

# **FinFETs and Other Multi-Gate Transistors**



Jean-Pierre Colinge  
Editor

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Springer

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Cambridge, MA 02139  
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Library of Congress Control Number: 2007935904

ISBN 978-0-387-71751-7      e-ISBN 978-0-387-71752-4

Printed on acid-free paper.

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## Preface

*The* adoption of Silicon-on-Insulator (SOI) substrates for the manufacturing of mainstream semiconductor products such as microprocessors has given SOI research an unprecedented impetus. In the past, novel transistor structures proposed by SOI scientists were often considered exotic and impractical, but the recent success of SOI in the field of microprocessor manufacturing has finally given this technology the credibility and acceptance it deserves.

The classical CMOS structure is reaching its scaling limits and “end-of-roadmap” alternative devices are being investigated. Amongst the different types of SOI devices proposed, one clearly stands out: the multigate field-effect transistor (multigate FET). This device has a general “wire-like” shape with a gate electrode that controls the flow of current between source and drain. Multigate FETs are commonly referred to as “multi(ple)-gate transistors”, “wrapped-gate transistors”, “double-gate transistors”, “FinFETs”, “tri(ple)-gate transistors”, “Gate-all-Around transistors”, etc. The International Technology Roadmap for Semiconductors (ITRS) recognizes the importance of these devices and calls them “Advanced non-classical CMOS devices”.

There exists a number of textbooks on SOI technology. Some of these books tackle the subject of multigate FETs, but there is no book that contains a comprehensive description of the physics, technology and circuit applications of this new class of devices. This is why we decided to compile chapters dedicated to the different facets of multigate FET technology, written by world-leading experts in the field. This book contains seven chapters:

- *Chapter 1: The SOI MOSFET: from Single Gate to Multigate*, by Jean-Pierre Colinge, is a general introduction that shows the evolution of the SOI MOS transistor and retraces the history of the multigate concept. The advantages of multigate FETs in terms of electrostatic integrity and short-channel control are described, and the challenges posed by the appearance of novel effects, some of quantum-mechanical origin, are outlined.
- *Chapter 2: Multigate MOSFET Technology*, by Weize (Wade) Xiong, outlines the issues associated with multigate FET manufacturing. This chapter describes thin-fin formation techniques, advanced gate stack deposition and source/drain resistance reduction techniques. Issues related to fin crystal orientation and mobility enhancement via strain engineering are tackled as well.
- *Chapter 3: BSIM CMG: A Compact Model for Multi-Gate Transistors*, by Mohan Vamsi Dunga, Chung-Hsun Lin, Ali M. Niknejad and Chenming Hu, describes the physics behind the BSIM-CMG (Berkeley Short-channel IGFET Model – Common Multi-Gate) compact models for multigate MOSFETs. A compact model serves as a link between process technology and circuit design. It is a concise mathematical description of the device physics in the transistor. Some simplifications in the physics, however, can be made to enable fast computer analysis of device/circuit behavior.
- *Chapter 4: Physics of the Multigate MOS System*, by Bogdan Majkusiak, analyzes the electrostatics of the multigate MOS system. Using quantum-mechanical concepts, it describes electron energy quantization and the properties of a one-dimensional and two-dimensional electron gas. The effects of tunneling through thin gate dielectrics on the electron population of a device are studied as well.

- *Chapter 5: Mobility in Multigate MOSFETs*, by Francisco Gámiz and Andrés Godoy, analyzes the behavior of electron mobility in different multigate structures comprising double-gate transistors, FinFETs, and silicon nanowires. Mobility in multiple gate devices is compared to that in single-gate devices and different approaches for improving the mobility in these devices, such as different crystallographic orientations and strained Si channels, are studied.
- *Chapter 6: Radiation Effects in Advanced Single- and Multi-Gate SOI MOSFETs*, by Véronique Ferlet-Cavrois, Philippe Paillet and Olivier Faynot, describes the effects of ionizing radiations such as gamma rays and cosmic rays on SOI MOSFETs. These effects are extremely important in military, space and avionics applications. Multi-gate FETs show exceptional resistance to total-dose and single-event effects and could become the new standard in radiation-hardened electronics.
- *Chapter 7: Multigate MOSFET Circuit Design*, by Gerhard Knoblinger, Michael Fulde and Christian Pacha, describes the interrelationship between the multi-gate FET device properties and elementary digital and analog circuits, such as CMOS logic gates, SRAM cells, reference circuits, operational amplifiers, and mixed-signal building blocks. This approach is motivated by the observation that a cost-efficient, heterogeneous SoC integration is a key factor in modern IC design.

*Jean-Pierre Colinge, August 2007*

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