

**THIN FILM FERROELECTRIC
MATERIALS AND DEVICES**

THE KLUWER INTERNATIONAL SERIES IN:
ELECTRONIC MATERIALS: Science and Technology

Series Editor
Harry L. Tuller
Massachusetts Institute of Technology

Other books in the series:

- DIAMOND: *Electronic Properties and Applications*
Lawrence S. Pan and Don R. Kania, Editors
- ION IMPLANTATION: *Basics to Device Fabrication*
Emanuele Rimini, Author
- SOLID STATE BATTERIES: *Materials Design and Optimization*
C. Julien and G. Nazri, Authors
- SOL-GEL OPTICS: Processing and Applications
L.C. Klein, Editor
- PHOTOREFRACTIVE EFFECTS AND MATERIALS
David Nolte, Editor
- MATERIALS FOR OPTOELECTRONICS
Maurice Quillec, Editor
- PIEZOELECTRIC ACTUATORS AND ULTRASONIC MOTORS
Kenji Uchino, Author
- WIDE-GAP LUMINESCENT MATERIALS: Theory and Applications
Stanley R. Rotman, Editor

The Series **ELECTRONIC MATERIALS: Science and Technology** will provide publication with an interdisciplinary approach in the following topic areas:

- Sensors and Actuators
- Electrically Active Ceramics & Polymers
- Structure-Property-Processing-Performance
Correlations in Electronic Materials
- Electronically Active Interfaces
- High Tc Superconducting Materials
- Optoelectronic Materials
- Composite Materials
- Defect Engineering
- Solid State Ionics
- Electronic Materials in Energy
Conversion-Solar Cells, High
Energy Density Microbatteries,
Solid State Fuel Cells, etc.

THIN FILM FERROELECTRIC MATERIALS AND DEVICES

edited by

R. Ramesh

University of Maryland at College Park



SPRINGER SCIENCE+BUSINESS MEDIA, LLC

Library of Congress Cataloging-in-Publication Data

Thin film ferroelectric materials and devices / edited by R. Ramesh.

p. cm. -- (Electronic materials--science & technology ; 3)

Includes bibliographical references (p.) and index.

ISBN 978-0-7923-9993-3 ISBN 978-1-4615-6185-9 (eBook)

DOI 10.1007/978-1-4615-6185-9

1. Random access memory. 2. Ferroelectric thin films. 3. Thin film devices--Materials. I. Ramesh, R. (Ramamoorthy), 1960-II. Series.

TK7895.M4T478 1997

621.39'732--dc21

97-26415

CIP

Copyright © 1997 by Springer Science+Business Media New York

Originally published by Kluwer Academic Publishers in 1997

Softcover reprint of the hardcover 1st edition 1997

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means, mechanical, photocopying, recording, or otherwise, without the prior written permission of the publisher, Springer Science+Business Media, LLC .

Printed on acid-free paper.

TABLE of CONTENTS

Preface	vii
Chapter 1: (Ba,Sr)TiO₃ Thin Films for DRAM's S. Summerfelt	1
Chapter 2: (Ba,Sr)TiO₃ Films and Process Integration For DRAM Capacitor N. Mikami	43
Chapter 3: Elastic Domains in Ferroelectric Epitaxial Films A.Roytburd	71
Chapter 4: Study of Growth Processes in Ferroelectric Films and Layered Heterostructures via <i>In Situ</i>, Real-Time Ion Beam Analysis O. Auciello, A. Krauss, J. Im	91
Chapter 5: Layered Perovskite Thin Films and Memory Devices J. F. Scott	115
Chapter 6: Pb(Zr,Ti)O₃ Based Thin Film Ferroelectric Nonvolatile Memories B. A. Tuttle	145
Chapter 7: Chemical Vapor Deposition of Ferroelectric Thin Films C. M. Foster	167
Chapter 8: Degradation Mechanisms and Reliability Issues for Ferroelectric Thin Films D. Dimos, W.L. Warren, H.N. Al-Shareef	199
Chapter 9: Low Voltage Performance in Lead Based Ferroelectric Thin Film Memory Elements With (La,Sr)CoO₃ Electrodes S. Aggarwal, B. Yang, R. Ramesh	221
Index:	243

PREFACE

The past five years have witnessed some dramatic developments in the general area of ferroelectric thin films materials and devices. Ferroelectrics are not new materials by any stretch of imagination. Indeed, they have been known since the early part of this century and popular ferroelectric materials such as Barium Titanate have been in use since the second world war. In the late sixties and seventies, a considerable amount of research and development effort was made to create a solid state nonvolatile memory using ferroelectrics in a very simple matrix-addressed scheme. These attempts failed primarily due to problems associated with either the materials or due to device architectures. The early eighties saw the advent of new materials processing approaches, such as sol-gel processing, that enabled researchers to fabricate sub-micron thin films of ferroelectric materials on a silicon substrate. These pioneering developments signaled the onset of a revival in the area of ferroelectric thin films, especially ferroelectric nonvolatile memories.

Research and development effort in ferroelectric materials and devices has now hit a feverish pitch. Many university laboratories, national laboratories and advanced R & D laboratories of large IC manufacturers are deeply involved in the pursuit of ferroelectric device technologies. Many companies worldwide are investing considerable manpower and resources into ferroelectric technologies. Some have already announced products ranging from embedded memories in micro-controllers, low density stand-alone memories, microwave circuit elements, and rf identification tags. There is now considerable optimism that ferroelectric devices and products will occupy a significant market-share in the new millennium.

In this fertile environment, we present this book as a compilation of research and development progress in two very important ferroelectric device technologies, namely ferroelectrics for Dynamic Random Access Memories (DRAM's) and Non-Volatile Ferroelectric Random Access Memories (NV-FRAM's). Given the pace of development and the broad scope of the general topic of ferroelectric materials, such a focused approach was deemed necessary. The primary focus of this book is to expound the materials and device aspects of these technologies. All the chapters have been written or co-written by leading players in this field. Therefore, each chapter provides a comprehensive treatment of a specific topic of relevance to these two technologies. We believe this book will be of great value to materials and device scientists, device and process engineers, students and postdoctoral associates. Furthermore, this should also serve as a rapid introduction for new entrants into this very exciting field.

R. Ramesh