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Editors

Silicon-based Nanomaterials

Springer

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Preface

Silicon is one of the "oldest" electronic materials and has served the microelectronics industry for more than half a century. On the other hand, silicon is also a "young" material since both novel exciting aspects in science and new technical applications continue to be revealed. However, subject to the simple crystal and band structure, the functional extension of silicon must rely on artificial modifications to its size and electronic structure. After years of efforts to find proper ways to further expand silicon's application areas, research interests have gradually focused on nanocrystallization, alloying, and integration with other functional materials.

Size and shape control is of central importance in developing silicon-based materials science. Nanosized silicon and porous silicon with characterized pore size dimension on the nanometer scale have been demonstrated to be irreplaceable in photovotaics, photonics, and energy harvesting and storage. However, the full advantage of their unique properties can be exploited or utilized only if controlled preparation of these nanomaterials in terms of orientation, dimension, and size can be achieved.

One characteristic feature of silicon is its highly chemical reactivity to other elements. It can easily react with metal and carbon to form metal silicides and silicon carbide of good crystallinity. Thus a rich functional material family including metals, thermoelectric materials, direct band gap semiconductors, and wideband gap semiconductors with adjustable physical properties can be achieved by alloying methods. More excitingly, nanocrystallization further endows novel properties to these silicon contained compounds.

Besides nanocrystallization and alloying approaches, another straightforward way to expand silicon's versatility is to integrate functional materials on available silicon chips. This can be realized by depositing heterogeneous materials such as nanosized III–V semiconductors on atomically reconstructed surfaces or patterned surfaces of silicon, i.e., a bottom-up growth process. In many cases, the performance of devices based on such heterostructures is completely determined by the epitaxial quality of heterogeneous thin films or nanostructures on silicon surface or existing circuits.

This book aims to provide a comprehensive survey of the research and development status on the above-mentioned silicon-based nanomaterials. It is organized as follows: Chaps. 1–6 are dedicated to elemental-silicon nanostructures. Chapters 1 and 2 introduce the science and applications of porous silicon nanostructures in lithium batteries. Chapter 3 describes novel optical properties of silicon nanowires whose applications in solar energy harvesting and nano-electro-mechanical systems are summarized in Chap. 4. Chapters 5 and 6 deal with the optical properties of silicon nanoparticles embedded in silica matrix and their applications for light emitting devices. Chapters 7–12 concentrate on silicon-contained compounds for nanomaterials. Chapter 7 starts with a theoretical analysis of electronic and optical properties of silicon carbide nanostructures. Chapters 8–10 discuss the fabrication and characterization of various silicon carbide nanostructures. Chapter 11 investigates the transport behaviors of silicon carbide nanostructures. Chapter 12 focuses on synthesis, properties, and applications of metal silicide nanostructures. Chapters 13–15 discuss integration of other functional nanomaterials on silicon. Chapter 13 covers the droplet epitaxy of strain-free III–V quantum dots on silicon. Chapter 14 highlights the monolithic growth of III–V quantum dots on silicon and related devices behaviors. Finally, the authors demonstrate the growth and characterization of gallium nitride quantum wells structures on patterned SiC/Si substrates in Chap. 15.

We would like to thank all of the authors who have contributed chapters to this book. It took nearly one year to put this work together, but we are confident that the effort was worthwhile and that the book will be an important reference for scientists as well as a helpful platform to explore many fundamental questions at the frontier of materials science.

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