Science and Technology of Electroceramic Thin Films

Edited by

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NATO ASI Series

Science and Technology of Electroceramic Thin Films

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PREFACE

The basic and applied science of electroceramic thin films constitute one of the fast interdisciplinary evolving fields of research worldwide. A major driving force for the extensive research being performed in many Universities and Industrial and National Laboratories is the promise of applications of electroceramic thin films into a whole new generation of advanced microdevices that may revolutionize various technologies and create new multibillion dollar markets. Properties of electroceramic thin films that are being intensively investigated include electrical conductivity, ferroelectricity, piezoelectricity, pyroelectricity, electro-optic activity, and magnetism. Perhaps the most publicized application of electroceramics is that related to the new high temperature superconducting (HTSC) materials, which has been extensively discussed in numerous national and international conferences, including NATO/ASI's and ARW's. Less glamorously publicized applications, but as important as those of HTSC materials, are those involving the other properties mentioned above, which were the subject of this ARW. Investigation on ferroelectric thin films has experienced a tremendous development in recent years due to the advent of sophisticated film synthesis techniques and a substantial improvement in the understanding of the related materials science and implementation of films in various novel devices. A major driving force behind the progress in this interdisciplinary field of research is the promise of the development of a new generation of non-volatile memories with long endurance and fast access time that can overcome the problems encountered in the semiconductor non-volatile memory technology. Researchers have also rediscovered the utility of ferroelectric materials as high dielectric constant capacitors, which opens new possibilities for manufacturing planar, very high density DRAM memories. Ceramic conductors can be applied to ohmic, voltage-dependent, and thermally sensitive resistors; fast-ion conductors; and humidity and gas sensors. Piezoelectricity is being exploited in micromachines such as accelerometers, displacement transducers, and actuators such as those required for inkjet printers, for video-recording head positioning and for micromachining metals. Pyroelectricity can be utilized in the fabrication of high sensitivity infrared detectors, while electro-optic activity can be used in color filter devices, displays, image storage systems, and optical switches for integrated optical systems. The applications of electroceramic thin films mentioned above are only a part of a more extensive list, which indicates the relevance of these materials in the new technological era of a modern society. Most materials science and device issues related to electroceramic thin films are discussed in various national and international conferences where researchers interact through formal presentations and informal discussions, which in general do not give an opportunity for detailed analysis of the issues that are most critical for the advancement of the science of electroceramic thin films and devices. The field of research on electroceramic thin films and related devices has reached a state of development in which substantial progress has been made. However, there are some critical materials and device issues that need to be solved for the realization of commercially available devices.

The format of this NATO/ARW was designed to facilitate extensive scientific discussions. Key speakers reviewed the most relevant topics, making critical assessments of the current state of knowledge. Invited speakers presented recent advances on "hot" topics, and several participants presented papers related to new research. Each session concluded with extensive discussions in round table format, which permitted a fruitful and spirited interchange of ideas.

An important aspect of our NATO/ARW was that we were able to support the participation of several scientists from Eastern European Countries and contribute in this manner to the beginning of the new era of scientific cooperation between East and West promoted by NATO.

Orlando Auciello
North Carolina, 1994

Rainer Waser
Aachen, 1994

REPORT ON THE NATO/ARW

The NATO/ARW was divided in three sessions which included comprehensive reviews, invited papers on "hot" topics, contributed papers on new research, and extensive round table discussions following each session. In addition, a night session was dedicated to the discussion of highly speculative ideas. The three main subjects of the NATO/ARW in which this book is also organized are described below:

(1) Synthesis of ferroelectric thin films and their integration into heterostructures with metal and metal oxide electrodes. Presentations included characterization of films composition, microstructure, and electrical properties and their relationships. The discussions included consideration of various deposition techniques such as pulsed laser ablation deposition (PLAD), ion beam sputter-deposition (IBSD), metalorganic chemical vapor deposition (MOCVD), and sol-gel synthesis. Descriptions on the state of the art hardware and critical analyses of the basic principles of each thin film deposition technique were presented.

(2) Electrical characterization of ferroelectric capacitors and modeling, including pulse switching characterization of ferroelectric thin films, modeling of voltage dependent dielectric losses for ferroelectric MMIC devices, polarization, conduction, and breakdown in non-ferroelectric perovskite thin films, induced strain responses in ferroelectric, and relaxor ferroelectric and phase switching thin films. In addition, two comparatively new topics were discussed in this Session, namely, *in situ*, real-time analysis of ferroelectric /conductive oxide layers during growth by a new time-of-flight ion beam surface analysis technique, and electron emission from the surface of ferroelectric cathodes.

(3) Materials integration and application to devices, including discussions of ferroelectric thin films for sensor applications, integration of ferroelectric thin films for memory applications, fundamental properties and applications of sol-gel ceramic thin films, processing and device issues of high permittivity materials for DRAM memories, ferroelectric and piezoelectric devices: issues and potentials, and integrated ferroelectric microelectromechanical systems.

The NATO/ARW was attended by professionals, postdoctoral, and students from thirteen countries, including: Australia, Belgium, Canada, France, Germany, Italy, The Netherlands, Russia, Slovakia, Spain, Switzerland, United Kingdom, and The United States of America.

The main objective of the ARW was to bring together experts in the field of electroceramic thin films to discuss the status of the field and future directions in research and development. The highly interdisciplinary nature of the ARW allowed participants to interchange ideas in an environment rarely available in other international conferences.


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HOTEL

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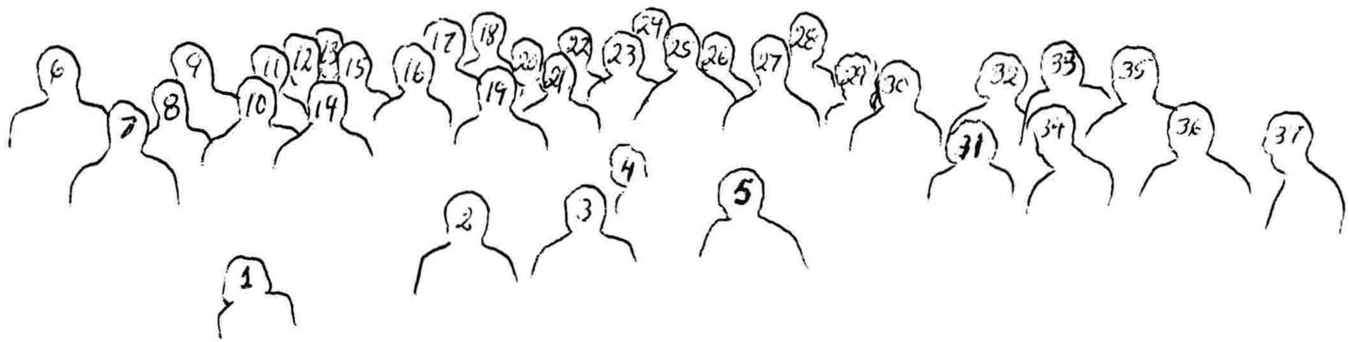

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PULSED LASER ABLATION-DEPOSITION AND CHARACTERIZATION OF FERROELECTRIC METAL OXIDE HETEROSTRUCTURES

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ABSTRACT. Materials integration strategies investigated by the NCSU-MCNC and Belcore groups have demonstrated that PZT-based heterostructure capacitors involving conductive oxide or hybrid metal-conductive oxide electrodes have negligible or no fatigue, long polarization retention and small tendency to imprint. The work reviewed involves the synthesis of heterostructure capacitors using the pulsed laser ablation deposition technique (PLAD). The properties observed for PZT-based heterostructure capacitors make them suitable for non-volatile ferroelectric memories. However, further work is necessary, particularly in producing small size capacitors ($\leq 1\ \mu m^2$), to determine if scaling down to dimensions compatible with high density memories will introduce undesirable effects.

The work discussed shows that PLAD will remain a very useful technique for fundamental research, but extensive work is necessary to make it a viable method for device fabrication on large area substrates.

1. Introduction

1.1. BACKGROUND INFORMATION

There is currently a strong research and development effort directed at producing a commercially viable solid state, nonvolatile ferroelectric memory (FRAM) technology. Many laboratories are focusing their work on integrating sub-micron thin ferroelectric capacitors of, for example, $Pb(Zr_xTi_{1-x})O_3$ (PZT), with the mature silicon based transistor technology to yield capacitor-transistor based memory architectures [1-5], as schematically illustrated in Fig.1. This figure also shows the perovskite unit cell of the ferroelectric PZT and the variety of interfaces (structural, chemical, electronic and ionic) that arise during the fabrication and integration of these metal oxide heterostructures on a Si substrate.

O. Auciello and R. Waser (eds.), Science and Technology of Electroceramic Thin Films, 1-22.