# ANX-PR/CL/001-01

# LEARNING GUIDE

## SUBJECT

**93001039 - Solar Cell Technology Laboratory**

## DEGREE PROGRAMME

09AX - Master Universitario en Energia Solar Fotovoltaica

## ACADEMIC YEAR & SEMESTER

2020/21 - Semester 1

# Index

## Learning guide

# 1. Description

## 1.1. Subject details

| | |
|---|---|
| **Name of the subject** | 93001039 - Solar Cell Technology Laboratory |
| **No of credits** | 5 ECTS |
| **Type** | Optional |
| **Academic year ot the programme** | First year |
| **Semester of tuition** | Semester 1 |
| **Tuition period** | September-January |
| **Tuition languages** | English |
| **Degree programme** | 09AX - Master Universitario en Energia Solar Fotovoltaica |
| **Centre** | 09 - Escuela Tecnica Superior de Ingenieros de Telecomunicacion |
| **Academic year** | 2020-21 |

# 2. Faculty

## 2.1. Faculty members with subject teaching role

| Name and surname | Office/Room | Email | Tutoring hours * |
|---|---|---|---|
| David Fuertes Marron | IES-201 | david.fuertes@upm.es | Sin horario. |
| Ignacio Tobias Galicia | IES-106 | ignacio.tobias@upm.es | Sin horario. |
| Carlos Del Cañizo Nadal (Subject coordinator) | IES-106 | carlos.canizo@upm.es | Sin horario. |

* The tutoring schedule is indicative and subject to possible changes. Please check tutoring times with the faculty member in charge.

### 2.2. Research assistants

| Name and surname | Email | Faculty member in charge |
|---|---|---|
| Garcia Vara, Ivan | ivan.garciav@upm.es | Cañizo Nadal, Carlos Del |

## 3. Prior knowledge recommended to take the subject

### 3.1. Recommended (passed) subjects

The subject - recommended (passed), are not defined.

### 3.2. Other recommended learning outcomes

- Fundamentals of physics and knowledge about semiconductor physics

## 4. Skills and learning outcomes *

### 4.1. Skills to be learned

CB06 - Poseer y comprender conocimientos que aporten una base u oportunidad de ser originales en el desarrollo y/o aplicación de ideas, a menudo en un contexto de investigación

CB07 - Que los estudiantes sepan aplicar los conocimientos adquiridos y su capacidad de resolución de problemas en entornos nuevos o poco conocidos dentro de contextos más amplios (o multidisciplinares) relacionados con su área de estudio

CB08 - Que los estudiantes sean capaces de integrar conocimientos y enfrentarse a la complejidad de formular juicios a partir de una información que, siendo incompleta o limitada, incluya reflexiones sobre las responsabilidades sociales y éticas vinculadas a la aplicación de sus conocimientos y juicios

CB10 - Que los estudiantes posean las habilidades de aprendizaje que les permitan continuar estudiando de un modo que habrá de ser en gran medida autodirigido o autónomo.

CE01 - Comprender, analizar y juzgar la relevancia de cualquier contribución en este campo, en relación con su entorno social, energético y científico-técnico.

CE03 - Realización, desarrollo e innovación de procesos tecnológicos para la fabricación de dispositivos fotovoltaicos.

CG05 - Gestión de la información: buscar y gestionar recursos bibliográficos adecuados con eficiencia, aprender a continuar los estudios de manera ampliamente autónoma como base para la futura actividad de investigación e innovación

CG07 - Trabajo en contextos internacionales: Llevar a cabo un proceso sustancial de investigación con seriedad e integridad académicas, integrado en un grupo de I+D+i con proyección internacional

CG08 - Aplicar metodologías, procedimientos, herramientas y normas del estado del arte para la creación de nuevos componentes tecnológicos; Construir nuevas hipótesis y modelos, evaluarlos y aplicarlos a la resolución de problemas

CG09 - Comunicar juicios, y conocimientos a audiencias especializadas y no especializadas, de una manera razonada, clara y sin ambigüedades

CT03 - Uso de la lengua inglesa: comprender los contenidos de clases magistrales, conferencias y seminarios en lengua inglesa; redactar en inglés informes y artículos científico-técnicos usando herramientas informáticas; realizar exposiciones públicas en inglés de trabajos, resultados y conclusiones de investigación, por ejemplo, en las asignaturas del Máster o en congresos de carácter mayoritariamente internacional o en estancias en centros extranjeros, todo ello con la ayuda de medios informáticos audiovisuales

## 4.2. Learning outcomes

RA8 - RA70 - Conocer los procesos de fabricación de células solares

RA9 - RA71 - Familiarizarse con los aspectos prácticos de fabricación de dispositivos fotovoltaicos

* The Learning Guides should reflect the Skills and Learning Outcomes in the same way as indicated in the Degree Verification Memory. For this reason, they have not been translated into English and appear in Spanish.

# 5. Brief description of the subject and syllabus

## 5.1. Brief description of the subject

Study of manufacturing technologies for photovoltaic solar cells and modules. Manufacturing processes for silicon solar cells, including diffusion, oxidation, film deposition. Manufacturing technologies for thin films and for solar cells based on III-V semiconductors.

## 5.2. Syllabus

1. Introduction to solar cell manufacturing
2. Manufacturing technologies for silicon solar cells
3. Manufacturing technologies for thin film solar cells
4. Manufacturing technologies for solar cells based on III-V semiconductors
5. Manufacturing costs
6. Lab sessions on the manufacturing of silicon solar cells
7. Selection of processing equipment for a PV module manufacturing plant

# 6. Schedule

## 6.1. Subject schedule*

| Week | Face-to-face classroom activities | Face-to-face laboratory activities | Distant / On-line | Assessment activities |
|---|---|---|---|---|
| 1 | **Introduction**<br>Duration: 02:00 | **Basic characterization of solar cells**<br>Duration: 02:00 | | |
| 2 | **Si technology: diffusion**<br>Duration: 02:00 | | **Optimizing a PV factory plant**<br>Duration: 02:00 | |
| 3 | **Si technology: layer deposition**<br>Duration: 02:00 | **Lab session: diffusion**<br>Duration: 02:00 | | |
| 4 | **Si technology showroom**<br>Duration: 02:00 | **Lab session: SiNx deposition**<br>Duration: 02:00 | | |
| 5 | **Thin film technology I**<br>Duration: 02:00 | **Lab session: texturing**<br>Duration: 02:00 | | |
| 6 | **Manufacturing costs**<br>Duration: 02:00 | | **Simulation of Manufacturing costs**<br>Duration: 02:00 | |
| 7 | **Thin film technology II**<br>Duration: 02:00 | **Lab session: lifetime measurements**<br>Duration: 02:00 | | |
| 8 | **Thin film technology III**<br>Duration: 02:00 | | **Progress in the group project**<br>Duration: 02:00 | |
| 9 | **Technology of III-V semiconductors I**<br>Duration: 02:00 | **Lab session: photolitography**<br>Duration: 02:00 | | |
| 10 | **Technology of III-V semiconductors II**<br>Duration: 02:00 | **Lab session: metallisation**<br>Duration: 02:00 | | **Assistance to lab sessions**<br><br>Continuous assessment<br>Presential<br>Duration: 00:01 |
| 11 | **Exercises about solar cell manufacturing technologies**<br>Duration: 04:00 | | | |
| 12 | | | | **Presentation of project**<br><br>Continuous assessment and final examination<br>Presential<br>Duration: 04:00 |

| | | | | |
|---|---|---|---|---|
| 13 | | | | |
| 14 | | | | |
| 15 | | | | |
| 16 | | | | |
| 17 | | | | **Exam**<br><br>Continuous assessment and final examination<br>Presential<br>Duration: 03:00<br><br>**Exam about lab processes**<br><br>Final examination<br>Presential<br>Duration: 01:00 |

Depending on the programme study plan, total values will be calculated according to the ECTS credit unit as 26/27 hours of student face-to-face contact and independent study time.

* The schedule is based on an a priori planning of the subject; it might be modified during the academic year, especially considering the COVID19 evolution.

# 7. Activities and assessment criteria

## 7.1. Assessment activities

### 7.1.1. Continuous assessment

| Week | Description | Modality | Type | Duration | Weight | Minimum grade | Evaluated skills |
|---|---|---|---|---|---|---|---|
| 10 | Assistance to lab sessions | | Face-to-face | 00:01 | 20% | 3 / 10 | CE03<br>CT03<br>CB10 |
| 12 | Presentation of project | | Face-to-face | 04:00 | 30% | 3 / 10 | CB08<br>CE01<br>CG09<br>CG05<br>CG08<br>CT03 |
| 17 | Exam | | Face-to-face | 03:00 | 50% | 3 / 10 | CB10<br>CG07<br>CB07<br>CE01<br>CB06<br>CE03<br>CG08 |

### 7.1.2. Final examination

| Week | Description | Modality | Type | Duration | Weight | Minimum grade | Evaluated skills |
|---|---|---|---|---|---|---|---|
| 12 | Presentation of project | | Face-to-face | 04:00 | 30% | 3 / 10 | CB08<br>CE01<br>CG09<br>CG05<br>CG08<br>CT03 |
| 17 | Exam | | Face-to-face | 03:00 | 50% | 3 / 10 | CB10<br>CG07<br>CB07<br>CE01<br>CB06<br>CE03<br>CG08 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 17 | Exam about lab processes | | Face-to-face | 01:00 | 20% | 3 / 10 | CB10<br>CE03 |

### 7.1.3. Referred (re-sit) examination

| Description | Modality | Type | Duration | Weight | Minimum grade | Evaluated skills |
|---|---|---|---|---|---|---|
| Presentation of project | | Face-to-face | 04:00 | 30% | 3 / 10 | CE01<br>CG09<br>CG05<br>CG08<br>CB08<br>CT03 |
| Exam | | Face-to-face | 03:00 | 50% | 3 / 10 | CG08<br>CB10<br>CG07<br>CB07<br>CE01<br>CB06<br>CE03 |
| Exam about lab processes | | Face-to-face | 01:00 | 20% | 3 / 10 | CB10<br>CE03 |

## 7.2. Assessment criteria

1. Presenting the team project on the design of a manufacturing line is compulsory.
2. Assisting to the lab sessions is compulsory.
3. Doing the written exam is compulsory

The final grade should be equal or above 5/10, when considering each of the evaluation activities and their weight, to pass successfully this course.

# 8. Teaching resources

## 8.1. Teaching resources for the subject

| Name | Type | Notes |
|---|---|---|
| Manufacturing lab | Equipment | Manufacturing equipment for silicon solar cells of the Solar Energy Institute |
| Characterization lab | Equipment | Equipment for the characterization of photovoltaic materials and devices |
| Moodle | Web resource | Repository for documentation, student forum and marks |
| References | Bibliography | Recommended books and scientific papers |
| Simulation software | Others | Access to software tools related to Photovoltaic Manufacturing |

# 9. Other information

## 9.1. Other information about the subject

Some of the lab sessions will take place in the facilities that the Instituto de Energía Solar has in the UPM Park in TecnoGetafe.

The goals and content of this course are aligned with the Sustainable Development Goals (SDG), as is in fact the whole Master on Photovoltaic Solar Energy to which it belongs. The promotion of Photovoltaic Solar Energy, which is becoming a cornerstone in the energy transition we are experiencing, has a clear positive impact in SDG 7 (Affordable and Clean Energy) and in SDG13 (Climate action).

Paying special attention to manufacturing processes, it also tackles some of the concerns included in SDG 9 (Industries, Innovation and Infrastructures), addressing sustainability aspects of the industrial processes and highlighting the importance of innovative manufacturing processes in the photovoltaic sector.