

Preface

Welcome to the world of high permittivity gate dielectric materials and its environment.

Genesis. I began writing a book on ultrathin gate dielectrics all by myself but was making poor progress; it was not clear to me when I would be able to complete the project. Then, at one of our annual high-k symposia, Dr. Claus E. Ascheron, Executive Editor Physics, Springer Science, Heidelberg, suggested that we undertake the writing of this book, consisting of some 15 chapters on different areas of the high-k gate stacks with different chapters being written by different authors with the coordination done by me as an editor. This is how this book was conceived. A number of books of this type (edited with chapters written by different authors) exist on this subject. These books were written quite a few years ago, before MOSFETs with high-k gate stacks and metal electrodes were introduced into the market in the year 2007 by Intel and other manufacturers for the 45 nm technology node. Since then the high-k world has seen significant changes in terms of technological maturity, high-k gate stack materials, and our scientific understanding of the different aspects and issues. Hence one could argue that this book is timely.

Multiple authorship. There are different intrinsic advantages and disadvantages built into a book authored by one person and a book written by many authors. A single-author book may enjoy a higher degree of cohesion, continuity, and readability, whereas a multiple-author book will have a larger pool of scientific knowledge, wisdom, experience, and expertise. A multiple-author book to be effective will require diligence, tenacity, and finesse in coordinating the needs, activities, and the response of a large number of busy and preoccupied individuals (the authors), and the cohesion and continuity of the book will depend upon the quality of this coordination and the mutual cooperation between all the actors. Which of these two options (modes) of writing a book on this subject would have taken a longer or a shorter time is difficult to predict. One interesting point to ponder in this connection is why no single-author book has been published on the subject of this book? Is it because the complexity of the subject is beyond the effective reach of a single author? Most of the chapters have been written by a single author, except [Chaps. 6, 10, and 12](#). In the case of [Chap. 12](#), the part dealing with the Ge channel has been authored by Michel Houssa, the part dealing with the

GaAs and InGaAs channel has been authored by Peide Ye, and the part dealing with the III–V interface characterization has been authored by Marc Heyns. All of Chap. 6 has been written jointly by Akira Toriumi and Toshihide Nabatame; all of Chap. 10 has been jointly written by Akira Toriumi and Koji Kita.

Readership. We have tried to make the readership of the book as wide as possible—as a reference book for researchers as well as a text book for graduate students with electrical engineering, chemical engineering, materials science, or physics background.

Introduction. An overview of this book and all its chapters is presented in Chap. 1 entitled “Introduction to High-k Gate Stacks”; this introductory chapter provides simple description of the concepts and defines the terminology to be encountered in the various chapters. Chapter 1 also provides the missing links to enhance the continuity and the readability.

Coverage of the topics and comprehensiveness. We have tried to see that each chapter begins with the definitions and the basics, reviews the current literature, and ultimately graduates to the current status of the technology, and our understanding. In addition to the introduction presented in Chap. 1, we have designed Chap. 2 to provide coverage of the basics, a theoretical foundation of the high-k gate stacks, the MOS structure and the MOSFET, and the missing links, to enhance the cohesion, the continuity, and the readability of the book. In the ten chapters—Chaps. 3–12, we have tried to cover the topic as completely and comprehensively as possible. In my view all the important current and emerging areas (in addition to those covered in Chaps. 1 and 2) have been treated including physical properties of the high-k materials, hafnium-based, and lanthanide-based high-k gate stacks—their processing, characterization and characteristics, and transistor performance, properties of ternary and doped higher-k materials, crystalline high-k oxides, high-k gate stack degradation and reliability, and high-mobility channels.

Search, reference (look-up), and readability-enhancement aids. To facilitate search and look-up and to enhance readability, we have provided aids such as a comprehensive subject index at the end of the book, and an exhaustive table of contents, a list of abbreviations, a complete list of acronyms, and a complete list of symbols at the beginning of the book. In addition, we have provided in the seven appendices values of the fundamental constants, the periodic table, and experimental data on the physical properties of a large number of semiconductors, and high-k materials. The reader may need to look up or wish to consult these values and data while going through the theory, experimental results, and their interpretation. In other words, an attempt has been made to make the book complete with all the necessary elements under one roof.

Readability, continuity, and cohesion. Each chapter begins with an abstract and ends with a summary and a list of references. To promote readability, we have tried to see that the treatment at the beginning of the chapter is simple; and that the characteristic terms are defined and the fundamental and the basics are covered first, to help a beginner to pick up the new material. In addition, Chap. 1 (in text) and Chap. 2 (in theory) should facilitate easier entry into the world of high-k gate stacks by providing an introduction and an insight into the topics of the other

chapters and the important links missing in those chapters. We have also incorporated cross-references to sections in the other chapters dealing with the same and/or similar topic. Our list of abbreviations and our list of acronyms have no duality; however, our list of symbols is not completely cohesive in the sense that for the same parameter, we have multiple symbols in a few cases. We tried but could not completely avoid in the case of a few parameters the use of different symbols by different authors for the same parameter. Acronyms are fortunately uniform and one could say standardized by virtue of the process of their formation or by definition. Abbreviations have also near-standard forms. In contrast, symbols do not enjoy standard representations. In the list of symbols, in the few cases where multiple notations occur, we have listed all the different notations used in the different chapters of this book for those parameters. Since the notations in almost all cases are suggestive, it should not cause any great problems for the reader in recognizing what the symbol stands for.

Acknowledgment. A book of this kind would not have seen the light of day without the untiring cooperation and perseverance of all the authors and the entire publishing team—in particular, Claus E. Ascheron, Executive Editor Physics, and S. A. Shine David who executed an excellent job of setting the figures, the tables, the text, and the references to a fine form. It will take too long to elaborate on the assistance and help they extended to me. I remain deeply grateful to all of them.

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