lectures: MH)**
- **Solid state lighting**: Light emitting diode (LED) principles, Gallium Nitride LED device technology, GaN LED operating characteristics, current trends, key technology challenges, future prospects, Organic LED device technology, Organic LED operating characteristics, current trends, key technology challenges, LED Lighting systems: colour rendering, power management.**(7 Lectures TWang/RS)**
- D**isplay Technologies: Int**roduction to display technologies & basic principles, Liquid Crystal displays and backlighting approaches, LED and OLED full-colour display technologies, Optical image projection technologies, digital light processing, Laser projection**. (6 lectures: GJW/MH)**
- **Energy generation:** Principles of solar energy conversion using photovoltaics (PV), PV materials and device approaches, PV systems, solar cell efficiency; current state of the art, future challenges, Thermal energy recovery (Thermophotovoltaic devices), Photo-electrolysis for fuel generation. **(6 lectures: JPRD/RS)**
- **Energy efficient semiconductor devices:** Energy efficient photonic devices; key principles, current approaches, future applications. Energy efficient electronic devices; basic principles, device scaling, low power integrated circuits, discrete devices for power conversion. Semiconductor optical detectors for thermal sensing; basic techniques, discrete devices, thermal imaging, brief introduction to remote environmental sensing (gas, chemical, biological etc) **(9 lectures: KMG, MH, CHT)**

Recommended Previous Courses

Students are required to have a background which covers basic semiconductor device structure, electronic and optical properties together with some previous knowledge of semiconductor technology. Sheffield undergraduates should have taken the modules EEE118 “Electronic Devices” and EEE225 “Analogue and Digital Devices” and passed in previous years. PGT students need to have taken external courses with equivalent learning outcomes to these modules (see module descriptions for those courses)

Assessment

Assessment is primarily in the form of a 2 Hour Examination the end of semester 2. Candidates must choose any three out of four questions (75% total marks)
A short interim test is performed in February based on semester 1 concepts (10%)
An assignment on the development of a infrared detection system takes place around Easter time (10%)
Finally, an assignment called ‘making estimates of power savings’ takes place at the end of the taught course (5%).

Recommended Books

S.M.Sze and M.J Lee *Semiconductor Devices: Physics and Technology* Wiley 2012

Optional

R. Hainich and O.Bimber	*Displays: Fundamentals and Applications*	CRC Press 2011
A.Zukauskas, M. Shur, R. Gaska	Introduction to Solid-State lighting	Wiley 2002
K.Mertens	*Photovoltaics: Fundamentals, Technology and Practice*	Wiley 2014

UK-SPEC/IET Learning Outcomes

Outcome	Supporting Statement
SM1m / SM1fl	Students will develop a comprehensive understanding of the underlying physical and chemical scientific principles behind the operation of energy efficient electronic and photonic devices. Assessed by exam and by assignments.
SM3fl	The course will introduce the climatic, social, economic and political concepts which are driving the development of energy efficient semiconductor devices. Students will also be able to critically evaluate potential energy savings across different sectors and to apply general concepts within many different engineering projects. Assessed by exam and by assignments.
SM4m	The course will introduce mathematic models to describe device operation which will be applied to understand device performance, with a particular focus on parameters which influence energy efficiency. Assessed by exam.
SM6m	The course will introduce the climatic, social, economic and political concepts which are driving the development of energy efficient semiconductor devices. Students will also be able to critically evaluate potential energy savings across different sectors and to apply general concepts within many different engineering projects. Assessed by exam and by assignments.
EA1m / EA1fl	The course will focus on state-of-the art technological approaches and will include elements of research led innovation, including those taking place at Sheffield. The students should leave this course with a good understanding of existing technologies and an appreciation of the potential of emerging approaches. Assessed by exam and by assignments.
EA2m	The course aims to give a comprehensive grounding for all key materials, device and systems approaches concerning energy efficient semiconductor devices. Assessed by exam and by assignments.
D2m	The course will describe the opportunities for energy saving using semiconductor technologies and examine the key technological constraints. The underlying risk, sustainability, safety and security issues will be discussed. Assessed by exam and by assignments.
D1fl	The course deals with uncertainty regarding deployment costs and performance data within power generation and power saving schemes. A specific assignment asks students to make estimates of power savings based on their assessment of the available data. From this, they are asked to state whether an energy saving project is financially viable or not and on what terms.
D3m / D3fl	The course deals with uncertainty regarding deployment costs and performance data within power generation and power saving schemes. A specific assignment asks students to make estimates of power savings based on their assessment of the available data. From this, they are asked to state whether an energy saving project is financially viable or not and on what terms.
D5m	The impact of electricity consumption on climate change and the needs for secure, efficient, renewable deice solutions runs throughout this course. The economic and political factors influencing the roll-out of technologies such as solid state lighting and photovoltaics will be discussed. Assessed by exam and by

assignments.

ET2m / ET2fl	Students will develop knowledge of the critical economic and social importance of semiconductor device developments to reducing global energy consumption and/or providing sources of renewable energy. Assessed by exam and by assignments. One assignment has a particular focus on making estimates of energy savings.
ET5m / ET5fl	European directives eg: the classification of consumer devices according to energy efficiency, the banning of certain items eg: standard incandescent lamps are described. Government subsidies towards photovoltaic power generation are discussed
EP2m	The course discusses the application of different semiconductor materials, different device structures and different systems of devices applied to the aims of energy efficiency. Students should be left with an understanding of state of the art capabilities and future potential in each of the materials and device areas. Assessed by exam and by assignments.
EP3p	At the end of the course the students will have a good knowledge of all aspects relating to the application of energy efficient semiconductor devices, including the appropriate choice of materials, the advantages and disadvantages of different device structures and the configuration of systems designed to generate or to save electrical energy. Assessed by exam and by assignments.
EP1fl	The course discusses the application of different semiconductor materials, different device structures and different systems of devices applied to the aims of energy efficiency. Students should be left with an understanding of state of the art capabilities and future potential in each of the materials and device areas. Assessed by exam and by assignments.