MINISTRY OF EDUCATION AND SCIENCE OF THE REPUBLIC OF ARMENIA

STATE ENGINEERING UNIVERSITY OF ARMENIA

CONFIRMED BY	CONFIRMED BY
EXECUTIVE DIRECTOR OF	VICE RECTOR OF STATE ENGENEERING
"SYNOPSYS ARMENIA" CJSC SG	UNIVERSITY OF ARMENIA
H. MUSAYELYAN	R. AGHGASHYAN
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SEMICONDUCTOR DEVICES

COURSE PROGRAM

INDEX: **20.02, 22.05**

SPECIALIZATION **"VLSI DESIGN"**

YEREVAN 2005

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The program has been discussed and approved by:

- At the sitting of the SEUA interdepartmental Chair of **“Microelectronic Circuits and Systems”** acting on the basis of “SYNOPSYS ARMENIA” CJSC SG
  Protocol No. 5 of. 22.02.2005

- At the sitting of the **Computer Systems and Informatics Department** authorities
  Protocol No. 4 of. 28.02.2005

- At the sitting of the **Cybernetics Department** authorities
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INTRODUCTION

Course program on **“Semiconductor Devices”** is assigned for undergraduate education on “**VLSI Design”** specialization and is taught on the 5th semester (3 year’s 1st semester).

The course duration is 68 hours, lectures volume is 68 hours.

COURSE GOALS AND OBJECTIVES

The goal of the course is to teach the future designers the principles of operation, design, and construction of contemporary semiconductor devices created on the basis of solid state physical effects as well as instrumental software, by the designers of the microelectronic circuits and systems.

The main objectives of the course are - studying all types of semiconductor devices used in the VLSI, their structure, operation principles, characteristics and computer models, as well as acquaintance with the peculiarities of models introduction in the CAD and application of semiconductor devices.

SYLLABUS

1. LECTURES (68 hours)

1.1. SEMICONDUCTOR FUNDAMENTALS (6 hours).

Semiconductor materials, different kinds, physical and chemical properties. Energy bands of semiconductors, electrons and holes, doping, carrier densities, carrier transport (drift, mobility, diffusion and currents). Recombination and generation. Diffusion length and continuity equation. Photoelectric effects.

1.2. P-N JUNCTION (12 hours).

P-N junction structure and principle of operation. Energy band diagram. Thermal equilibrium. The built-in potential. Forward and reverse bias. The P-N junction currents. Voltage-current characteristics. Diffusion and barrier capacitances. The characteristics of the real diode. Recombination-generation current. I-V characteristics of real P-N diode. General breakdown characteristics.. Tunnel, avalanche, and thermal breakdown. Time response of P-N diode. The transient properties of diodes. Equivalent circuit of diode. Parameters dependence on temperature. Types of semiconductor diodes. The heterojunction P-N diode. Quantum well structures.

1.3. METAL-SEMICONDUCTOR JUNCTIONS (4 hours).

Structure and principle of operation. Energy band diagram. Thermal equilibrium. The built-in potential. Forward and reverse bias. Voltage-current characteristics. Schottky barrier diode parameters. Linear metal-semiconductor contact. Ohmic and tunnel contacts.

1.4. METAL-SEMICONDUCTOR FIELD EFFECT TRANSISTORS (4 hours) .

Structure and principle of operation. Voltage-current characteristics and parameters. Analysis for MESFET devices under various bias conditions. Gallium arsenide as a perspective material for MESFET devices.

1.5. BIPOLAR JUNCTION TRANSISTORS (12 hours).

Structure and principle of operation, Energy band diagram. Static characteristics and parameters of bipolar transistors. Ideal transistor model. Forward active mode of operation, general bias modes of operation. The Ebers-Moll model. Saturation.. Secondary effects in real devices. Base width modulation, punch-through and thermal effects, recombination in the depletion region, est. Gummel-Poon model. Charge-control analysis. BJT dynamic performance.

Transit time effects. Equivalent transistor circuits and determination of their components values by means of physical parameters. Heterojunction bipolar transistors. SPICE model of bipolar transistor.

1.6. METAL-OXIDE-SEMICONDUCTOR (MOS) CAPACITORS (4 hours).

Structure and principles of operation. Energy band diagram. Accumulation, depletion and inversion modes. MOS analysis.

1.7. MOS FIELD EFFECT TRANSISTORS (18 hours).

Structure and principles of operation. MOSFET analysis. The linear, quadratic and variable depletion layer models. Parameters and characteristics. Threshold voltage calculation, the substrate bias effect. Performance limitations. SPICE models of MOS transistors.

Structure of CMOS transistors, operation principles, characteristics, models, impact of technological peculiarities on their characteristics.

Advanced MOSFET issues, channel length modulation. Short channel effects, sub-threshold current, field dependent mobility, punch through, velocity saturation, bipolar action, oxide injection etc.

1.8 PHOTO AND OPTOELECTRONIC DEVICES (4 hours).

Photovoltaic effects. Photoresistor, photodiodes, solar cells, light emitting diodes, laser diodes. Structures and principle of operation, parameters and application**.** Optoelectronic circuits and optron pairs.

1.9. NANOELECTRONIC DEVICES (4 hours).

Reduction in the size of conventional field-effect transistors. Next-generation electronics devices. Resonant tunneling devices and single-electron transistor. Operation principles and functional capabilities.

METHODIC PROVISION OF THE COURSE

To study the course the necessary list of references is given below.

The course program is compiled taking into account that the following courses had been studied beforehand:

- “Electrical Engineering”
- “Physical Fundamentals of Microelectronics” or “Solid State Electronics Fundamentals”

Understanding of the course is the basis for the further specialized subjects destined by the educational plan of “VLSI Design” specialization.

REFERENCES

1. B. Van Zeghbroeck, ”Principles of Semiconductor Devices,“ Colorado University, 2001.
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3. R.F. Pierret, “Semiconductor Devices Fundamentals,” Addison Wesley, 1996.
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6. B.G. Streetman, Solid State Electronic Devices, Prentice-Hall, 1990.
7. Y. Tsividis. Operating and Modeling of the MOS Transistor, McGraw-Hill, New York, 1999.