School of Photovoltaic and Renewable Energy Engineering

SOLA9120 – Advanced Photovoltaic Manufacturing

Course Outline – Term 3 2019

1 Administration

Course staff:

Course Convener:	Prof Gavin Conibeer, TETB 245 (K-H6-132), g.conibeer@unsw.edu.au
Lecturers:	Prof Gavin Conibeer, Dr Ran Chen, Dr Rhett Evans, Dr Nathan Chang
Tutor:	Kean Khoo, Adrian Shi

Consultations:

For all enquiries about the course, please contact the course convenor. A regular weekly consultation time will be announced during the lecture in Week 1. For all other questions or enquiries, you are encouraged to ask the lecturer after class or post your question on the Discussion Board on Moodle.

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

Keeping Informed:

All course material and announcements will be posted on Moodle. Please note that you will be deemed to have received this information, so you should take careful note of all announcements.

Credits:

This is a 6 UoC course and the expected workload is 13–15 hours per week throughout the 10-week term.

2 Course Description

Silicon photovoltaic solar cells have reached the modern age of high-volume manufacturing. Solar cell manufacturing capacity has expanded 100-fold in the past 15 years and has reached 100 gigawatts of annual production. Photovoltaics engineers, scientists and managers must have a good working understanding of how solar cells are manufactured, improved and sustained in real solar cell factories, in order to succeed in their fields.

Students enrolled in this class will learn about the manufacture of silicon solar cells, specifically about engineering in the manufacturing environment. The course covers several engineering tools/methods used by engineers to improve solar cell performance and reduce solar cell cost in manufacturing, namely statistical decision making, cost modelling and regression modelling. Students will use these tools in the course's virtual laboratory – the Virtual Cell Factory – where they will work as virtual employees of the "Virtual Cells Inc." company. This company is in dire financial straits, and students will work to "save the company" from imminent bankruptcy.

Students who successfully complete this course will have a practical understanding of the manufacturing engineering skills/tools that engineers use to make improvements in cost and performance in a real solar cell factory environment.

Assumed Knowledge

Students should have a good foundation in basic mathematics, statistics, physics, and chemistry.

Learning Objectives of This Course

Students who successfully complete this course will:

1. Be able to create good quality graphical models that are appropriate for the data being analysed, including scatter plots, bar charts, histograms, distribution histograms, population distribution histograms, variability diagrams, Pareto charts, and more.
2. Have a good understanding of the normal probability distribution and be able (1) plot the normal distribution, (2) integrate the normal probability distribution over a range using Excel, Minitab and/or standard tables, (3) compute Z and T values using Excel, Minitab and or standard tables.
3. Be able to analyse samples of normal distributed populations to extract (1) an estimate of the mean, (2) an estimate of the standard deviation, and (3) confidence intervals on the mean when the standard deviation is either known or estimated.
4. Be able to compute a statistical comparison of means and draw appropriate conclusions for several cases of the Z (standard deviation known) and T (standard deviation unknown), and for one (test of mean) or two samples (difference of means).
5. Have a good understanding of basic product cost accounting methods and be able to construct cost behaviours models, transactions/conversions, T-accounts, COGM/COGS computations, and financial summary statements.
6. Understand basic manufacturing process-cost modelling and be able to construct a process-cost model from basic cost inputs of throughput, yield, materials, labour etc.
7. Be able to construct a single-factor, polynomial regression model, including experiment design, regression coefficient determination, testing of the model and use of the model to make decisions about engineering improvements/changes.
8. Be able to construct a multiple-factor, polynomial regression model using the Screening-to-RSM Design of Experiments approach, including experiment design, screening of significant factors/interactions and use the model to optimise a production process.
9. Be able to combine 1-8 above to make statistical-plus-cost based decisions about engineering improvements and changes.

10. Present (written and oral presentation) data, analysis, and discussion in a concise, compelling argument that supports engineering decisions in a manufacturing environment.
11. Have a broad understanding and appreciation of basic principles of photovoltaics manufacturing science and engineering and a good foundation for future learning in this area.
12. Gain improved data handling and analysis skills, especially with MS Excel and Minitab.

3 Lecture Times and Locations

Lecture times and rooms are given below.

Day of the Week	Time	Lecture Room	Activity
Monday weeks 1-3 & 5-11	10:00 to 12:30	Quadrangle G034 (K-E15-G034)	Lecture
Wednesday weeks 2-10	14:00 to 16:30	Quadrangle 1043 (K-E15-1043)	Tutorial/Workshop
Monday weeks 1,2,6,8-11	13:00 to 14:30	TETB 245 (K-H6-245)	Open Office Hours

4 Textbooks/Resources, Lecture Notes

4.1 Texts and Reference Materials. The main text for this course is:

- Introduction to Photovoltaics Manufacturing Science and Technology by Jeffrey Cotter (2015)

4.2 Hardware and Software Applications. The tutorials of this course use the following hardware/software:

- Windows PC (laptop suggested) – at least one machine per group of 2-4 students
- "Virtual Manufacturing Execution System (VMES)" software: Download link will be posted on Moodle.
- Microsoft Excel or equivalent
- Minitab: Download link and instructions will be posted on Moodle.

4.3 In addition, the following reference materials may be helpful:

- PV-Manufacturing.org: A free online resource about photovoltaic manufacturing
- PVEducation.org: A free online resource about solar cell basics.
- Applied Photovoltaics by Stuart R Wenham, Martin A Green, Muriel E Watt and Richard Corkish
- Engineering Statistics Books: There are a number of good engineering statistics books, some suggestions:
    - Design and Analysis of Experiments by Douglas C Montgomery
    - Engineering Statistics by Douglas C Montgomery, George C Runger and Norma F Hubele
- Cost Accounting Books: Accounting is a wide field, if you're looking for a book, check for a chapter on Process Costing or Product Costing, in addition to basic info on cost behaviours, T-accounting and financial statements. For example:
    - Cost Accounting by Cecily A Raiborn, Michael R Kinney and Jenic Prather-Kinsey

4.4 Lecture Notes. Lecture notes will be made available on Moodle as they are presented in class.

5 Assessment

The assessment of the course consists of tutorials, three assignments, a midterm test, and a final examination paper.

Assessment	Weight
Tutorials (x7)	10% of total course mark
Assignment 1	10% of total course mark
Assignment 2	10% of total course mark
Assignment 3	15% of total course mark
Mid-term Exam (x1)	15% of total course mark
Final Exam (x1)	40% of total course mark
Total	100%

All material presented during the session will be examinable unless otherwise noted.

6 Schedule for the course (subject to change)

Week	Date	Lectures	Tutorials		Assessments	
1	Sept 16	Introduction and graphs				
2	Sept 23	Confidence Intervals	Tut0: Setup	Tut1: Graphs (yield)		
3	Sept 30	Hypothesis 1	Tut2: Population models		Assignment 1: Lectures 2-4	
4	Oct 7	Public Holiday	Hypothesis 2	Tut3: Conf. intervals		
5	Oct 14	Tut4: HT Z test	Tut5: HT T tests and TutX			
6	Oct 21	Finance (calculation)	Finance (tables)			
7	Oct 28	Tut6: Cost/performance	Midterm Exam		Midterm Exam	
8	Nov 4	Regression models	Tut7: Regression models		Assignment 2" Lectures 6-7	
9	Nov 11	Design of experiments	Tut8: Ass 3 guide		Assignment 3: Lectures 8-9	
10	Nov 18	Nathan Chang: Monte Carlo	Tut9: Ass3 DOE guide			Guest lecture
11	Nov 25	Rhett Evans: Big Data				Guest lecture
Study	Dec 2					
					Final Exam	

This is the current schedule for lectures, tutorials and assignments.

There may be changes through the term that will be posted on Moodle.

7 Student Responsibilities and Class Policies

7.1 **Late assignments** will be penalised 5% plus 5% per day that the work is late, to a maximum penalty of 50%. Late Assignments will be accepted; however, once the solutions are presented, the maximum penalty will apply.

7.2 **Tutorials** are due at the end of the class period in which they are presented.

7.3 **Attendance and Attention.** Students are recommended to attend all lectures and tutorials, to avail themselves of the subject resources (as above), to complete their assignments on time and to the best of their ability, participate in the workshops, and to be fully aware of the course syllabus, including any announcements or changes to that syllabus.

Students are expected to not distract their colleagues during lectures and tutorials.

7.4 **Plagiarism.** Students are expected to understand the university's academic honesty and plagiarism policies. Penalties will apply for breaches in these policies.