课程大纲
COURSE SYLLABUS

1.	课程代码/名称 **Course Code/Title**	集成电路制造技术 **Integrated circuit manufacturing technology**
2.	课程性质 **Compulsory/Elective**	专业课
3.	课程学分/学时 **Course Credit/Hours**	3/48
4.	授课语言 **Teaching Language**	中文/English
5.	授课教师 **Instructor(s)**	化梦媛
6.	是否面向本科生开放 **Open to undergraduates or not**	否
7.	先修要求 **Pre-requisites**	（如面向本科生开放，请注明区分内容。 If the course is open to undergraduates, please indicate the difference.） EE201 模拟电路，和 EE203 固态电子学/EE204 半导体器件导论 EE201 Analog Circuit, EE203 Solid State Electronics/EE204 Introduction of Semiconductor Device

8. 教学目标
Course Objectives

（如面向本科生开放，请注明区分内容。 If the course is open to undergraduates, please indicate the difference.）

本课程主要适用于微电子学与固体电子学，也适用于集成电路系统设计、集成电路工程等专业，是电子科学与技术专业的学位课。通过本课程的教学，使学生能了解当前集成电路工艺的发展动态和前沿技术，深刻理解集成电路制造的工艺原理与方法，熟练掌握现代集成电路制造的先进工艺特征与先进工艺流程，领会工艺技术与集成电路设计的关系，具备较强集成电路工艺的设计能力，能够综合运用集成电路工艺原理分析和解决工艺相关复杂工程问题，为将来从事集成电路设计和制造等技术工作奠定坚实的基础。

This course is mainly applied to students major in microelectronics and solid-state electronics, also suitable for students major in integrated circuit system design, integrated circuit engineering, etc. It is a degree course in Electronic Science and Technology. Through this course, students can understand the current development trend and cutting-edge technology of integrated circuit technology, deeply understand the process principle and method of integrated circuit manufacturing, master the advanced process characteristics and advanced process flow of modern integrated circuit manufacturing, and understand the process technology. With strong integrated circuit design capabilities, students can comprehensively apply integrated circuit process principles to analyse and solve process-related complex engineering problems. This course will lay a solid foundation for students in future work of integrated circuit design and manufacturing.

9. 教学方法
Teaching Methods

（如面向本科生开放，请注明区分内容。 If the course is open to undergraduates, please indicate the difference.）

多媒体方式授课，课堂讲授方式与讨论方式相结合，插入行业最新动态和科研成果的讲座与讨论，并配以课程设计以提升教学效果。课程原则上不向学生提供文字型课件，强调学生听课笔记与总结归纳的能力。

The multimedia method will be used in teaching. The lecture will be combined with discussion, and the talks on the latest developments and scientific research achievements of the industry will also be inserted. The curriculum design is combined to enhance the teaching effect. In principle, the course

	does not provide students with text-based courseware, emphasizing the ability of students to take notes and summarize them.
10.	**教学内容** **Course Contents** （如面向本科生开放，请注明区分内容。 If the course is open to undergraduates, please indicate the difference.）
Section 1	**集成电路制造工艺技术简介** 知识点：集成电路制造技术的发展历史、摩尔定律与后摩尔定律、关键技术与前沿技术、集成电路设计与制造的关系、集成电路制造流程的关键工艺与设备。 教学重点：典型 CMOS 集成电路制造工艺流程，各单步工艺的特点。 教学难点：集成电路各单步工艺之间的联系，集成电路工艺与其他相关专业课程的联系。 **Introduction to integrated circuit manufacturing process technology** Knowledge points: the history of integrated circuit manufacturing technology, Moore's Law and post-Moore's Law, the relationship between key technologies and cutting-edge technologies, integrated circuit design and manufacturing, and key processes and equipment for integrated circuit manufacturing processes. Teaching focus: typical CMOS integrated circuit manufacturing process, the characteristics of each single step process. Difficulties in teaching: the connection between the single-step processes of integrated circuits, the connection between integrated circuit technology and other related professional courses.
Section 2	**掺杂技术** 知识点：扩散工艺的原理、特点、局限性及设备，离子注入工艺的原理、特点、设备、应用、热退火及最新技术。 教学重点：扩散系数与杂质浓度的关系，两步扩散，注入离子浓度分布，注入损伤与热退火，沟道效应及其抑制方法，轻掺杂漏极(LDD)技术，超浅结技术，离子注入在 CMOS 集成电路中的应用。 教学难点：运用扩散工艺、离子注入工艺的理论对实际问题进行定性分析和定量计算。 **Doping technique** Knowledge points: Principles, characteristics, limitations and equipment of the diffusion process, principles, features, equipment, applications, thermal annealing and latest technologies of the ion implantation process. Teaching focus: relationship between diffusion coefficient and impurity concentration, two-step diffusion, injection ion concentration distribution, injection damage and thermal annealing, channel effect and its suppression method, lightly doped drain (LDD) technology, ultra-shallow junction technology, ion Injection into applications in CMOS integrated circuits. Teaching Difficulties: Using the theory of diffusion process and ion implantation process to qualitatively analyze and quantitatively calculate actual problems.
Section 3	**薄膜制备技术** 知识点：热氧化、物理气相淀积、化学气相淀积、外延等工艺的原理、特点、设备及影响因素。

	教学重点：热氧化生长动力学，化学气相淀积原理和方法，影响外延生长速率的因素，外延层杂质分布。 教学难点：运用热氧化生长动力学原理、化学气相淀积原理对实际问题进行定性分析和定量计算，气相外延原理应用。 **Film preparation technology** Knowledge points: principles, characteristics, equipment and influencing factors of processes such as thermal oxidation, physical vapor deposition, chemical vapor deposition, and epitaxy. Teaching focus: thermal oxidation growth kinetics, chemical vapor deposition principles and methods, factors affecting epitaxial growth rate, epitaxial layer impurity distribution. Difficulties in teaching: qualitative analysis and quantitative calculation of practical problems using the principle of thermal oxidation growth kinetics and chemical vapor deposition, and the application of vapor phase epitaxy.
Section 4	**微细图形加工技术** 知识点：光刻工艺流程及步骤、正性和负性光致抗蚀剂、分辨率及其影响因素、曝光方式与光刻设备、曝光光源、非光学光刻技术、分辨率增强技术，刻蚀速率与选择比、常用湿法刻蚀技术和干法刻蚀技术的的特点与应用。 教学重点：光刻工艺流程，分辨率及其影响因素、移相掩模技术，极紫外、角度限制投影电子束、离子束投影、X 射线等先进光刻技术，等离子体刻蚀、溅射刻蚀、反应离子刻蚀等干法刻蚀技术。 教学难点：分辨率及提高分辨的途径，分辨率增强技术，非光学曝光，光刻与刻蚀技术的区别与联系。 **Micro-pattern processing technology** Knowledge points: lithography process and steps, positive and negative photoresist, resolution and its influencing factors, exposure methods and lithography equipment, exposure light source, non-optical lithography, resolution enhancement technology, engraving Characteristics and applications of etch rate and selection ratio, common wet etching techniques and dry etching techniques. Teaching focus: lithography process, resolution and its influencing factors, phase shift mask technology, extreme ultraviolet, angle-limited projection electron beam, ion beam projection, X-ray and other advanced lithography, plasma etching, sputtering Dry etching techniques such as etching and reactive ion etching. Difficulties in teaching: resolution and ways to improve resolution, resolution enhancement techniques, non-optical exposure, lithography and etching techniques.
Section 5	**金属化与多层互连** 知识点：铝及铝合金，金属硅化物技术，铜互连工艺，平坦化技术，多层金属互连技术，接触孔与通孔技术。 教学重点：铝加热合金，自对准硅化物技术，接触窗薄膜工艺，电迁移现象及其改进方法，铜互连，High K 和 Low K 介质，化学机械平坦化技术的应用。 教学难点：铜互连大马士革镶嵌工艺。 **Metallization and multilayer interconnection**

	Knowledge points: aluminum and aluminum alloy, metal silicide technology, copper interconnect technology, planarization technology, multilayer metal interconnect technology, contact hole and through hole technology. Teaching focus: aluminum heating alloy, self-aligned silicide technology, contact window film process, electromigration phenomenon and its improved method, copper interconnect, High K and Low K media, chemical mechanical planarization technology. Difficulties in teaching: copper interconnected Damascus inlay process.
Section 6	工艺集成 知识点：集成电路隔离技术的演变与发展，集成电路中的有源和无源器件、CMOS 集成电路工艺集成，双极集成电路工艺集成，BiCMOS 集成电路工艺集成，鳍式 MOSFET(FinFET)工艺技术。 教学重点：PN 结隔离与介质隔离，LOCOS(硅局部氧化)技术，沟槽隔离，绝缘体上硅隔离技术，铝栅 P-Well CMOS 制造工艺，双阱 CMOS 制造工艺，双阱 BiCMOS 制造工艺。 教学难点：CMOS 集成电路工艺与双极集成电路工艺的区别，CMOS 集成电路和 BiCMOS 集成电路的工艺设计。 **Integration Process** Knowledge points: evolution and development of integrated circuit isolation technology, active and passive devices in integrated circuits, CMOS integrated circuit process integration, bipolar integrated circuit process integration, BiCMOS integrated circuit process integration, fin MOSFET (FinFET) process technology . Teaching focus: PN junction isolation and dielectric isolation, LOCOS (silicon local oxidation) technology, trench isolation, silicon-on-insulator isolation technology, aluminum gate P-Well CMOS fabrication process, dual-well CMOS fabrication process, dual-well BiCMOS fabrication process. Difficulties in teaching: the difference between CMOS integrated circuit technology and bipolar integrated circuit technology, process design of CMOS integrated circuits and BiCMOS integrated circuits.

11. 课程考核
Course Assessment

（①考核形式 Form of examination；②.分数构成 grading policy；③如面向本科生开放，请注明区分内容。If the course is open to undergraduates, please indicate the difference.）

课程随堂报告（30%）+项目书面报告（30%）+期末口头报告（40%）
Curse Presentation （30%）+Final Review Report (30%)+Final Presentation (40%)

12. 教材及其它参考资料
Textbook and Supplementary Readings

1.张汝京等著，纳米集成电路制造工艺(第 2 版)，清华大学出版社，2017.
2.潘桂忠等著，MOS 集成电路工艺与制造技术，上海科学技术出版社，2012.
3.Campbell, S.A.等著，严利人等译，微纳尺度制造工程(第三版)，电子工业出版社，2011.
4.Gary S.May 著，代永平译，半导体制造基础，人民邮电出版社，2007.
5.Michael Quirk and Julian Serda 著，韩郑生等译，半导体制造技术(Semiconductor Manufacturing Technology)，电子工业出版社，2015。

1. Zhang Rujing, et al., Nano-integrated Circuit Manufacturing Process (2nd edition), Tsinghua University Press, 2017.

2. Pan Guizhong, et al., MOS Integrated Circuit Technology and Manufacturing Technology, Shanghai Science and Technology Press, 2012.
3. Campbell, S.A. Waiting, Yan Liren, et al., Micro-nano Scale Manufacturing Engineering (third edition), Electronic Industry Press, 2011.
4. Gary S. May, et al., Foundation of Semiconductor Manufacturing, People's Posts and Telecommunications Press, 2007.
5. Michael Quirk, Julian Serda, etc., Semiconductor Manufacturing Technology, Electronic Industry Press, 2015.