# National Cheng Kung University
# Modular Course 2025 Winter Program

Academic Year：113, Semester：2 領域：自然與工程科學

## 半導體電漿蝕刻和粒子網格法模擬
## Semiconductor Plasma Etching and Particle-in-Cell (PIC) Simulation

| Instructor | Affiliation | Graduation (Ph.D.) |
|---|---|---|
| Yasutaro Nishimura<br>nishimura@pssc.ncku.edu.tw | Institute of Space and Plasma Sciences<br>National Cheng Kung University | University of Wisconsin-Madison, USA<br>(美國威斯康辛大學麥迪遜分校) |

| Course Type | Course Credit | Student Size (Maximum) |
|---|---|---|
| Lecture + Recitation | 1.5 | 15 |

### Student Background

College of Science, College of Engineering, College of Bioscience and Biotechnology,
College of Electrical Engineering and Computer Science, College of Medicine,
College of Planning and Design,

### Difficulty

☐ Challenging ☐ Moderately Difficult ■ Medium ☐ Entry Level ( Basic)

### Format of The Course

Lecture 60%, Hands-on Practice 30%, Discussion 10%

### Grading Policy

- 問題考試 30%：Short Quiz on very basic on industrial plasmas ( ~ 45min on Wednesday).
  周三安排一次基礎的工業電漿 Quiz，時間 45 分鐘。
- 作業 30%：One homework on basics of industrial plasmas, due on Thursday.
  一份關於工業電漿基礎知識的家庭作業，週四繳交。
- 報告 40%：One final report on using computers, due on Monday after the class week.
  報告課程結束後周一繳交。

### Code of Conduct for The Course

Freshman level math and general physics.

### Course Description

Plasma physics, one branch of physics, is a field to study statistical behavior of charged particles and its collective behavior (here, the term collective is used antithetically to randomness). Besides its strong link to nuclear fusion research and space science research, plasma discharge techniques have been successfully applied in various industrial applications such as plasma etching of semiconductors (which is now being controlled at nanoscales) and Plasma-immersion ion implantation (PIII) which is a surface modification of materials. From plasma physics point of view, the success in the industrial application is specifically linked to "sheath dynamics" at the plasma-material boundary. The sheath dynamics manifest itself as "anisotropy" (in plasma etching, ions bombard the material surfaces perpendicularly) and "conformality" in PIII. The introductory key concepts of plasma physics are discussed in the course. Computationally, we revisit RF discharge [two most popular way employed in semiconductor industries : Capacitively coupled plasma (CCP) and inductively coupled plasma (ICP) ] and the dynamics of ion bombardment employing a Particle-in-Cell approach. This course will lower the threshold at the entrance level of computing by providing students with simple but paradigmatic examples. The course will take an interactive style to give the students hands-on training. Open for all the levels, even for those who do not have any experience in programming language at all.

Keywords: Semiconductor etching. Sheath at plasma-material boundaries. Principles of RF plasma discharge (CCP and ICP). Self-made Particle-in-Cell simulation.

## Timetable and Syllabus

| Period | Timetable | Syllabus |
|---|---|---|
| 2025/1/13(Mon) | 9:00-12:00 | Lectures : Key basic plasma physics to understand semiconductor etching. |
| | 12:00-13:00 | Lunch Time |
| | 13:00-15:30 | Intro to programming (1) Add one to ten (2) Numerical integration. Laptop PCs with compilers will be provided to all the students. |
| 2025/1/14(Tue) | 9:00-12:00 | Basic plasma physics. Principles of RF plasma (CCP and ICP) discharges for semiconductor etching. |
| | 12:00-13:00 | Lunch Time |
| | 13:00-15:30 | Hands-on training in constructing PIC simulation (Ordinary Differential Equation) |
| 2025/1/15(Wed) | 9:00-12:00 | Debye shielding and sheath dynamics. |
| | 12:00-13:00 | Lunch Time |
| | 13:00-15:30 | Hands-on training in constructing PIC (Poisson solver) |
| 2025/1/16(Thu) | 9:00-12:00 | Ion anisotropy and etching semiconductor “trench geometries” on the wafers. |
| | 12:00-13:00 | Lunch Time |
| | 13:00-15:30 | Hands-on training in constructing PIC (simulating RF discharges) |
| 2025/1/17(Fri) | 9:00-12:00 | Plasma processing. Plasma-immersion ion implantation |
| | 12:00-13:00 | Lunch Time |
| | 13:00-15:30 | Hands-on training in constructing PIC (simulating sheath dynamics). |

## Goal of the Course

1. Understand basic principles of RF plasma discharges conventionally employed in semiconductor industries.
2. Understand sheath dynamics which has been the corner stone of modern semiconductor etching technology.
3. Construct students’ own Particle-in-Cell simulation code to model semiconductor plasma processing (codes can be immediately transferred to thesis research).

## The Importance, Cross-Over Disciplinary and Contemporary of The Curriculum

The development of the semiconductor industry, which has been leading Taiwan's economy, would not have been realized without the plasma processing technology. In order to understand plasma processing, one needs to understand the fundamental dynamics of charged particles and the interaction between charged particles and material surfaces. Topics that are mutually beneficial to fundamental physics, engineering, and numerical calculation techniques are the focus of discussion.

引領台灣產業和經濟的半導體產業的發展，離不開電漿處理技術。 為了了解電漿處理，需要了解帶電粒子的基本動力學以及帶電粒子與材料表面之間的相互作用。 與基礎物理、工程和數值計算技術互惠互利的議題是討論的焦點。

## Remarks

None

本課程若因天災等不可抗力之因素或中央、地方政府公告停課，授課教師需依情況依建議補課方式調整課程進度與補課；若需使用假日、國定假日補課，則需與所有修課學生達成共識方能用例假日補課。

建議補課方式：

1. 線上授課方式補課；
2. 當預期可能會因天災(颱風、超大豪雨…等)宣佈停課時，建議老師先行調整加快課程進度或預先增加可能天氣預警之前幾次課程時數；
3. 停課後隔天起延後下課，補足停課延誤的進度；若停課超過 1 天，則在開始上課後延後下課補課，或當週星期六、日補課；

更改課程授課方式，例如：DEMO 改以考試、報告、作業取代。