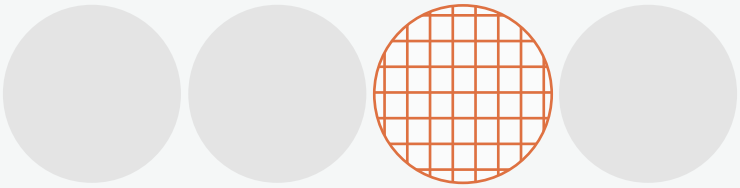
Integrated Circuit Design and
Implementation Courses

Taiwan-Europe Semiconductor Short-term Training Program 2024



Session I
Jul 27- Aug 4

Semiconductor in Taiwan: Trends and Transformations
for 1 week: National Taiwan University

or The Essentials of Semiconductor Technology and Supply Chains
for 1 week: National Cheng Kung University

Session II
Aug 5- Aug 16

Pratical Training for 2 weeks:
Taiwan Semiconductor Research Institution

Supported by
Ministry of Foreign Affairs, ROC(Taiwan)

NTU

Semiconductor in Taiwan: Trends and Transformations

NTU Courses

	Morning Session	Afternoon Session
JUL 27	Arrival & Check-in	
JUL 28	One Day Trip National Palace Museum/Tamsui	
JUL 29	- Campus Tour Orientation - Opening Ceremony Welcome Lunch	- Introduction of Semiconductor in Taiwan - The History and Future of Chip Design and Manufacturing (Chip Wars)
JUL 30	IC Technologies	Project Discussion
JUL 31	Materials/Physics/ Chemistry -Sciences Behind Chips	Project Discussion
AUG 01	The Future of Semiconductor Electronics	NTU Farm/ NTU Museum/ NTU NEMS Research Center
AUG 02	Electronic Design Automation	- Culture Excursion Shenkeng Old Street / Tofu DIY - Project Discussion
AUG 03	Overview of Digital IC Design Flow	Project Discussion/ Rehearsal
AUG 04	- Hotel Check-out - Final Presentation Closing Ceremony - Farewell Lunch	Departure to TSRI

** Schedule is subject to change

@ National Taiwan University

Taiwan-Europe Semiconductor Short-term Training Program

Semiconductor in Taiwan: Trends and Transformations

Course		Description
JUL **29**	14:00-15:00 **Introduction to Semiconductor Industry in Taiwan** 劉致為 Chee Wee Liu	Semiconductor industry are classified as IC + OSD (Optoelectronics/Sensors/Discrete) with the estimated market size of 600B USD WW in 2024. Display and solar cell do not belong to semiconductor industry. The largest foundry tsmc has the revenue around 70B USD, about 10% of WW revenue. IC has 4 categories, Logic/Micro/Memory/ Analog. Most advanced technologies are led by logic. The logic roadmap will be taught. Taiwan is strong in logic process, but weak in memory, micro, and analog. Although chip design in Taiwan is not as strong as foundry, CBI (Chip-based Industrial Innovation Program) is planned to invest 300B NT in the next decade (2024-2033) to strengthen the national IC design capabilities. However, no plans for memory are particularly proposed. GaN/SiC are also the focus of Taiwan's national programs. The recent revenues of each segment in TW will be presented.
JUL **29**	15:30-17:30 **The History and Future of Chip Design and Manufacturing (Chip Wars)** 陶儀芬 Yi-feng Tao	In this course, we will put the development of Taiwan's semiconductor industry in the context of global political economy. Based upon Chris Miller's Chip War, we will first briefly go through the history of semiconductor industry in the United States and Japan and then focus on how semiconductor manufacturing has developed in Taiwan and how China has tried to catch up and pose a challenge to the U.S.-led global supply chain of the chips. And then, we will address how the geopolitical competition between China and the U.S. since Xi Jinping came to power has reinforced the two superpowers' determination to decouple with each other in this industry. It has in terms complicated the status of Taiwan's Silicon Shield.
JUL **30**	09:30-12:00 13:30-16:00 **IC Technologies** 劉致為 Chee Wee Liu	What are the 7 nm, 5 nm, 3 nm even 2 nm nodes in the daily news? What is the definition of node names with the correlations of gate length/contact poly pitch/cell height? What do we need the FinFETs after planar transistors? Why do FinFETs have the difficulty to meet requirements of the technology nodes beyond 3 nm? Nanosheets after FinFETs can save the transistor scaling to continue Moore's law. How long can nanosheets last? What are after nanosheets? What the final destination of technology roadmap? Any end? I will show how to make planar/FinFET/nanosheets transistors by yourself, and the possible roadmap in the future. Nanoscale transistors have quantum behaviors beside the classical diffusion and drift, making colorful pictures of advanced transistors. Based on the amazing diamond structures of Si lattice, band diagram (physical points of view) and chemical bonding structure are the starting points to understand the electron and hole concentration, n-type vs p-type doping, and MOSFET device physics. Advanced transistors featuring small gate length, 3D structure, and sophisticated device physics which can be understood by TCAD simulation. The concepts with graphic drawing can help you to understand the transistor working principle. However, very simple math will be introduced to understand the scaling length and on-state currents

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Course		Description
JUL **31**	09:30-12:00 13:30-16:00 **Materials/ Physics/ Chemistry-Sciences Behind Chips** 劉致為 Chee Wee Liu	Nanoscale transistors have quantum behaviors beside the classical diffusion and drift, making colorful pictures of advanced transistors. Based on the amazing diamond structures of Si lattice, band diagram (physical points of view) and chemical bonding structure are the starting points to understand the electron and hole concentration, n-type vs p-type doping, and MOSFET device physics. Advanced transistors featuring small gate length, 3D structure, and sophisticated device physics which can be understood by TCAD simulation. The concepts with graphic drawing can help you to understand the transistor working principle. However, very simple math will be introduced to understand the scaling length and on-state currents.
AUG **01**	09:30-12:00 **The Future of Semiconductor Electronics** 謝馬利歐 Mario Hofmann	Current electronic progress relies on the continued decrease in transistor dimensions to enhance circuit performance and decrease cost. However, fundamental physical problems arise when transistors are scaled toward nanometer size, including quantum mechanical tunneling, hot electrons, and loss of electrostatic control. This course will illustrate the origin of these issues and review the promise of nanomaterials to overcome them. Surprisingly, quantum mechanical processes are not only the source of scaling problems but may lead to new solutions. The lecture will introduce new developments in transistor operation and electronic circuits beyond FETs and describe new ideas for computation that do not rely on traditional circuits and binary logic.
AUG **02**	09:30-12:00 **Electronic Design Automation** 江蕙如 Iris Hui-Ru Jiang	The increasing design complexity and continuous technology scaling pose a tough challege to chip design or even system design. Nowadays, Electronic Design Automation (EDA) tools become vital to tacle this challenge. In this course, we will mainly focus on VLSI design automation. This course covers front-end and back-end design automation techniques.
AUG **03**	09:30-12:00 **Overview of Digital IC Design Flow** 吳安宇 An-Yeu (Andy) Wu	Computing tools have evolved from the abacus to modern billion-transistor CPUs and GPUs. One of the primary reasons for this advancement is the invention of integrated circuits (ICs). In this lecture, we will provide a brief overview of the history of transistors, as well as their close relationship with computers and CPUs. We will use a simple MIPS CPU design (detailed design is not covered) to illustrate the digital IC design flow by using front-end and back-end EDA tools.

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Semiconductor in Taiwan: Trends and Transformations

Instructor	Education and Major Research Areas
劉致為 **Chee Wee Liu**  Distinguished Professor, Department of Electrical Engineering, IEEE FELLOW	**Ph.D., Electrical Engineering, Princeton University, 1994** His research includes SiGe/GeSn epi/photonics, stacked 3D transistors, RF device and circuit/thermal simulation (physics-based and machine learning-based), IGZO TFT, SRAM/MIM/FTJ, FRAM, FeFET/MTJ/SOT/DRAM, and Si photonics. He demonstrates the tallest transistor (8/16/24 stacked channels), the record high 2,400,000 cm2/Vs electron mobility in strained Si, the first Si-capped SiGe/Ge channels with 3x mobility enhancement (in 5nm node production now), the first CVD GeSn outperforming MBE in terms of hole mobility, the first stacked GeSn/GeSi channel GAA(nanosheet/nanowire) transistors, and the first Si/SiGe/SiC MIS LED/photodetectors. He also invented the tree/E transistors, beyond Stacked GAA. He has 718+ papers (277+ journal papers, 32 IEDM, 19VLSI), 86 US patents, 2 China patents, 57 Taiwan ROC patents, more than 8981+ citations with h-index=43, 44 Ph.D. graduates, and 143 master graduates. He has 5 graduate students as professors (2 NTU, 1 NCHU, 1 NDHU, 1 NJUST), and 3 postdocs as professors (1 NTU, 1 NCU, 1 CGU). Currently, he is advising 26 PhD students and 37 masters.
陶儀芬 **Yi-feng Tao**  Associate Professor, Department of Political Science	**Ph.D. Columbia University in New York City, 2001** 1. Chinese politics 2. International Political Economy 3. Comparative Politics
謝馬利歐 **Mario Hofmann**  Professor, Department of Physics	**Ph.D., Electrical Engineering, Massachusetts Institute of Technology, 2011** Nanoelectronics and nanomaterials
江蕙如 **Iris Hui-Ru Jiang**  Professor, Department of Electrical Engineering	**Ph.D., Electronics Engineering, National Chiao Tung University, 2002** 1. Timing analysis and optimization 2. Physical design 3. Design for manufacturability
吳安宇 **An-Yeu Andy Wu**  Distinguished Professor, Department of Electrical Engineering, IEEE FELLOW	**Ph.D., Electric Engineering, University of Maryland, 1995** 1. VLSI/CAD 2. Communication integrated circuits 3. Signal processing

NCKU

The Essentials of Semiconductor Technology and Supply Chains

- Overall of Courses in NCKU

	Morning Session	Afternoon Session
JUL 27	Arrival Check-in Welcome Reception	
JUL 28	Cultural Tour -KAOHSIUNG-	
JUL 29	- Opening Ceremony - IC Design Overview : _ Binary Logic & Arithmetic Modules _ Essences of Computer Organization _ Transform Design using HDL & EDA Tools	IC Design Overview : Smart sensing heterogeneous integration chip technology
JUL 30	TSRI Advanced Packaging Technology/ Clean Room-Module Tour	Techniques of Nanomaterials and Nanocomposites (session I)
JUL 31	Industry/ Company Visit	
AUG 01	- Semiconductor-based Nanophotonics and their applications - Semiconductor Fabrication	- Techniques of Nanomaterials and Nanocomposites (session 2)
AUG 02	Latest Trend on Semiconductor Technology by Applied Materials Taiwan (session I)	Latest Trend on Semiconductor Technology by Applied Materials Taiwan (session 2)
AUG 03	Circular Economy of Electronics Industry (session I)	- Circular Economy of Electronics Industry (session 2) - Final Presentation Farewell Dinner
AUG 04	Departure for TSRI	

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@ National Cheng Kung University

Taiwan-Europe Semiconductor Short-term Training Program

The Essentials of Semiconductor Technology and Supply Chains

Prof. Jen-Sue Chen

The most comprehensive selection of topics offered by the Academy of Innovative Semiconductor and Sustainable Manufacturing of NCKU. With a theme on the essentials of semiconductor technology and supply chains, a series of lectures will be delivered by both the Academy's faculty and industry experts from top-notch research centers and businesses in Taiwan for an inclusive presentation of this subject. The topics will include IC design, techniques of nanomaterials and nanocomposites, fundamentals of device physics and fabrication, advanced packaging technology with AI, IoT, and 5G application, digital twin and IC packaging, VLSI process integration, and device measurement. This course consists of 7 topics shown in the table.

Course		Description
JUL **29**	**IC Design Overview**	**Prof. Chih-Hung Kuo** - Binary Logic & Arithmetic Modules **Prof. Ing-Chao Lin** - Essences of Computer Organization **Prof. Lih-Yih Chiou** - Transform Design using HDL & EDA Tools **Director Hann-Huei Tsai** - Smart sensing heterogeneous integration chip technology IC design overview is to introduce the fundamentals of IC design to those interested in this field. It starts from basic binary logic blocks followed by arithmetic modules. Modules are organized in a logical way to perform computation. Then how to transform and realize a design into an integrated circuit by hardware description language and state-of-the-art design tools. In the end, how one can validate and confirm the success of the design. A concise yet insightful view can help learners quickly grasp the essences of IC design. It would be highly useful to people who want to have a jump start and know how we train students in Taiwan.
AUG **01**	**Semiconductor-based nanophotonics and their applications** Prof. Jui-Nung Liu	The short course provides an introduction to nanophotonics based on semiconductors and their device applications. Types of optical resonators, including photonic crystals, antennas, and bound states in the continuum will be introduced. Applications of nanophotonic resonators to nanospectroscopy and cavity quantum electrodynamics (CQED) will also be discussed.
AUG **01**	**Semiconductor Fabrication** Prof. Ying-Yuan Huang	Semiconductor Fabrication delves into the heart of the microelectronics industry, focusing on the manufacturing process of semiconductor devices. This course offers students an essential understanding of the steps involved in the fabrication of semiconductors, including material preparation, chemical/physical vapor deposition, photolithography, etching, and ion implantation. Students will gain insight into the sophisticated processes and innovations that enable the production of ever-smaller and more powerful semiconductor devices.

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Course		Description
JUL **30**	**TSRI-Heterogeneous Integration and Manufacturing Lab Tour**	**Dr. Pei Ling Li; Mr. Tang Yuan Fu; Mr. Laifu Tsai; Mr. Yuming Yeh; Mr. Shih Han Hsu** Advanced Packaging Technology/Clean Room-Module Tour
JUL **30**	**Techniques of Nanomaterials and Nanocomposites** Prof. Su-Wen Hsu	This course will introduce the basic principle of the fabrication of nanomaterials and nanocomposites. The unique properties of nanomaterials strongly depend on their morphology and composition, leading to specialized applications, such as sensing, optical and electronic devices. Therefore, the fabrication process of nanomaterials plays an important role in manipulating material properties. The properties of nanocomposites can be influenced by the intrinsic properties of individual materials and extrinsic properties of syngenetic effects between materials, which make it possible to engineer the desired properties of nanocomposites. This course also focuses on designing the special functions of nanomaterials and nanocomposites for desirable applications.
AUG **02**	**Latest Trend on Semiconductor Technology by Applied Materials Taiwan** Dr. Samuel Chiu Dr. Albert Lan	Innovative 3DHI (3D Heterogeneous Integration) Packaging Technology Development □3D Heterogeneous Integration (3DHI) has been widely used as one of the effective enablers for “More-than-Moore” technology since the advanced wafer node scaling down relying on front-end technology is getting hard to achieve the goal of business return. □With traditional transistor pitch scaling facing fundamental challenges, 3D Heterogenous Integration Packaging technologies adopting Through Si Via (TSV) and Hybrid Bonding are poised to help enabling the future AI / HPC device applications. □In this class, to help the students to realize the advantages of 3D Heterogeneous Integration (3DHI), market trend, technology benchmark, process challenges and its effective solutions for the following topics will be specifically addressed.□Topic Coverage:□1.3DHI Market Trend and Product Applications, focusing on AI / HPC□2.3DHI Technology for CPO (Co Package Optics)□3.3DHI Technology for COWOS(TSV/BVR) / Hybrid Bonding (C2W / W2W)□4.3DHI Technology for Advanced Substrate
AUG **03**	**Circular Economy of Electronics Industry** Prof. Wei-Sheng Chen	The concept of circular economy has gained significant attention in recent years, with various industries adopting different systems to tackle issues. In Taiwan, the electronics industry is a key contributor to the economy, but it also generates a significant amount of waste, pollution, and some problems. Therefore, there is a pressing need to improve the sustainability of this sector. This class aims to introduce some systems and recycling technologies (silicon resources) which can help Taiwan achieve the goals of the circular economy and address these challenges.

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The Essentials of Semiconductor Technology and Supply Chains

Instructor	About
陳貞夙 **Prof. Jen-Sue Chen**  Ph.D., California Institute of Technology, USA	**Professor** **Dept. Material Science and Engineering & Program on Key Material, NCKU** Thin Film Transistors, Light Gating Transistors, Resistance Switching RAMs, Charge Trapping Memory, Impedance Spectroscopy on Electronic Devices
郭致宏 **Prof. Chih-Hung Kuo**  PhD, Electrical Engineering, University of Southern California	**Professor** **Dept. Electrical Engineering & Program on Integrated Circuit Design, NCKU** IC Design/ Electrical Engineering
林英超 **Prof. Ing-Chao Lin**  PhD, Computer Science and Engineering, Pennsylvania State University	**Professor** **Dept. Computer Science and Information Engineering & Program on Integrated Circuit Design, NCKU** IC Design/ Computer Science & Information Engineering
邱瀝毅 **Prof. Lih-Yih Chiou**  PhD, VLSI and Circuit Design, Purdue University	**IC Design/ Electrical Engineering** IC Design/ Electrical Engineering
蔡瀚輝 **Director Hann-Huei Tsai**  Master of Science Electrical Engineering, National Cheng Kung University	**Research Fellow/Division Director, National Applied Research Laboratories (NARLabs), Taiwan Semiconductor Research Institute(TSRI), Tainan** IC Design
劉瑞農 **Prof. Jui-Nung Liu**  PhD, Electrical and Computer Engineering, University of Illinois at Urbana-Champaign	**Assistant Professor** **Dept. Electrical Engineering and Institute of Microelectronics &Program on Semiconductor Manufacturing Technology, NCKU** Mid-infrared group-IV photonics/Optical nanocavity/ Surface-enhanced vibrational spectroscopy/Cavity QED

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Instructor	About
黃英原 **Prof. Ying-Yuan Huang**  Ph.D., Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, GA, USA	**Professor** **Dept. Material Science and Engineering & Program on Key Material, NCKU** High-efficiency silicon solar cells; Tunnel Oxide Passivated Contacts; Light Emitting Diodes; Semiconductor device simulation, fabrication and characterization
許蘇文 **Prof. Su-Wen Hsu**  PhD, Materials Science and Engineering, University of California, San Diego	**Associate Professor** **Dept. Chemical Engineering& Program on Key Materials, NCKU** Key Materials/Chemical Engineering
邱興邦 **Dr. Samuel Chiu**  PhD, Materials Science and Engineering, University of California, Los Angeles (UCLA)	**Senior Technical Director, Applied Materials Taiwan** Semiconductor fabrication flow and integration/ Plasma and thermal applications in semiconductor process technology/ Materials and Failure Analysis tools and applications/ Quality Assurance and Supplier Chain Engineering/ Large Scale product and project management.
藍章益 **Dr. Albert Lan** 	**Global Sr. Packaging Account TD Head,** **Applied Materials, USA** Over 30 years of job experience in semiconductor industry, esp. advanced packaging technologies. Senior Engineering Center Director, 14 years, SPIL PD, Quality, & Sales, 6 years, Amkor Taiwan Advanced 3D Heterogeneous Integration Packaging Technology Development
陳偉聖 **Prof. Wei-Sheng Chen**  PhD, Resource Engineering, NCKU	**Associate Professor** **Dept. Resource Engineering, NCKU** Waste Disposal Resource Technology Mineral Waste Classification Refined Metallurgy

TSRI

Overall of Courses in TSRI

8/05-8/09	**R303**	- Full-Custom IC Design and Simulation
	R305	- Full-Custom IC Design and Simulation
	Tainan New	- Operational Amplifier Design Essentials
8/12-8/16	**R423**	- Silicon Photonics Design and Analysis
	R303	- CMOS RF IC Design and Simulation
	Tainan New	- Power Management IC Design in CMOS BCD Technologies

01 Full-Custom IC Design & CMOS RF IC Design

Full-Custom IC Design and Simulation (1-week)

Day 1	Day 2	Day 3	Day 4	Day 5
- Full-Custom IC Design Overview - Foundry Design Kit Introduction	Fundamentals of Full-Custom Cell Design and Simulation	Layout Skill and Implementation	Layout Verification (DRC/LVS/LPE) and Debugging	Hands on Labs for Layout and Post-Sim.

CMOS RF IC Design and Simulation (1-week)

Day 6	Day 7	Day 8	Day 9	Day 10
- Passive Components - Matching Networks	- EM Simulation - MOS Devices	Verification Flow	LNA Project Design	LNA Layout and Verification

02 Full-Custom IC Design & Silicon Photonics Design and Analysis

Full-Custom IC Design and Simulation (1-week)

Day 1
- Full-Custom IC Design Overview
- Foundry Design Kit Introduction

Day 2
Fundamentals of Full-Custom Cell Design and Simulation

Day 3
Layout Skill and Implementation

Day 4
Layout Verification (DRC/LVS/LPE) and Debugging

Day 5
Hands on Labs for Layout and Post-Sim.

Silicon Photonics Design and Analysis (1-week)

Day 6
- Silicon photonics introduction
- Silicon photonics foundry-type process/platform
- Si waveguide

Day 7
- Grating coupler and spot size converter design
- Coupler testing

Day 8
Silicon photonics related company visiting

Day 9
- Modulator types and modulation mechanism
- Photonic integrated circuit design and simulation

Day 10
Photonic integrated circuit layout

03 Operational Amplifier Design Essentials & Power Management IC Design in CMOS BCD Technologies

Operational Amplifier Design Essentials (1-week)

Day 1
- Device & model introduction
- Specifications of OPamp
- Opamp architecture introduction

Day 2
- Gm/Id design concepts
- Single-stage OPamp design

Day 3
- Two-stage OPamp Design
- Common-mode Feedback
- Bias Circuit Design

Day 4
- Noise &PVT variation
- Lab-Single-stage OPamp design

Day 5
- Lab-Opamp simulation techniques by Virtuoso
- Lab-Opamp simulation techniques by Hspice

Power Management IC Design in CMOS BCD Technologies (1-week)

Day 6
- Introduction
- Process Overview
- High Voltage Circuit Design
- Design Environment I: Circuit Simulation

Day 7
- Chip Implementation I: Schematic and Circuit Simulation
- Design Environment II: Layout & Layout Verification

Day 8
- Protection Mechanism I: Internal LV Device
- Chip Implementation II: Level Shifter Layout and Verification

Day 9
- Protection Mechanisms II: (1) Internal HV Device (2) HV I/O Device & Parasitic ESD Rules
- Chip Implementation III: Level Shifter Layout and Verification

Day 10
- Chip Implementation IV: Full Chip Layout
- Chip Implementation V: Post-layout Simulation