

# Preface

The applications of ferroelectric materials have been manifold and overspreading, covering all areas of our workplaces and homes over the present century. By far the largest number of applications in ferroelectric materials remained to be associated with bulk ceramics, but a trend toward thin films for specified applications, which provides additional benefits including lower operating voltage, higher speed operations, and scaling ability, has been energetically developed. Among various applications of ferroelectric thin films, the development of nonvolatile ferroelectric random access memory (FeRAM) has been most actively progressed since the late 1980s and reached modest mass production for specific application since 1995. These activities have been mainly motivated by the physical limitation and technological drawbacks of the Flash memory. There are two types of memory cells in ferroelectric nonvolatile memories. One is the capacitor-type (1T1C-type) FeRAM, in which a ferroelectric material is used as in the storage capacitor of a dynamic random access memory (DRAM) structure. The other is the field effect transistor (FET)-type (1T-type) FeRAM, in which the conventional gate insulator is replaced with a ferroelectric thin film. Although the FET-type FeRAM claims the ultimate scalability and nondestructive readout characteristics, the capacitor-type FeRAMs have been the main interest for the major semiconductor memory companies, because the ferroelectric FETs have fatal handicaps of cross-talk for random accessibility and short retention time. The present main applications of the commercialized FeRAMs are low-density nonvolatile embedded memory. Eventually, the huge expectations for the FeRAMs turned out to be somewhat different from what they had in prospect, to the contrary, the Flash memories keep the overwhelmingly dominant position in the nonvolatile memory-related industries thanks to their fascinating technology improvements and tremendously increasing needs for them.

Unlike these Si-based electronics demanding an ultra-high performance and an aggressive device scaling, the requirements for the nonvolatile memory components embedded into the large-area electronics implemented on glass, plastic or paper substrates are considerably different. If we can additionally obtain such features as

mechanical flexibility, transparency to the visible light, lower power operation and higher device reliability with a simpler process at lower temperature, it would have a great impact on the related industries. The ferroelectric gate field effect transistor (FeFET) is a very promising candidate because it can be reproducibly operated with a definitely designable principle and be prepared by a very simple process.

There are already lots of books dealing with the capacitor-type FeRAMs. Thus, this book aims to provide the readers with development history, technical issues, fabrication methodologies, and promising applications of FET-type ferroelectric memory devices, which have not been comprehensively discussed in the published books. The book is composed of chapters written by remarkable leading researchers. Authors are organized with top experts, who have been engaged with in ferroelectric materials and related device technologies, including oxide and organic ferroelectric thin films for a long time.

In Chap. 1, this book presents a comprehensive review of past and present technologies for the FET-type ferroelectric memories through historical development background. The feature, principle, theoretical analysis and improvement of FET-type ferroelectric memories are also overviewed. The Chap. 2 contains practical characteristics of FET-type ferroelectric memory devices. With the important aspects of channel layers, the practical properties of silicon-based and thin film-based channel layer ferroelectric gate field effect transistors are discussed in Chap. 2. In Chap. 3, the properties of organic ferroelectric materials such as poly(vinylidene fluoride) (PVDF), polyvinylidene fluoride trifluoroethylene [P(VDF-TrFE)] and polyvinylidene fluoride tetrafluoroethylene [P(VDF-TeFE)] in ferroelectric gate field effect transistors are studied. This chapter is also contains discussions on both silicon-based and thin film-based channel layer of ferroelectric gate field effect transistors. Utilizing advantage of the organic materials, flexible ferroelectric gate field effect transistors using plastic and paper substrates are fabricated and discussed in Chap. 3. Finally, future prospects for novel applications such as NAND flash memory circuits, relaxor, adaptive-learning synaptic devices and high- $k$  gate oxide thin film transistors are discussed in Chap. 4.

The technology field of FET-type ferroelectric memory has great impacts on both fundamental device physics and commercial industrial opportunities. Notwithstanding, there have hardly been appropriate technical books dealing with an insightful review to all the key technologies and applications of the FET-type ferroelectric memory devices. This book provides a comprehensive coverage of material characteristics, process technologies, and device operations for the memory field effect transistors employing inorganic or organic ferroelectric thin films, which have not been discussed in previously published books. These issues would be big helps for further advances in large-area electronics implemented on glass, plastic or paper substrate as well as in conventional silicon (Si) electronics. Thus, this book is a useful source of information for graduate students of material science and electronic engineering, device and process engineers in industries.

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