Department of Electrical Engineering
Indian Institute of Technology Kanpur

Proposal for a New Course

Course No : EE6XX

Course Title. : Nanoscale Devices

Pre-requisite : EE614, EE311 or equivalent course on basics of semiconductor physics and devices

Course Credit : 3-0-0-0 [9]

Course Duration : Full Semester

Proposing Instructor : Mohit Ganeriwala, mohitdg@iitk.ac.in

Others Faculty members who may be interested in teaching the proposed course : Dr. Shubham Sahay, Dr. Avinash Lahgere

Course Type : PG, 4th year UG, Open Elective

Course Description :

As MOSFETs scale, their architecture evolves to overcome increasingly fundamental limits in electrostatics, transport, variability, and manufacturability. This course aims to develops the device physics needed to understand the evolution from bulk MOSFETs to modern 3D transistors, 2D materials-based devices, and emerging More-than-Moore technologies.

The course will begin with the review of MOSFET scaling and short-channel effects, and examines the architectural innovations developed to address them. It will progress from bulk MOSFETs to PDSOI and FDSOI, FinFETs, nanosheet and nanowire FETs, and complementary FETs (CFETs). The course will develop the fundamentals of electrostatics and carrier transport in thin and highly confined channels, including the effects of geometry, confinement, band structure, mobility, defects, surface roughness, and device variability. Approaches for modeling and simulating these effects will also be introduced.

The course will then explores the atomic limit of channel scaling through 2D materials. It will covers representative material systems such as graphene, transition-metal dichalcogenides (TMDs), and hexagonal boron nitride (hBN), focusing on their electronic properties i.e. electrostatics, and transport. Particular attention will be given to the challenges of realizing practical 2D devices, including contacts, gate dielectrics, substrates, defects and doping.

The course concludes with an introduction to More-than-Moore device concepts, such as realizing new material system with 2D materials based hetro-integrations, leveraging the defect in these materials to build new devices for neuromorphic computing, leveraging phase change and spin to realise new devices, and other emerging device concepts for unconventional computing and specialized applications.

The main objective is to develop an understanding of device physics beyond the bulk MOSFET and the technological directions shaping future transistors. The course also aims to provide students with a framework for analyzing emerging devices: identifying the physical limitations of a device, understanding how its architecture addresses those limitations, evaluating the associated trade-offs, and developing informed ideas for new device concepts.

Tentative Course Contents :

Topics	Lecture hours
MOSFET scaling and Short-channel effects	3
SOI : PDSOI and FDSOI	2
FinFETS and 3D transistor architecture	2
Nanosheet and Nanowire FETs	2
CFETs	1
Quantum confinement and band structure effects, DOS, various capacitances	5
Mobility, defects, surface rougness and variability	5
Device modeling and multi-scale simulations	3
2D Materials : Graphene, TMDs and hBN	5
Electrostatics and tansport in 2D materials based devices	4
Contacts, gate dielectric, doping, defects and other challenges	5
2D hetrostructure and hetrointegrations	1
Other emerging and unconventional device concepts	2
Total	**40**

Reading material :

The course will rely primarily on research papers, supplemented by several books and reference texts.

1. J.-P. Colinge, Ed., FinFETs and Other Multi-Gate Transistors, Springer, 2008.
2. P. Avouris, T. F. Heinz, and T. Low, Eds., *2D Materials: Properties and Devices*, Cambridge University Press, 2017.
3. M. Houssa, A. Dimoulas, and A. Molle, Eds., *2D Materials for Nanoelectronics*, CRC Press, 2016.
4. D. Jena, Quantum Physics of Semiconductor Materials and Devices, Oxford University Press, 2022.
5. J. H. Davies, The Physics of Low-Dimensional Semiconductors: An Introduction, Cambridge University Press, 1998.

Date: 06/10/2026



Signature of the Proposer

Convenor, DPGC
Department of Electrical Engineering

Chairperson, SPGC
IIT Kanpur