WSPC—COSTED SERIES IN EMERGING TECHNOLOGY

Physics of Semiconductor Devices

PROCEEDINGS OF THE FOURTH INTERNATIONAL WORKSHOP

Madras (India) December 10–15 1987

Editors
S C JAIN & S RADHAKRISHNA

World Scientific
Singapore • New Jersey • Hong Kong

COMMITTEE ON SCIENCE & TECHNOLOGY
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PREFACE

The Fourth International Workshop on Physics of Semiconductor Devices is being organised in the Department of Physics, Indian Institute of Technology , Madras , India during December 10-15 1987. We are grateful to all the invited speakers who have sent their manuscripts in advance to enable us to prepare the proceedings in time for the Workshop. This year the emphasis has been on microelectronics, VLSI, and special aspects related to semiconductor applications.

We would like to express our grateful appreciation of the support provided by Department of Science and Technology, Defence Research and Development Organisation and several other government departments.

We gratefully acknowledge the support provided by Messers World Scientific Publishers for having brought out the proceedings in time for the Workshop in the very short time given to them.

S C Jain
S Radhakrishna

November 15, 1987.

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CONTENTS

Preface v

MICROELECTRONICS

Novel MOSFET Structures for Integrated Magnetic Field Sensors 3
B S Gill, D Misra & E Heasell

Performance-Directed Synthesis of VLSI Systems 13
J Allen

A Steady-State Model for the Insulated Gate Bipolar Transistor 22
A R Hefner Jr., D L Blackburn & K F Galloway

Recent Developments in Physics of Silicon Di-Oxide Very Thin Films for VLSI. New Oxidation Models and Electrical Characterization 39
G Kamarinos

Electrical Characterization of Very Thin SI Epitaxial Layers Used for Bipolar VLSI 48
P Spirito, S Bellone & C M Ransom

HEMT LSI: Status and Trends 58
T Mimura, M Abe, J Komeno & K Kondo

ISIT: Ultra High Speed Ballistic Devices 67
J Nishizawa

Physical Limits of VLSI 76
A Jakubowski & A Swit

Problems of Extraction of MOS Transistor Parameters 85
K Iniewski, A Jakubowski & B Majkusiak

An Analytical Model and Computer Simulation of the J-V Characteristics of N^+PN^+ (P^+NP^+) Two-Terminal Devices 95
Z J Staszak, S C Jain & R H Mattson

A Quasi One-Dimensional Model for Short-Channel MOST 107
C R Viswanathan

VLSI Packaging Design Methodology Considerations 115
J L Prince, O A Palusinski, Z J Staszak & M R Scheinfein

MOSFET Modeling for VLSI Simulation 126
N D Arora

Pulse Anneal Processing in Three-Dimensional Microelectronics 136
L N Aleksandrov

Measurement and Control of Mechanical Properties of Thin Films 142
H Guckel & D W Burns

Flicker Noise in Semiconductor Devices 151
R Sharan

Junction Termination – A Technique for Near Ideal Breakdown in Planar Junctions 157
S Ahmad

Some Implications of Miniaturisation of Semiconductor Devices 168
M Satyam, K Ramkumar & K S Gurumurthy

Submicron CMOS Technology 183
D K Sharma

Computer Integrated Manufacturing Science and Technology for VLSI 193
K C Saraswat

Non-Equilibrium Carrier Transport in Hot Electron and Heterojunction Bipolar Transistors 198
J R Hayes

Some Aspects of Lightly Doped Drain Transistor 208
W S Khokle, P N Andhare, R K Nahar,
N M Devashrayee & S Chandra

MATERIALS

Recent Advances in Silicon Devices 223
S C Jain & K H Winters

Modeling Semiconductor Devices with Position-Dependent Material Parameters 238
A H Marshak

Oxygen-Related Defects in Silicon 249
G Pensl & M Schulz

Interface Properties of InP-Dielectric Systems 261
R Blanchet

Recent Analytical Efforts to Model Minority Carrier Transport in Moderately to Heavily Doped Semiconductor Regions 269
C R Selvakumar

Deposition and Direct Writing of Al on Si by Light-Assisted Chemical Processing 279
J E Bouree

1/f Noise in Semiconductor Devices: Theory and Applications 290
B Pellegrini

Recent Developments of Low Temperature Epitaxial Growth of Semiconductors 300
T Hariu

Electronic Properties of CVD Amorphous Silicon 310
S M Pietruszko

Thermal Considerations in the Design of Millimeter Wave Devices 320
I Chandra

Overview of Power Semiconductor Devices 329
H Mehta & V A K Temple

Thin Film Polycrystalline Devices Using Ternary Semiconductors 337
R W Miles, M Carter, A Knowles, S Arshed, H Oumous & R Hill

Layer Compounds and Their Use as Secondary Battery Electrodes 346
A A Balchin

Oxide Materials in Semiconductor Science and Technology 356
C A Hogarth

Topological Reasoning of Thermodynamic and Kinetic of CVD Processes 366
V A Voronin, V A Prochorov, M I Dronyuk & V A Goliousov

DLTS Investigations of the Metastability of the DX Centre in MBE Grown Algaas 369
Y N Mohapatra, V Kumar, S Subramanian & B M Arora

Dry Oxidation of Silicon: Growth Kinetics for Thin Oxides 378
J Vasi, S S Moharir & A N Chandorkar

The Changing Nature of Reliability Physics 389
J W Lathrop

Phase Diagram Studies in the Te-RICH HgCdTe System 399
S C Gupta, F R Chavda & A K Garg

Growth, Characterization and Heavy-Doping Effects in Indium Phosphide 408
D N Bose & B Seishu

Liquid Phase Epitaxial Growth of $In_{1-x}Ga_xAs_yP_{1-y}$ ($y \approx 2.2x$) Lattice Matched to InP 413
S S Chandvankar & B M Arora

PHOTOVOLTAICS

Technology and Characteristics of Amorphous Silicon for Solar Cells Applications 435
F P Califano

New Type of Heterostructures for Solar Cells 445
B L Sharma, G C Dubey & V K Jain

Considerations for Optimizing Light Coupling to Solar Cells in a Flat-Plate Photovoltaic Module 463
B L Sopori

Effect of Annealing on Electrical Activity of Surfaces in Silicon 473
R Kumar, R K Kotnala, N K Arora & B K Das

Physics and Technology of Thin Film Polycrystalline Solar Cells 486
P K Ajmera

GALLIUM ARSENIDE DEVICES

Electron and Hole Injections into Semi-Insulating GaAs and Implications for Side-Gating of LSI Circuits 499
K Lehovec & H Bao

Present Status and Future Trends of High Speed Devices Using GaAs and Related Compounds 511
H Hasegawa

The Physics of Resonant Tunnelling in Gallium Arsenide Heterostructure 520
D K Roy & A Ghosh

MICROELECTRONICS

Novel MOSFET Structures for Integrated Magnetic Field Sensors

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Introduction

The development of integrated, sensor devices has become a significant activity. The MOSFET structure in particular has been employed for ionic and gaseous sensing and for the detection of magnetic fields.

Magnetic field sensors, based on MOS technology, or MAGFETS, are attractive in a range of sensor applications, magnetic bar-code readers, displacement or rotation transducers etc. They lend themselves well to integration with on-chip data processing.

1, The conventional MAGFET.

A variety of magnetic field sensitive devices have been described. A recent review [1]. gives an excellent, overall picture of current work.

The devices all rely upon some variant of the Lorentz force or Hall effect. The attraction of the MOS family is based upon a naive application of the Hall effect formula :

$$V_H = R_H BI(W/t) \qquad (1.1)$$

V_H is the Hall voltage, R_H the Hall coefficient, W the width of the conducting channel and 't' its thickness.

The available Hall voltage is governed by consideration of the permissable power dissipation in the device, and by the Hall coefficient R_H. Conventional Hall sensors exploit the larger carrier mobilities available in the III-V compounds, InAs in particular.

Conventional, flat-plate, Hall transducers, fabricated from Silicon, are less useful since the available electron mobility, even in pure material is low. The MOSFET structure allows the realisation of very large values of (W/t), it might seem idealy suited to the development of Hall effect transducers, exploiting standard n-MOS technology.

To achieve such a sensor, more-or-less conventional MOSFET devices, using two, isolated drain diffusions have been employed, [2]. Typical structures are shown in Fig.1. These devices have been called MAGFET's, [3]. Such devices exhibit a differential redistribution of the channel current, between the drains, in the presence of a magnetic field. The sensitivity is quite poor. However, when operating in saturation, the electrical output impedance is high, and standard MOS, active loads may be used to achieve larger output signals, [2].

In fact the design of these devices is at fault. The split-drain configuration is sensitive to the charge redistribution in the channel, not to the actual Hall field or voltage. The charge distribution needed to sustain even a large Hall-field, is very small. (indeed if E_H is uniform, then only a small surface charge, at the channel edges, is needed).

Charge separation can occur only over a short distance in the immediate vicinity of the drain, where the carriers are free to move laterally.

The mobility of electrons in the channel of a MOSFET is reduced both by the additional scattering resulting from the extreme narrowness of the channel, as well as by velocity saturation effects, observed also in bulk material, at high fields. The saturation of carrier velocity is especially significant in the drain region of a MOSFET, operating in saturation.

Since the chordal mobility falls, the Hall angle decreases and the deflection of the carriers, by the Lorentz force, is reduced. In addition, the carrier are only deflected in the region immediately adjacent to the drains, so that current redistribution occurs only over a very small fractin of the total channel length.

The next structure described attempts to ovecome these limitations.

2, The Graded Gate MAGFET.

To limit the longitudinal electric field in the channel, and to increase the path length over which it operates, we modify both the gate and drain structure of the device.

We use a resistive (refered to as GRADED) gate structure. Ohmic contacts to the ends of the gate permit the application of either aiding or retarding fields in the channel. The gate is made of undoped polysilicon and exhibits a resistance of around 10^9 ohms. Power dissipation, due to the gate bias is negligible, [4].

To prevent the Hall field from developing, lateral drain diffusions are placed along either side of the channel. These diffusions (refered to as lateraal-drains), are biased so that the drain potentials are more positive than the surface potential at any point in the channel. Fig.2. In some devices a third drain is placed at the end of the channel, in order to collect undeflected carriers.

The theory for the simple GGFET (without lateral drains) can be derived, assuming an Ihanolta-Moll type model (drift only). The analysis confirms that it is possible to achieve reasonably uniform, electric fields over the entire length of the channel. We can arrange operation to avoid the major effects of velocity saturation. These devices exhibit significantly higher sensitivities. The sensitivity is, as anticipated, an increasing function of the aiding, gate field. Fig.3.

Fig.3b shows the offset current versus

A first order model of the channel potential, in the presence of an external, magnetic field, predicts sensitivities in fair agreement with experiment. The device sensitivity can be determined by solving the lateral diffusion problem and integrating along the drains. Fig.4.

In the structures considered, we can regard the drain currents as a superposition of two components, the carriers deflected by the Lorentz force in the channel, and a much larger, undeflected portion, which ideally divides evenly, between the drains. In practice, due to manufacturing tolerances, the current does not divide symmetrically in the absence of an external field.

In an attempt to avoid the latter problem we consider the inclusion of an additional drain diffusion, to collect undeflected carriers.