

National Cheng Kung University

Modular Course 2025 Summer Program

Academic Year : 114, Semester : 1

Category : Natural and Engineering Sciences

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.)
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Category	Course Credit	Student Size (Maximum)
Natural and Engineering Sciences	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

- **Exam 30%:** Short Quiz on very basic on industrial plasmas (~ 60 min on Friday).
- **Assignments 30%:** One homework on basics of industrial plasmas, due on Thursday.
- **Presentation 40%:** One final report on using computers, due on Monday after the class week.

Code of Conduct for The Course

Freshman level mathematics

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 nano-scales) 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

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interactive style to give the students hands on training. Open for all the levels, even for those who do not have any experiences 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
2025/9/1(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.
2025/9/2(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)
2025/9/3(Wed)	9:00-12:00	Debye shielding and sheath dynamics.
	13:00-15:30	Hands-on training in constructing PIC (Poisson solver)
2025/9/4(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)
2025/9/5(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 cornerstone 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

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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.

Remarks

Sample codes for computational programming (not all the contents but partial components as hints) will be provided in Python and C (ANSI C).

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。