Photovoltaic and Renewable Energy Engineering

Course Outline

Term 2 2021

SOLA3020

Photovoltaic Technology and Manufacturing

Contents

1. Staff contact details

Contact details and consultation times for course convenor:

Name: Prof Bram Hoex
Office location: TETB 132
Tel: (02) 9385 7934
Email: b.hoex@unsw.edu.au
Microsoft Teams Video Chat Hours: 11 am – 1 pm Tuesday (you can always send a message in MS Teams)

Contact details and consultation times for additional lecturers/demonstrators/lab staff

Demonstrator:
Name: Mr Alvin Mo
Email: Mr Alvin Mo
Microsoft Teams Video Chat Hours: Workshop time.

Please see the course Moodle.

2. Important links

- Moodle
- Health and Safety
- Student Resources
- UNSW Timetable
- UNSW Handbook
- Engineering Student Support Services Centre
- UNSW Photovoltaic and Renewable Energy Engineering

3. Course details

Credit points

This is a 6 unit-of-credit (UoC) course and involves 4 hours per week (h/w) of scheduled online contact (2 hours Q&A and 2 hours Workshop).

The normal workload expectations of a student are approximately 25 hours per term for each UOC, including class contact hours, other learning activities, preparation and time spent on all assessable work.

You should aim to spend about 10-12 h/w on this course. The additional time should be spent in making sure that you understand the lecture material, completing the set assignments, further reading, and revising for any examinations.

Contact hours

	Day	Time	Delivery Mode
Lectures	N/A	2 hrs/wk	Moodle links/MS Teams videos
Q&A session	Tuesday	11 am to 1 pm	MS Teams
Workshop	Thursday	3 pm – 5 pm	MS Teams

All classes in T2 2021 will be online. Please consult this course's Moodle module for details about delivery.

Summary and Aims of the course

Silicon photovoltaic modules comprise ~90% of the photovoltaic modules manufactured and sold worldwide. This course introduces students to the technology used to manufacture screen-printed silicon solar cells and important manufacturing concepts such as device design, yield, throughput, process optimisation, reliability, in-line quality control and fault diagnosis. Using the versatile SunSolve platform, the students will explore various aspects of solar cell optimisation and directly assess its impact on the PV module performance. Optionally, the students can also fabricate aluminium back surface field (Al-BSF) solar cells using the virtual producation line "PV Factory".

The aims of this course are:

- To introduce students to the technologies used to manufacture silicon photovoltaic modules;
- To expose students to a solar cell manufacturing environment and important manufacturing concepts such as device design, yields, throughput, process optimisation, reliability, in-line quality control and fault diagnosis; and
- To develop students' ability to optimise a solar cell production line involving many inter-related processes and processing parameters.

Student learning outcomes

After successful completion of this course, you are able to:

1. Apply an understanding of the physics and chemistry underlying the main photovoltaic manufacturing processes to the optimisation of screen-printed solar cell production lines;
2. Analyse solar cell performance and losses through the use of common testing and characterisation techniques;
3. Use an experimental methodology and apply important manufacturing concepts such as device performance, yield, throughput, quality control to optimise solar cell production lines; and
4. Communicate an awareness of emerging manufacturable solar cell technologies.

This course is designed to address the learning outcomes (LO) below and the corresponding Engineers Australia Stage 1 Competency Standards for Professional Engineers as shown below. The full list of Stage 1 Competency Standards may be found in Appendix A.

	Program Intended Learning Outcomes		Relevant LO
PE1: Knowledge and Skill Base	PE1.1 Comprehensive, theory-based understanding of underpinning fundamentals	✓	L01, L02
	PE1.2 Conceptual understanding of underpinning maths, analysis, statistics, computing		
	PE1.3 In-depth understanding of specialist bodies of knowledge	✓	L01, L02
	PE1.4 Discernment of knowledge development and research directions		
	PE1.5 Knowledge of engineering design practice	✓	L01,L03
	PE1.6 Understanding of scope, principles, norms, accountabilities of sustainable engineering practice		
PE2: Engineering Application Ability	PE2.1 Application of established engineering methods to complex problem solving	✓	L03
	PE2.2 Fluent application of engineering techniques, tools and resources	✓	L02, L03
	PE2.3 Application of systematic engineering synthesis and design processes		
	PE2.4 Application of systematic approaches to the conduct and management of engineering projects		
PE3: Professional and Personal Attributes	PE3.1 Ethical conduct and professional accountability		
	PE3.2 Effective oral and written communication (professional and lay domains)	✓	L04
	PE3.3 Creative, innovative and pro-active demeanour		
	PE3.4 Professional use and management of information		
	PE3.5 Orderly management of self, and professional conduct		
	PE3.6 Effective team membership and team leadership		

4. Teaching strategies

Delivery Mode:
The teaching strategy for this course comprises online content (videos & website) and blended workshop sessions. The online video series will present theory related to manufacturing technology and processes and up-to-date information about available equipment, costing and quality control resources. Also, some select seminars from the School of Photovoltaic and Renewable Energy Engineering (SPREE) are included which will go into detail in some important aspects of the course.

All workshop sessions require the use of SunSolve. A tutor will be available to give assistance during each of the scheduled workshop sessions.

The course contains a substantial component of self-learning through the experience gained via operating SunSolve simulation. The main textbook for this course is the PV-Manufacturing.org website which was first released in January 2018 and is continuously updated (let the course convenor know if you find any mistakes!). This website describes the main processes used in photovoltaic manufacturing with tailored animations and videos. The PV-Manufacturing.org website is complemented by additional information provided via Moodle & MS Teams such as the lecture videos and slides.

Learning in this course
You are expected to read/view all the online material and attend all workshops to maximise learning. Group learning is also encouraged. UNSW *assumes* that a self-directed study of this kind is undertaken in addition to attending face-to-face classes throughout the course.

Workshop classes
Attendance at the workshop classes is compulsory from Week 1 to 10 (except Week 6). In the workshop classes, you will work in small groups on optimisation exercises using SunSolve. You will also need to use Microsoft Excel to perform basic statistical analyses on processes cell data that you download from SunSolve. In some exercises, you may also need to use some of the features of Excel Stat. On the completion of the workshop class, your tutor will check each group's simulation results and ensure that you can answer a short quiz correctly about the process that you were optimising. You will receive marks for each workshop from Weeks 1 to 10 (10% of your final mark).

5. Course schedule

Indicative online course content schedule:

Period	Summary of Content
Week 1	Current status of the photovoltaic market
Week 2	Crystal growth and wafering
Week 3	Wet chemistry: cleaning and texturing
Week 4	Junction formation and electron-hole pair generation/recombination
Week 5	Antireflection coating and surface passivation
Week 6	*Flexibility week*
Week 7	Metallisation and cell testing
Week 8	Current and future module fabrication
Week 9	Manufacturing statistics and photoluminescence imaging
Week 10	Recent trends in photovoltaics

Indicative Workshop Schedule:

Period	Summary of Workshop Program
Week 1	Introduction to SunSolve and basic statistics
Week 2	Optimisation of surface texture
Week 3	Group presentations
Week 4	Optimisation of bill of materials
Week 5	Optimisation of antireflection coatings
Week 6	*Flexibility week*
Week 7	Optimisation of metallisation
Week 8	Bifacial vs monofacial solar cells
Week 9	Optical losses in heterojunction solar cells
Week 10	SIRF visits & Assignment 2 assistance

6. Assessment

Assessment overview

Assessment	**Group Project?** (# Students per group)	**Length**	**Weight**	**Learning outcomes assessed**	**Assessed material**	**Due date and submission requirements**	**Deadline for absolute fail**	**Marks returned**
Quiz	No	Up to 20 multiple choice questions	10%	1 – 4	Course content of that week	End of each week (excluding Week 6)	End of the week	Instant
Tutorial participation	No	Questions checked by your demonstrator	5%	1 – 4	Course content	During workshop	Following week	Instant
Group presentation	Yes (4)	Up to 15 minutes	5%	4	Presentation skills and handling of questions.	Week 3 workshop	Week 4 (alternative is a 1,000 word essay on a chosen topic)	End of Week 4
Assignment 1	No	3 – 4 multipart questions	20%	1, 2, 4	Course material up to Week 4	End of Week 5	Standard penalty clause[1]	End of Week 6
Assignment 2	Yes (2)	3 – 4 multipart questions	20%	1 – 4	Course material up to Week 8	End of Week 10	Standard penalty clause[1]	End of Week 11
Final Exam	No	3 – 4 multipart questions	40%	1 – 4	All course material	TBD	Exam rules	TBD

[1] 30% of the maximum possible mark for the assessment item on the due date, plus 10% per 24 hours after that.

Assignments

Presentation

All submissions are expected to be neat and clearly set out. Your results are the pinnacle of all your hard work and should be treated with due respect. Presenting results clearly gives the marker the best chance of understanding your method; even if the numerical results are incorrect.

Submission

Work submitted late without an approved extension by the course coordinator or delegated authority is subject to a late penalty of 30% of the maximum possible mark for the assessment item on the due date, plus 10% per 24 hours after that.

The late penalty is applied per calendar day (including weekends and public holidays) that the assessment is overdue. There is no pro-rata of the late penalty for submissions made part way through a day.

Work submitted after the 'deadline for absolute fail' is not accepted and a mark of zero will be awarded for that assessment item.

For some assessment items, a late penalty may not be appropriate. These are clearly indicated in the course outline, and such assessments receive a mark of zero if not completed by the specified date. Examples include:

a. Weekly online tests or laboratory work worth a small proportion of the subject mark, or
b. Online quizzes where answers are released to students on completion, or
c. Professional assessment tasks, where the intention is to create an authentic assessment that has an absolute submission date, or
d. Pass/Fail assessment tasks.

Marking

Marking guidelines for assignment submissions will be provided at the same time as assignment details to assist with meeting assessable requirements. Submissions will be marked according to the marking guidelines provided.

Examinations

You must be available for all quizzes, tests and examinations.

Final examinations for each course are held during the University examination periods: February for Summer Term, May for T1, August for T2, and November/December for T3.

Please visit myUNSW for Provisional Examination timetable publish dates.

For further information on exams, please see the Exams webpage.

Special consideration and supplementary assessment

If you have experienced an illness or misadventure beyond your control that will interfere with your assessment performance, you are eligible to apply for Special Consideration prior to submitting an assessment or sitting an exam.

Please note that UNSW now has a Fit to Sit / Submit rule, which means that if you attempt an exam or submit a piece of assessment, you are declaring yourself fit enough to do so and cannot later apply for Special Consideration.

For details of applying for Special Consideration and conditions for the award of supplementary assessment, please see the information on UNSW's Special Consideration page.

7. Expected resources for students

Reference Books
S. R. Wenham, M. A. Green, M. E. Watt, and R. Corkish (2006) “Applied Photovoltaics” 2nd Edn. Blue book.

On-line Resources

- PV-Manufacturing.org
  - *PV-Manufacturing.org was developed to become the de facto standard educational resource about PV manufacturing for scholars and professionals working in the PV field. The website contains text complemented by tailored animations and videos about the solar cell manufacturing process. This website was developed by the SOLA3020 team so is perfectly aligned with the course and consequently is your main resource for this course. We are constantly looking at improving the website, so please let us know if you have any ideas how to improve it further!*
- SunSolve
  - *SunSolve is a online cloud-based ray tracing software which can be used to assess the optical and electrical performance of PV modules. The platform gives you a lot of freedom to design and optimise your PV modules.*
- PV Factory
  - *PV Factory is an online simulation of how screen-printed solar cells are manufactured. The simulation is hosted by PV Lighthouse and can be accessed at factory.pvlighthouse.com.au.*
- Moodle
  - *As a part of the teaching component, the learning management system (LMS) Moodle will be used to disseminate teaching materials, host forums and occasionally quizzes. Assessment marks will also be made available via Moodle: https://moodle.telt.unsw.edu.au/login/index.php.*

Announcements and Discussion Board

Announcements concerning course information will be given in on MS Teams and/or on Moodle. A Discussion Board will also be established on MS Teams for you to post questions or initiate course-related discussions.

UNSW Library website: https://www.library.unsw.edu.au/

Moodle: https://moodle.telt.unsw.edu.au/login/index.php

8. Course evaluation and development

Feedback on the course is gathered periodically using various means, including the UNSW myExperience process, informal discussion in the final class for the course, and the School's Student/Staff meetings. Your feedback is taken seriously, and continual improvements are made to the course based, in part, on such feedback.

In this course, recent improvements resulting from student feedback include:

- The development of PV-Manufacturing.org.
- The development of animations to explain key processes.
- The introduction of weekly quizes as formative feedback.
- The development of the SunSolve workshops.

9. Academic honesty and plagiarism

UNSW has an ongoing commitment to fostering a culture of learning informed by academic integrity. All UNSW students have a responsibility to adhere to this principle of academic integrity. Plagiarism undermines academic integrity and is not tolerated at UNSW. *Plagiarism at UNSW is defined as using the words or ideas of others and passing them off as your own.*

Plagiarism is a type of intellectual theft. It can take many forms, from deliberate cheating to accidentally copying from a source without acknowledgement. UNSW has produced a website with a wealth of resources to support students to understand and avoid plagiarism, visit: student.unsw.edu.au/plagiarism. The Learning Centre assists students with understanding academic integrity and how not to plagiarise. They also hold workshops and can help students one-on-one.

You are also reminded that careful time management is an important part of study and one of the identified causes of plagiarism is poor time management. Students should allow sufficient time for research, drafting and the proper referencing of sources in preparing all assessment tasks.

If plagiarism is found in your work when you are in first year, your lecturer will offer you assistance to improve your academic skills. They may ask you to look at some online resources, attend the Learning Centre, or sometimes resubmit your work with the problem fixed. However more serious instances in first year, such as stealing another student's work or paying someone to do your work, may be investigated under the Student Misconduct Procedures.

Repeated plagiarism (even in first year), plagiarism after first year, or serious instances, may also be investigated under the Student Misconduct Procedures. The penalties under the procedures can include a reduction in marks, failing a course or for the most serious matters (like plagiarism in an honours thesis) even suspension from the university. The Student Misconduct Procedures are available here: www.gs.unsw.edu.au/policy/documents/studentmisconductprocedures.pdf

10. Administrative matters and links

All students are expected to read and be familiar with UNSW guidelines and polices. In particular, students should be familiar with the following:

- Attendance
- UNSW Email Address
- Special Consideration
- Exams
- Academic Honesty and Plagiarism
- Equitable Learning Services

Appendix A: Engineers Australia (EA) Competencies

Stage 1 Competencies for Professional Engineers

	Program Intended Learning Outcomes
PE1: Knowledge and Skill Base	PE1.1 Comprehensive, theory-based understanding of underpinning fundamentals
	PE1.2 Conceptual understanding of underpinning maths, analysis, statistics, computing
	PE1.3 In-depth understanding of specialist bodies of knowledge
	PE1.4 Discernment of knowledge development and research directions
	PE1.5 Knowledge of engineering design practice
	PE1.6 Understanding of scope, principles, norms, accountabilities of sustainable engineering practice
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	PE2.2 Fluent application of engineering techniques, tools and resources
	PE2.3 Application of systematic engineering synthesis and design processes
	PE2.4 Application of systematic approaches to the conduct and management of engineering projects
PE3: Professional and Personal Attributes	PE3.1 Ethical conduct and professional accountability
	PE3.2 Effective oral and written communication (professional and lay domains)
	PE3.3 Creative, innovative and pro-active demeanour
	PE3.4 Professional use and management of information

	PE3.5 Orderly management of self, and professional conduct
	PE3.6 Effective team membership and team leadership