Ferroelectricity Newsletter

A quarterly update on what's happening in the field of ferroelectricity

Volume 4, Number 1 Winter 1996

CELEBRATING OUR FOURTH YEAR OF PUBLICATION

At the beginning of 1996, which coincides with the fourth year of publishing the ***Ferroelectricity Newsletter***, we wish all our readers health, prosperity and much success in all scientific endeavors.

In order to bring you as much practical information as possible, the main part of this issue consists of lists of papers presented at various conferences. We thank **Poul Larsen** from Philips Research Laboratories in Eindhoven and **Mark Eligh** from Elsevier Science B.V. for the permission to reprint the Table of Contents of the **Proceedings of the 1st European Meeting on Integrated Ferroelectrics (EMIF1)** to be published this January as a special volume of the journal ***Microelectronic Engineering***.

Even though Pierre-Yves Lesaicherre could not attend the **56th Autumn Meeting of the Japan Society of Applied Physics** last August, he did provide the list of the 80 presentations made in the session devoted to ferroelectric thin films and related issues. Thank you, Mr. Lesaicherre, for your excellent service!

In this issue we introduce a new feature, called ***MAILBOX***. Located on the last but one page, this space is reserved for inquiries and comments from you, the readers. We ask you to keep your contributions concise and to deal only with **noncommercial** matters as required by the mandate of this publication. We look forward to see you use the ***MAILBOX*** to strengthen the ever widening web of our networking efforts.

It is probably a case of preaching to the choir when we mention that whoever wanted to receive a hard copy of the last issue of the ***Ferroelectricity Newsletter*** had to request it since it is now available in electronic form on **World Wide Web**. Hard copies of the Fall 1995 issue were mailed only to our subscribers abroad and to those in the United States who asked for the newsletter by mail. If you know colleagues who did not get a hard copy and want one, please tell them to let us know--by mail, phone, fax, or e-mail--that they want to continue getting the newsletter by mail. Extra copies of the Fall 1995 issue are available for the asking.

Rudolf Panholzer
Editor-in-Chief

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EMIF1 PROCEEDINGS

Integrated ferroelectric memories

Memory applications based on ferroelectric and high-permittivity dielectric thin films
R.E. Jones, Jr., P. Zurcher, P. Chu, D.J. Taylor, Y.T. Lii, B. Jiang, P.D. Maniar, and S.J. Gillespie

Integrated ferroelectric structures for information storage and CCD microprocessor devices
V.I. Petrovsky and A.S. Sigov

Device processing and integration of ferroelectric thin films for memory applications
H. Achard, H. Macé, and L. Peccoud

Integration of sol-gel PZT with silicon-on-sapphire CMOS circuitry
T. Bland, J. Obhi, A. Patel, P. Kirby, M. Robinson, and J. Kerr

Direct-contact ferroelectric capacitors for memory applications
G.J.M. Dormans, J. H.H.M. Kemperman, R. A.M. Wolters, P.J. van Veldhoven, M.S. de Keijser, R.B.F. Janssen, M.J.E. Ulenaers, and P.K. Larsen

Some physical and technological aspects of designing ferroelectric nonvolatile SRAM
V.V. Lemanov, Yu.V. Frolov, A.A. Iofan, and V.K. Yarmarkin

Ferroelectric capacitors for integrated circuits
K.A. Vorotilov, M.I. Yanovskaya, L.I. Solovjeva, A.S. Valeev, V.I. Petrovsky, V.A. Vasiljev, and I.E. Obvinzeva

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CONFERENCE REPORTS

1ST EUROPEAN MEETING ON INTEGRATED FERROELECTRICS (EMIF1)

*The following report is an excerpt from the **Preface** of the EMIF1 Proceedings, written by **P.K. Larsen** and **G.J.M. Dormans.***

The **1st European Meeting on Integrated Ferroelectrics** was held in **Nijmegen, The Netherlands, from 3 - 5 July 1995**. It was organized as a satellite meeting to the 8th European Meeting on Ferroelectrics (EMF8), which took place from 4 - 8 July 1995 also in Nijmegen. The partial overlap in time of EMIF1 and EMF8 allowed participants to attend both meetings. The attendance at EMIF1 exceeded the expectations by far. About 160 participants were registered, 75 attending EMIF1 only, 85 attending both EMIF1 and EMF8. The majority of the participants came from Europe, but the rest of the world was also well represented: USA, Japan, Korea, China, Australia, and other countries.

Some 130 abstracts were submitted. For about 30 of these, presentation at EMF8 was considered to be more appropriate. From the remaining 100 abstracts the scientific program committee selected 80 for presentation. Together with a few post-deadline papers and 11 invited papers, 92 papers were accepted. The presentations were divided into plenary sessions (invited papers), two parallel sessions with oral contributions (48 papers), and one poster session (33 papers).

The **EMIF1 Proceedings**, containing 66 papers, are published in a special volume of the journal ***Microelectronic Engineering***, scheduled to come out in January 1996. Guest editors are **P.K. Larsen** and **G.J.M. Dormans** from Philips Research Laboratories, Eindhoven, The Netherlands.

The **topic** of the meeting, integrated ferroelectrics, was directed toward the **preparation and application of ferroelectric thin films**. In this sense EMIF1 has a scope similar to very successful meetings in the USA, such as the Material Research Society meetings on ferroelectric thin films and the International Symposium on Integrated Ferroelectrics. Although these meetings attract considerable interest from outside the USA, they remain regional and cannot substitute for European meetings. Both the large number of submitted abstracts and the attendance at EMIF1 were clear evidence for the need of European meetings focused on integrated ferroelectrics.

The next meeting, **EMIF2**, will be held in **June 1997** in the **Paris area in France**, with **Dr. J.P. Ganne** from **Thomson-CSF, Orsay,** as chairman.

The **EMIF1 Proceedings** are published in January 1996 as a special volume of the journal ***Microelectronic Engineering*** with **P.K. Larsen** and **G.J.M. Dormans** as guest editors.

PAPERS

PAPERS ON PIEZO/PYRO/FERROELECTRIC POLYMERS

Volume 171, Numbers 1-4 (1995), a special issue of the Gordon and Breach journal **Ferroelectrics** *is dedicated to piezo/ferroelectric polymers, in honor of* ***Heiji Kawai****, the discoverer of piezoelectricity in oriented PVDF. François Bauer (Saint-Louis, France), Lewis F. Brown (Brookings, SD, USA), and Eiichi Fukada (Tokyo, Japan) are the guest editors of this volume.*

In 1969 Professor Kawai reported a large piezoelectric effect in oriented polyvinylidene fluoride (PVDF), a discovery that has led not only to extensive research on PVDF itself, but has also resulted in the discovery and study of many other new piezo/ferroelectric polymer materials. Many companies now sell commercial products which employ PVDF and other piezoelectric polymers, such as polyvinylidene-trifluoroethylene P(VDF-TrFE) copolymer. The piezo/ferroelectric polymers are used in ultrasound transducers, underwater shock sensors and hydrophones, accelerometers, and contactless switches.

Although is has been more than 25 years since Professor Kawai's historic paper on PVDF, much is still not fully understood concerning the polarization mechanisms of PVDF and other polymers, as evidenced by several papers in this special issue. It also contains a number of papers on the copolymer P(VDF-TrFE) and its applications for transducers. The higher electromechanical coupling and ability to produce high quality transducers with spincoating and casting fabrication processes have made this ferroelectric polymer one of the most widely studied for commercial transducer applications.

Other important piezo/ferroelectric polymer developments discussed in this issue include polyvinylidene cyanide copolymers, the odd-numbered nylons, and the newest polymers of interest, the polyureas. The polyureas look particularly exciting since they can be manufactured with a dry deposition process which is conducive to high volume semiconductor integrated circuit manufacturing. A large number of papers in this issue describes transducer applications for the piezo/ferroelectric polymers, further evidence of their successful integration into commercial products.

This issue also contains four personal tributes to Professor Kawai, written by his former students and colleagues expressing the highest respect and admiration for him and his work. Heiji Kawai graduated from the Department of Physics at the University of Tokyo in 1933 and received his doctoral degree for his work on piezoelectric properties of Rochelle Salt crystals. He spent most of his life as a scientist and research director at the Kobayashi Institute of Physical Research. He has been a mentor to many young scientists and engineers who have become distinguished in their own work. Thus, even though Professor Kawai is now retired, he continues to have a lasting impact in this area.

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Reactive ion etching of Pt/PZT/Pt thin film capacitors in high density DECR plasma
H. Macé, H. Achard, and L. Piccoud

Sensors and actuators

Microelectromechanical systems based on ferroelectric thin films
D.L. Polla

Integrated thin film PZT pyroelectric detector arrays
N.M. Shorrocks, A. Patel, M.J. Walker, and A.D. Parsons

Characterization of PZT thin films for micromotors
P. Muralt, A. Kholkin, M. Kohli, T. Maeder, and N. Setter

The use of composite piezoelectric thick films for actuation and control of miniature cantilevers
D.F.L. Jenkins, M.J. Cunningham, and W.W. Clegg

Thermal simulation of micromachined bridges for integrated pyroelectric sensor arrays
B. Ploss, D. Lienhard, and F. Sieber

Two ways to pyroelectric P(VDF/TFE) thin film sensors and arrays
R. Köhler, N. Neumann, and R. Gottfried-Gottfried

Realization of an integrated VDF/TFE copolymer-on-silicon pyroelectric sensor
D. Setiadi, P.P.L. Regtien, and P.M. Sarro

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sponse of a hybrid pyroelectric detector based on epitaxial grown $K_{0.9}Na_{0.1}Ta_{0.6}Nb_{0.4}O_3$ thin films
H. Pierhöfer, Z. Sitar, T. Dietrich, F. Gitmans, and P. Günter

Processing and properties of thin film pyroelectric devices
M. Kohli, Y. Huang, T. Maeder, C. Wuethrich, A. Bell, and P. Muralt, N. Setter, P. Ryser, and M. Forster

Pyroelectric properties of thin ferroelectric films and their applications for integrated circuits
E.Ph. Pevtsov, M.I. Maleto, V.I. Petrovsky, A.S. Sigov, and V.V. Chernokozhin

Thin nickel films as absorbers in pyroelectric sensor arrays
D. Lienhard, F. Heepmann, and B. Ploss

Epitaxial structures

Epitaxial growth of $LiNbO_3$ thin films on (001) sapphire by pulsed laser deposition
P. Aubert, G. Garry, R. Bisaro, J. Olivier, J. Garcia Lopez, and C. Urlacher

Structural and electrical properties of laser ablated epitaxial niobium doped lead-zirconium-titanate thin films
C. Björmander, K. Sreenivas, M. Duan, A.M. Grishin, and K.V. Rao

Preparation of $Pb(Mg_{1/3}Nb_{2/3})O_3$ - $PbTiO_3$ thin films on silicon substrates by pulsed laser deposition

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RESEARCH

NOVEL OXIDE COMPOSITES FOR PHASED ARRAY ANTENNAS

Introduction

Phased array antennas are advantageous in comparison to their mechanical counterparts with respect to their speed, accuracy, and reliability. Furthermore, ferroelectric phased array antennas offer significant cost savings (<1/10 of the cost) of conventional ferrite phased arrays.

The optimal electronic parameters of the material of choice for phased array applications should be: (a) moderate to low dielectric constant at microwave frequencies (approximately 30 to 1,500), (b) low electronic loss tangents (tan ∂; <0.007), and (c) high dielectric tunability (change in dielectric constant with applied voltage, 12 to 50 percent).

The tunability of a particular material affects the material's electronic properties by how much the dielectric constant changes with applied voltage. The degree of phase shifting ability is directly related to the tunability; therefore, higher tunabilities are desired. The insertion loss is inversely related to the tunability so that the larger the tunability, the smaller the insertion loss.

The loss tangent (intrinsic to the material) serves to dissipate or absorb the incident microwave energy and therefore is desired to be in the range of 0.007 or less. The low loss tangent serves to decrease the insertion loss and hence increase the phase shifting per decibel of loss. The operating frequency of the device can be extended by reducing the loss tangent.

At the Materials Directorate of the Army Research Laboratories, novel barium strontium titanate (BSTO) composites have been fabricated and characterized. These composites have exhibited low intrinsic material loss tangents at a wide frequency range such that at the microwave frequency (< 3 dB insertion loss) they can be realistically incorporated into phased array antennas.

Bulk Ceramic Processing

Barium strontium titanate ($Ba_{0.6}Sr_{0.4}TiO_3$) composites were formed by mixing the BSTO powder with the other oxide powders (alumina, oxide II, oxide III) in the proper weight ratio. The resulting mixture was prepared into a cintered ceramic disc. X-ray diffraction methods were used to confirm the composition of the ceramics. The discs were then metallized through the screen printing process to perform the electronic measurements.

Electronic Measurements of Bulk Composites

The electronic properties were measured at a frequency range of 1 KHz to 1 MHz. Separate microwave measurements were also performed to determine the dielectric constant and the electronic loss of the material at 2 to 5 GHz.

The semilog plot of the dielectric constants of the BSTO-alumina composites, the BSTO-oxide II composites, and the BSTO-oxide III composites is shown in Fig. 1. As shown there, the rate of reduction is similar for all

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the composites for compositions < 20 wt percent. However, between 20 wt percent to 50 wt percent the rate of reduction in the dielectric constant is the most for the BSTO-alumina composites. The decrease in the dielectric constant for the composites is again similar from 60 wt percent to 100 wt percent additive content. Also, the magnitude of the dielectric constant for all of the BSTO-alumina composites is less than that of the BSTO-oxide II and BSTO-oxide III composites. These differences in the BSTO-alumina composites may be due to the formation of glassy secondary phases.

The tunability (percentage) and the pertinent applied electric fields for the BSTO-alumina, BSTO-oxide II, and BSTO-oxide III composites are shown in Table I. The tunabilites of the 1 wt percent BSTO-alumina and BSTO-oxide II are more than that of the BSTO-oxide III material. This is because the Curie temperature (temperature below which the material is *ferroelectric* and above which the material is *paraelectric*), as shown in Fig. 2, is lowered from 5˚C in pure $Ba_{0.4}Sr_{0.6}TiO_3$ to -30˚C in the BSTO - 1 wt percent oxide III composite; whereas in the other 1 wt percent composites the Curie temperature shifts to 0˚C. However, the tunabilites of the BSTO-alumina and BSTO-oxide II composites decrease drastically for additive content beyond 20 to 30 wt percent. The improved tunability (above 30 wt percent additive content) in the BSTO-oxide III material is partially due to the fact that oxide III has a much smaller particle size than the other oxides. Also no secondary phase formation has been shown in the BSTO-oxide III composite, which may create nonferroelectric phases and hence inhibit tuning in the material.

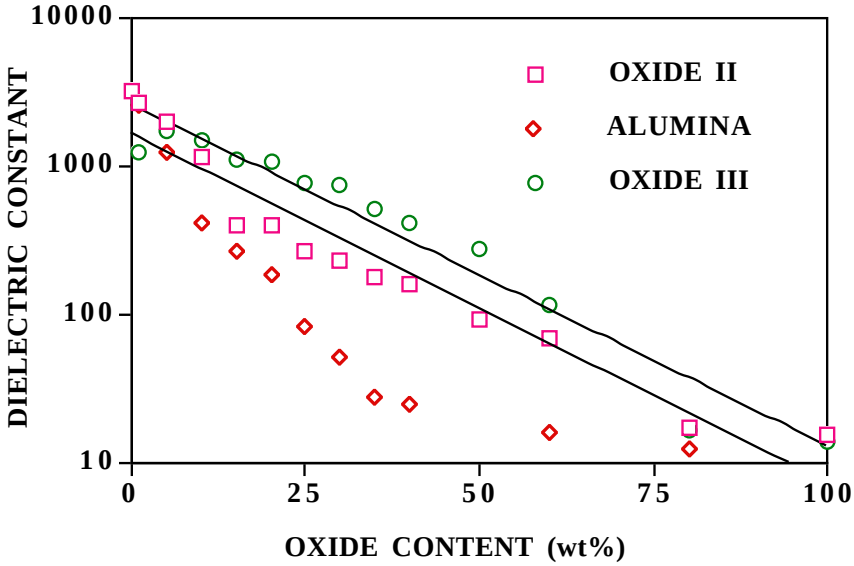

FIGURE 1. Semi-log plot of the Dielectric Constant versus Oxide Content (wt%) for BSTO-Alumina, BSTO-Oxide II, and BSTO-Oxide III composites (lines are best fit to the data).

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C. Tantigate and A. Safari

Ferroelectric properties of epitaxial $PbTiO_3/YBa_2Cu_3O_{7-8}/SrTiO_3$ thin film heterostructure
K. Sreenivas, C. Björmander, A.M. Grishin, and K.V. Rao

Structural and electrical characterization of sputter-deposited $SrTiO_3$ thin films
L.D. Madsen, C.N. Johnson, S.N. Jacobsen, U. Helmersson, S. Rudner, I. Ivanov, L.-D. Wernlund, L. Ryen, and E. Olsson

Growth and properties of epitaxial ferroelectric/superconductor heterostructures
Yu. Boikov, Z.G. Ivanov, A.N. Kiselev, A.L. Vasiliev, E. Olsson, and T. Claeson

Domains and switching

Domain-wall and intrinsic contributions to the dielectric response of epitaxial ferroelectric films
N.A. Pertsev, G. Arlt, and A.G. Zembilgotov

Transient modeling of ferroelectric capacitors for semiconductor memories
A. Sheikholeslami and P. Glenn Gulak

Characterization of the fatigued state of ferroelectric PZT thin film capacitors
E.L. Colla, A. Kholkin, D. Taylor, A.K. Tagantsev, K. Brooks, and N. Setter

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switching processes in ferroelectric thin films
V.I. Petrovsky, E.Ph. Pevtsov, and A.S. Sigov

Switching kinetics in epitaxial PZT thin films
V.Ya. Shur, S.D. Makarov, N.Yu. Ponomarev, V.V. Volegov, N.A. Tonkachyova, L.A. Suslov, N.N. Salashchenko, and E.V. Kluenkov

Thin film deposition

Sol-gel processing of perovskite thin films
D. Sporn, S. Merklein, W. Grond, S. Seifert, S. Wahl, and A. Berger

Preparation and properties of $Pb(Zn_{1/3}Nb_{2/3})O_3$-$PbTiO_3$ thin films by metalorganic chemical vapor deposition
Y. Kamisuki, T. Taniguchi, and T. Takenaka

MOCVD of ferroelectric PLZT thin films and their properties
M. Shimizu, H. Fujisawa, and T. Shiosaki

In-situ sputter deposition of PT and PZT films on platinum and RuO_2 electrodes
T. Maeder, P. Muralt, L. Sagalowicz, and N. Setter

Sputtering of ferroelectric $(PbCa)TiO_3$ films
H. Schmitt, J. Mendiola, F. Carmona, C. Alemany, and B. Jimenez

Sol-gel and MOD processing of layered perovskite and $SrTiO_3$ films
M. KLee and U. Mackens

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RESEARCH

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The loss tangents of the BSTO-oxide III composites, as well as the other BSTO-oxide III compound composites, are extremely low for almost all compositions (they decrease slightly, with an increase in oxide III) as shown in Fig. 3. Again, the low loss tangetns are due to the shift in the Curie temperatures to < -30˚C (as shown in Fig. 2), therefore allowing room temperature operation well into the *paraelectric* region. These low loss tangents translate into low insertion losses which are sufficient enough to consider these materials candidates for phased array antennas.

Oxide Content (wt %)	% Tunability, Electric Field (V/μm)		
	Alumina	Oxide II	Oxide III
0.0	19.91, 0.73	19.91, 0.73	19.91, 0.73
1.0	22.5, 0.76	46.0, 2.72	16.07, 2.32
15.0	5.72, 0.87	5.07, 1.11	7.27, 1.91
20.0	3.58, 0.48	5.39, 0.76	15.95, 2.33
30.0	5.13, 2.21	1.21, 0.73	9.35, 1.62
50.0		1.67, 1.12	9.55, 2.14
60.0	0.01, 0.60		11.08, 2.70
80.0			0.61, 1.72

TABLE 1. *Comparison of tunabilities of BSTO-alumina, BSTO-oxide II, and BSTO-oxide III.*

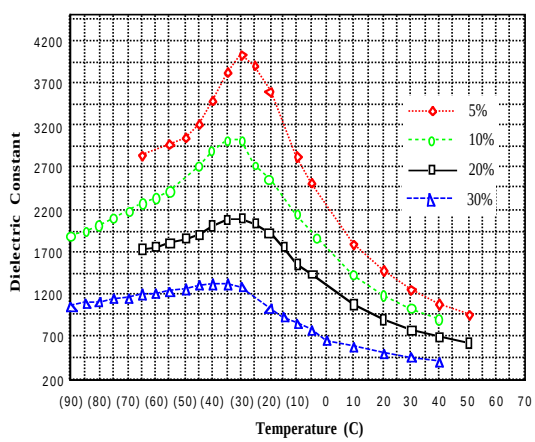

FIGURE 2. *Dielectric constant vs. temperature for BSTO-oxide III composites.*

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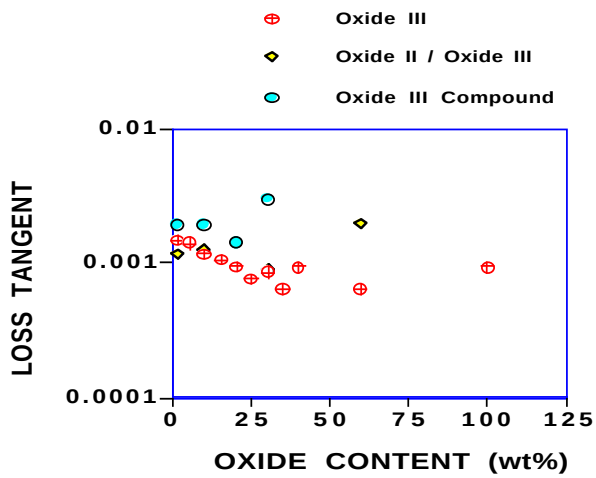

FIGURE 3. *Loss tangent vs. oxide content for BSTO-oxide III, BSTO-oxide II/oxide III and BSTO-oxide III compound composites measured at 1 KHz.*

Table II shows that the low loss features of BSTO-oxide III composites are maintained in the GHz range. A four-element phase shifter was designed in collaboration with ARL-PSD with the BSTO-oxide II composites. It demonstrated a 360 phase shift and less than 3 dB loss at 5 GHz.

Oxide III content	Frequency (GHz)	Dielectric Constant	Loss Tangent
30 wt%	2.139	646	0.004
40 wt%	1.815	404	0.0042
40 wt%	3.304	401	0.0051
60 wt%	4.581	113	0.0065

TABLE II. *Microwave dielectric constants and loss tangents of the BSTO-oxide III composites.*

Summary

BSTO composites have been utilized in fabricating phase shifter elements. The material has demonstrated excellent performance in the microwave frequency. The diversity of the designs of the antenna employed also underscores the versatility of the material in different forms.

In future issues of the ***Ferroelectricity Newsletter*** we will discuss the application of these composites in thick film and thin film form in order to address higher frequency needs.

Acknowledgments

The authors wish to acknowledge **R.G. Geyer** of NIST, CO, for his GHz measurements and **R.W. Babbit** of ARL-PSD for his phase shifter measurements.

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Coating uniformity and device applicability and spin coated sol-gel PZT films
D.P. Birnie, III, R.N. Vogt, M.N. Orr, and J.R. Schifko

Measurement of carbon contamination in barium strontium titanate films
W.B. Stannard, P.N. Johnston, J.F. Scott, I.F. Bubb, S.R. Walker, D.D. Cohen, N. Dytlewski, and J.W. Martin

Pyrochlore-perovskite phase development of sol-gel derived modified lead titanate thin films
M.L. Calzada, J. Mendiola, F. Carmona, and R. Sirera

Characterization of lithium tantalate thin films sputter-deposited onto RuO_2Si substrates
C.-H. Kohli, J. Moser, K. Prasad, P.E. Schmid, F. Lévy, and G. Burri

Deposition of $PbTiO_3$ thin films from thd-complexes by an aerosol source MOCVD method
I.E. Korsakov, A.R. Kaul, L. Klippe, J. Korn, U. Krause, M. Pulver, and G. Wahl

Pulsed laser deposition of Ca modified $PbTiO_3$ thin films
J. Mendiola, M.J. Martin, P. Ramos, and C. Zaldo

Simple composition control of ferroelectric thin films grown by sputtering with an original oxide target design
D. Remiens, M. Descamps, B. Jaber, and B. Thierry

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Influence of the Pt electrode on the properties of sol-gel PZT films
G.J. Willems, D.J. Wouters, and H.E. Maes

Electrodes and interfaces
$La_{0.5}Sr_{0.5}CoO_3$ electrode technology for $Pb(Zr,Ti)O_3$ thin film nonvolatile memories
B.A. Tuttle, H.N. Al-Shareef, W.L. Warren, M.V. Raymond, T.J. Headley, J.A. Voigt, J. Evans, and R. Ramesh

Pt investigation and electrical properties of RF magnetron sputtered $Pb(Zr,Ti)O_3$
B.Ea Kim, F. Varniere, B. Agius, and R. Bisaro

Stresses in $Ru/PbZr_{0.4}Ti_{0.6}/Ru$ thin film stacks for integrated ferroelectric cpacitors
G.A.C.M. Spierings, J.M. Breed, M.J.E. Ulenaers, P.J. van Veldhoven, and P.K. Larsen

Characterization of rapid thermally annealed ruthenium oxide electrodes for PZT ferroelectrics
L. Weaver, E.M. Griswold, D.S. McIntyre, and M. Sayer

$Pt(PbTiO_3)$ buffer layer effects on the electrical properties of $Pb(Zr,Ti)O_3$ thin films
N.-H. Cho and H.-G. Kim

Electrical properties
Electrical conductivity in ferroelectric thin films
D.J. Wouters, G.J. Willems, and H.E. Maes

Procedure of microwave investigations of ferroelectric films and tunable microwave devices based on ferroelectric films
A.B. Kozyrev, V.N. Keis, G. Koepf, R. Yandrofski, O.I. Soldatenkov, K.A. Dudin, and D.P. Dovgan

Interferometric study of piezoelectric degradation in ferroelectric thin films
A. Kholkin, E. Colla, K. Brooks, P. Muralt, M. Kohli, T. Maeder, D. Taylor, and N.Setter

Electron emission of Ca modified $PbTiO_3$ thin films
K. Biedrzycki, L. Markowski, M.L. Calzada, and J. Mendiola

Effect of Nb doping on the hysteresis parameters of sol-gel derived $Pb_{1.1-x/2}(Zr_{0.53}Ti_{0.47})_{1-x}Nb_xO_3$ thin films
R.D. Klissurska, A.K. Tagantsev, K. Brooks, and N. Setter

Structural porperties
Microstructural characterization of ferroelectric thin films in transverse section
I.M. Reaney

Texture, structure, and domain microstructure of ferroelectric PZT thin films
J. Hector, N. Floquet, J.C. Niepce, P. Gaucher, aand J.P. Ganne

Structure and properties of $LiTaO_3$ thin films grown by modified gas source molecular beam epitaxy
F. Gitmans, Z. Sitar, and P. Günter

Investigation of $Pb(Zr_{0.70}Ti_{0.30})O_3$ thin films of different textures on Ti/Pt electrodes
K. Brooks, R.D. Klissurska, P. Moeckli, and N. Setter

Microstructure of PZT sol-gel films on Pt substrates with different adhesion layers
R.D. Klissurska, T. Maeder, K. Brooks, and N. Setter

Quantitative study of the microstructure of Sm substituted lead titanate thin films
L. Pardo, J. Ricote, R. Sirera, and M.L. Calzada

The scanning electron microscopy investigation of $LiTaO_3$ thin films on silicon substrates
V.T. Volkov, L.S. Kokhanchik, V.N. Matveev, and S.V. Nosenko

Transmission electron microscopy of epitaxial $SrTiO_3$ films on $LaAlO_3$ substrates
L. Ryen, E. Olsson, L.D. Madsen, C.N. Johnson, X. Wang, S.N. Jacobsen, U. Helmersson, S. Rudner, and L.-D. Wernlund

Optical properties
Determination of optical properties of lead based ferroelectric thin films for integrated optics applications
E. Dogheche, B. Jaber, D. Rémiens, and B. Thierry

Studies of optical waveguide barium sodium niobate thin films
M.S. Zhang, Z. Yin, P. Zhang, and J.M. Liu

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PROFESSIONAL JOURNALS

INTEGRATED FERROELECTRICS

Integrated Ferroelectrics, *published by Gordon and Breach, provides an international, interdisciplinary forum for electronic engineers and physicists, as well as process engineers, ceramicists, and chemists who are involved in research, design, development, manufacturing, and utilization of integrated ferroelectric devices.* ***George W. Taylor*** *is editor-in-chief.*

Volume 8, Numbers 3-4 (1995)
contains the following articles:

A comparative study of tunable $Ba_{1-x}Sr_xTiO_3$ thin film capacitors prepared by RF sputtering and liquid phase deposition
A. Outzourhit, A. Naziripour, J.U. Trefny, T. Kito, B. Yarar, R. Yandrofski, J.D. Cuchiaro, and A.M. Hermann

Preparation and properties of sputtered lead titanate thin films on MgO single crystals and MgO buffer layers
N. Neumann and R. Bruchhaus

Ferroelectric lead iron-chromium-nickel niobate films
C.V.R. Vasant Kumar, M. Sayer, and R. Pascual

The structure and dielectric properties of thin PZT-type ferroelectric films with a diffuse phase transition
Z. Surowiak, D. Czekaj, A.A. Bakirov, E.V. Sviridov, and V.P. Dudkevich

Epitaxy and interfacial phase in thin films of lead scandium tantalate deposited by reactive sputtering on a platinum interlayer
C.D. Pawlaczyk, A.K. Tagantsev, K. Brooks, I.M. Reaney, R. Klissurska, and N. Setter

Ferroelectric properties and reliability of La-Sr-Co-O/Pb-La-Zr-Ti-O/La-Sr-Co-O heterostructure on Si for nonvolatile memory applications
J.Lee, R. Ramesh, V.G. Keramidas, and O Auciello

Landau Theory of thin ferroelectric films
C. Brennan

Volume 9, Numbers 1-3 (1995)

contains the proceedings of **The Second Pacific Rim Conference on Ferroelectric Applications**, held 21-24 November 1994 in Melbourne, Australia. Guest editors are **James F. Scott, Alexander S. Sigov**, and **Sidney B. Lang**.

The Winter 1995 issue of the ***Ferroelectricity Newsletter*** brought a report on this conference by **Maria Huffman**.

-- continued on page 10

EMIF1 PROCEEDINGS -- continued from page 8

Optical losses in sol-gel derived lead lanthanum titanate waveguides
G. Teowee. S. Motakef, T.J. Bukowski, J.M. Boulton, D.P. Birnie III, and D.R. Uhlmann

Electrooptic properties of sol-gel derived PZT and PLZT thin films
G. Teowee, J.T. Simpson, T. Zhao, M. Mansuripur, J.M. Boulton, and D.R. Uhlmann

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PROFESSIONAL JOURNALS

FERROELECTRICS

Ferroelectrics, *edited by* ***George W. Taylor*** *and published by Gordon and Breach, is an international journal devoted to the theoretical, experimental, and applied aspects of ferroelectric and related materials.*

Volume 168, Numbers 1-2 (1995)
is a special issue on **Low temperature ferroelectric effects and thermal properties of ferroelectrics**. Guest editors are **E. Hegenbarth, W. Kinase, Sidney B. Lang, W.N. Lawless,** and **B.A. Strukow**.

Volume 169, Numbers 1-4 (1995)
contains Part I of the proceedings of **The Fifth Russian-Japanese Symposium on Ferroelectricity**, held from 22-27 August 1994 in Moscow, Russia. Guest editors are **B.A. Strukow, L.N. Rashkovich, Y. Ishibashi**, and **Y. Uesu**.

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The PDF file format maintains the graphics and organization of the printed newsletter. Adobe Acrobat Reader is a helper application distributed free for Web browsers. Acrobat is available for Macintosh, Windows, DOS, SGI, and Sun SPARC operating systems.

CONFERENCE REPORTS

56TH AUTUMN MEETING OF THE JAPAN SOCIETY OF APPLIED PHYSICS

The 56th Autumn Meeting of the Japan Society of Applied Physics was held in Kanazawa City, Ishikawa Prefecture, on the Sea of Japan, 26-29 August 1995. Following is a list of the 80 presentations made in the session devoted to ferroelectric thin films and related issues.

26a-ZG-1	Analysis of CVD RuO_2 using TDS	Fujitsu
26a-ZG-2	Physicochemical properties of a metallorganic compound for the MOCVD of dielectric materials [IV], $Ba(DPM)_2$	Chuo University
26a-ZG-3	Preparation of $SrTiO_3$ thin films by layer by layer MOCVD	Tokyo Institute of Technology
26a-ZG-4	Preparation of $(Ba,Sr)TiO_3$ films by MOCVD	Fujitsu, Tri Chemical
26a-ZG-5	Electrical properties of $(Ba,Sr)TiO_3$ films prepared by ECR CVD	NEC
26a-ZG-6	Stoichiometry control for conformal growth of $(Ba,Sr)TiO_3$ by chemical vapor deposition	Toshiba
26a-ZG-7	On the properties of CVD BST films close to the bottom electrode	Mitsubishi Electric
26a-ZG-8	Sol-gel process for lower crystallization temperature of BST thin films	Mitsubishi Materials
26a-ZG-9	Effect of donor impurities on the absorption current of MOD $(Ba_{0.5}, Sr_{0.5\dagger})TiO_3$	Texas Instruments Japan
26a-ZG-10	Low temperature deposition of $SrTiO_3$ thin films by ECR sputtering	Fujitsu
26a-ZG-11	Preparation of $BaTiO_3$ thin films by intense pulsed ion-beam evaporation (backside deposition)	Nagaoka University of Technology, Nippon Seiki
26p-ZG-1	Preparation and electrical characteristics of the $SrTiO_3/SiO_2/Sr$ structure	Sharp
26p-ZG-2	Preparation of $(Sr_{0.7},Ba_{0.3})TiO_3$ thin films by laser ablation and their electrical properties	Murata Mfg., Osaka Univ.
26p-ZG-3	Effect of oxygen on $(Ba,Sr)TiO_3$ thin films during the initial RF sputtering step	Oki Electric
26p-ZG-4	Dielectric properties of sputtered $(Ba_x,Sr_{1-x})TiO_3$ thin films prepared with a high deposition rate	Mitsubishi Electric, Mitsubishi Materials
26p-ZG-5	Correlation between dielectric properties of BST thin films and the Ti thickness in bottom electrode Pt/Ti	Texas Instruments Japan
26p-ZG-6	WN_x electrode applied to 300˚C sputtered $SrTiO_3$ capacitor	Toshiba
26p-ZG-7	Electrical properties of BST capacitors prepared on RuO_2/Ru electrodes	Mitsibishi Electric
26p-ZG-8	Fabrication of $BaTiO_3$ thin films by the laser ablation method	Keio University
26p-ZG-9	AFM observation of $SrTiO_3$ surfaces designed by atomic layer epitaxy	Osaka University, Harvard University, Kinki University
26p-ZG-10	Epitaxial $BaTiO_3$ thin films grown by laser MBE in unit-cell layer-by-layer mode	Tokyo Institute of Technology
26p-ZG-11	Change in the structure of $BaTiO_3$ epitaxial films with film growth	University of Osaka Prefecture
26p-ZG-12	Bottom electrode structure of STO capacitors for microwave application	Sharp
26p-ZG-13	Temperature coefficient of capacitance and microwave properties of $(Zn,Sn)TiO_3$ thin films by laser ablation	Murata Manufacturing, Osaka University
26p-ZG-14	Preparation of $Ba(Ti_{1-x},Sn_x)O_3$ thin films and their dielectric properties	NTT
27a-ZG-1	Fabrication of ferroelectric micropatterns using metal octylates	Science University of Tokyo
27a-ZG-2	Low temperature deposition of $Bi_4Ti_3O_{12}$ thin films by MOCVD	Sharp
27a-ZG-3	Electrical properties of $Bi_4Ti_3O_{12}$ thin films by low temperature MOCVD	Sharp
27a-ZG-4	Preparation of highly c-axis oriented $Bi_4Ti_3O_{12}$ thin films	Shibaura Institute of Technology
27a-ZG-5	Preparation of $Bi_4Ti_3O_{12}$ thin films by ECR sputtering	Shonan Institute of Technology
27a-ZG-6	Preparation of $Bi_4Ti_3O_{12}$ thin films by the laser ablation method (3)	Osaka University
27a-ZG-7	Preparation and electrical properties of PLT thin films by MOCVD	Chubu University
27a-ZG-8	Relationship between orientation and electrical properties of PLZT thin films by MOCVD	Chubu University
27a-ZG-9	PZT thin film on MgO/Si (100) substrate (2)	Tokyo University of Agriculture and Technology
27a-ZG-10	MOCVD of $Pb(Zr,Ti)O_3$ thin films at low temperature	Hitachi

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CONFERENCE REPORTS

1995 AUTUMN MEETING OF THE JAPAN SOCIETY OF APPLIED PHYSICS -- continued from page 11

27a-ZG-11	Electrical properties of PZT thin films using $Zr(t\text{-}OC_4H_9)_4$ as a CVD precursor	Chubu University, Horiba
27p-ZG-1	Investigation of leakage of ferroelectric PZT thin films by MOCVD	Kyoto Univ., Himeji Institute of Technology
27p-ZG-2	Photovoltaic current characteristics of $Pb(Zr,Ti)O_3$ thin films prepared by the MOCVD method	Kyoto University, Himeji Institute of Technology
27p-ZG-3	Preparation of IrO_2 thin films and their properties as a bottom electrode for PLZT thin films	Chubu University, Nippon Sanso
27p-ZG-4	MOCVD growth and characteristics of PZT thin films on Ir and IrO_2 electrodes (II)	Kyoto University, Himeji Institute of Technology
27p-ZG-5	C-axis oriented $PbTiO_3$ thin films by sputter-assisted plasma CVD	Osaka National Research Institute
27p-ZG-6	Preparation of (111) oriented $(Pb,La)TiO_3$ thin films by the sol-gel method	Toyota
27p-ZG-7	The influence of excess lead on sol-gel derived crystallization processes	Texas Instruments Japan
27p-ZG-8	$PbTiO_3$ films on conductive oxide by the co-evaporation method	Osaka National Research Institute
27p-ZG-9	The effect of ozone on reactive evaporation on PZT thin films	Hitachi
27p-ZG-10	Fabrication of transition metal doped PZT films and their characteristics	Oki Electric, Tokyo Ohka Kogyo
27p-ZG-11	Low temperature fabrication of PZT films by reactive sputtering	Kanazawa University
27p-ZG-12	Preparation of Pb-based ferroelectric thin films using excimer laser assisted sputtering deposition (II)	Matsushita Electric
27p-ZG-13	Fabrication and characterization of Pt (100)/YSZ/Si (100) substrates	Japan Energy Corporation
27p-ZG-14	Preparation of $Pb(Zr_x,Ti_{1-x})O_3$ thin films on YSZ/Si substrates by the reactive sputtering method	Japan Advanced Institute of Science and Technology
27p-ZG-15	Preparation and characterization of PZT/STO/Si (100) structures	Tokyo Institute of Technology
27p-ZG-16	Relation between internal bias field and retention characteristics of ferroelectric thin films	NEC
27p-ZG-17	Electrical properties of PZT thin films prepared by laser ablation on Si substrates with an MgO buffer layer	Kanazawa University
27p-ZG-18	Growth of PZT films on Si using room temperature grown epitaxial CeO_2 as a buffer layer	Tokyo Inst. of Techn.
27p-ZG-19	Influence of the IrO_2 thickness for use in PZT thin film capacitors	Rohm
28a-ZG-1	Fabrication of Bi layer structured ferroelectric films by dipping pyrolysis of metal naphtenates	Science University of Tokyo
28a-ZG-2	Fine $SrBi_2Ta_2O_9$ thin films by a new MOD annealing process	Sharp
28a-ZG-3	Preparation of $SrBi_2Ta_2O_9$ on Ir/IrO_2 electrode	Rohm
28a-ZG-4	Preparation of Bi layer structured ferroelectric thin films by MOCVD (II)	Chubu University
28a-ZG-5	Preparation of $Bi_2SrTa_2O_9$ thin films by the flash MOCVD method	Sony
28a-ZG-6	Preparation of $Bi_2SrTa_2O_9$ thin films by the RF magnetron sputtering method	Kojundo Chemical, Matsushita Electronics
28a-ZG-7	Preparation of $SrBi_2Ta_2O_9$ thin films by laser ablation (2)	Osaka University
28a-ZG-8	Formation of Bi layer structures ferroelectric superlattices by the laser MBE technique	Osaka University
28a-ZG-9	Preparation of Bi layer structered ferroelectric films by the MBE technique	Sanyo
28a-ZG-10	Optical properties of bismuth layered structure ferroelectric $SrBi_4Ti_4O_{15}$ thin films	Osaka University
28a-ZG-11	Preparation of $Bi_2WO_6/SrTiO_3$ artificial lattices by a laser ablation technique	Osaka University
28p-ZG-1	Electric states of $ATiO_3$ (1): General characteristics	Sony
28p-ZG-2	Electric states of $ATiO_3$ (2): Comparison with experimental results	Sony
28p-ZG-3	Fabrication of $La_2Ti_2O_7$ ferroelectric thin films	Mitsubishi Electric
28p-ZG-4	Proposition of $ReMnO_3$ (Re: rare earth) thin films for nonvolatile memory devices	University of Osaka Prefecture
28p-ZG-5	Electrical properties of ferroelectric $BaMgF_4$ films on Si substrates (2)	Tokyo Institute of Technology

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CONFERENCE REPORTS

1995 AUTUMN MEETING OF THE JAPAN SOCIETY OF APPLIED PHYSICS -- continued from page 12

28p-ZG-6	Electrical properties of ferroelectric $BaMgF_4$/AlGaAs/GaAs (100) structures	Tokyo Institute of Technology
28p-ZG-7	Preparation of MFSFETs by using $BaMgF_4$ films grown on Si (111) substrates	Tokyo Institute of Technology
28p-ZG-8	Preparation and characterization of ferroelectrics/oxide semiconductor structures	Tokyo Institue of Technology
28p-ZG-9	Fabrication of metal/insulator junction devices using perovskite type oxides (1)	Osaka University
28p-ZG-10	Fabrication of MFM MOSFET structures	Tokyo Institute of Technology
28p-ZG-11	Study of YSZ epitaxial layer on Si as a buffer layer on an MFIS FET	Waseda University, Asahi Chemical, Nissan Motor
28p-ZG-12	Study of CeO_2 layer on Si as a buffer layer for an MFIS FET III	Waseda University, Asahi Chemical
28p-ZG-13	Study of CeO_2 layer on Si as a buffer layer for an MFIS FET IV	Waseda University, Asahi Chemical
28p-ZG-14	Quarter-wave infrared absorber for pyroelectric detectors	Mitsubishi Electric

SUMMARY

PZT	(18)	$(Ba,Sr)TiO_3$	(11)	$SrBi_2Ta_2O_9$	(9)	MOCVD	(23)
$PbTiO_3$	(6)	$SrTiO_3$	(7)	$Bi_4Ti_3O_{12}$	(6)	Sputtering	(17)
PLT	(2)	$BaTiO_3$	(4)	$BaMgF_4$	(3)	Sol-Gel	(10)
PLZT	(2)	$Ba(Ti,Sn)O_3$	(1)	$(Zr,Sn)TiO_4$	(1)	PLD	(10)
				Bi_2W_6	(1)	MBE	(8)
				$La_2Ti_2O_7$	(1)	Evaporation	(3)
				$YMnO_3$	(1)	MOD	(3)
						Other	(1)

University - National Laboratory	(48)
Industry	(49)

Pierre-Yves Lesaicherre
ULSI Device Development Laboratories, NEC Corporation, 1120, Shimokuzawa, Sagamihara, Kanagawa 229, Japan
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8th International Conference on Integrated Ferroelectrics (ISIF 96)
17 - 20 March 1996
Tempe, Arizona

On page 14 of the Summer 1995 issue of the **Ferroelectricity Newsletter** *we published information on ISIF 96. Here are some additional details.*

Plenary session speakers

Dr. J. Shimer
VP Technical Staff, Advanced Custom Technology, Motorola

Dr. Y. Nishi
VP and Director of Semiconductor Products Group, Texas Instruments

Mr. H. Esaki
Director, Board Member, Semiconductor Business Group, Kyoto Research Lab, Matsushita Electronics Corp.

Mr. H.H. Takasu
General Manager, R&D Division, Advanced Technology, Rohm Co., Ltd.

-- continued on page 14

UPCOMING MEETINGS

ISIF 96 -- continued from page 13

Dr. J. Alexander
Program Director, Electronics Technology Office, Advanced Research Projects Agency
D.Y. Miyasaka
Director, Ferroelectric Thin Film Group, Materials Research Lab, Fundamental Research Labs, NEC Corporation

Invited papers

Applications and devices - Nonvolatile memory
Performance of $SrBi_2Ta_2O_9$ for low voltage, nonvolatile memory applications, *R. Jones*
250 bit CMOS nonvolatile memory using low fatigue/imprint capacitors, *J.T. Evans*

DRAMs
A review of perovskite-type dielectrics for DRAMs, *D. Kotecki*

Piezoelectric sensors and actuators
Integrated ferroelectric monomorph transducers for acoustic imaging, *J. Bernstein*
Integrated ferroelectric microelectromechanical systems: Technology issues and device applications, *D.L. Polla*

Applications and devices - Microwave and biomedical
Biocompatibility testing of prostheses as exemplified by the auditory brainstem prosthesis, *H.L. Seldon*

Materials processing - CVD
Chemical vapor deposition of $(Ba,Sr)TiO_3$ thin films for application in giga-bit scale dynamic random access memories, *K. Eguchi*
The relationship between MOCVD processing parameters and microstructures of ferroelectric thin films, *Z. Li*

Materials processsing - PVD
High performance of $Pb(Sr,Ti)O_3$ film nonvolatile memories with oxide electrode technology, *R. Ramesh*
Deposition of self-polarized PZT films by planar multitarget sputtering, *R. Bruchhaus*

Materials processing - Sol-gel
Solution derived ferroelectric thin films for sensor and memory applications, *A. Patel*
Orientation effects and low temperature (<450˚) perovskite phase formation in $Pb(Zr_{0.4}Ti_{0.6})O_3$ thin films derived using the MMAP approach, *P. Phule*

Materials processing - MOD
Synthesis of low carbon content MOD precursor solutions for bismuth layered structures, *O.G. Ramer*
Characterization
Structure/property characteriation of $Pb(Zr,Ti)O_3$ thin films for microsensor applications, *B.A. Tuttle*
Dielectric analysis of integrated ceramic thin film capacitors, *R. Waser*
Imprint induced ferroelectric failure modes and effects, *J. Benedetto*

Modeling and theory
A model for the switching process in ferroelectric ceramics, *G. Arlt*

Device integration issues and testing
Integration technology of ferroelectric thin films and its application to Si devices, *E. Fujii*
Process integration technologies on half-micron, mega-bits ferroelectric memories, *K. Sakiyama*

For more information on ISIF 96 contact
Alona S. Miller, University of Colorado at Colorado Springs, PO Box 7150, Colorado Springs, CO 80933-7150
phone +(719) 593-3488, fax +(719) 594-4257

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UPCOMING MEETINGS

International Seminar on Relaxor Ferroelectrics
21 - 23 May 1996
Dubna (Moscow region), Russia

Contact

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International Symposium on Ferroic Domains and Mesoscopic Structures (ISFD 4)
25 - 29 May 1996
Vienna, Austria

Contact

H. Warhanek or **I.A.U. Grafeneder**, Institute for Experimental Physics, University of Vienna, Strudlhofgasse 4, A-1090 Vienna
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e-mail isfd4@pap.univie.ac.at

10th American Conference on Crystal Growth (ACCG-10)
in conjunction with
9th International Conference on Vapor Growth and Epitaxy (ICVGE-9)
4 - 9 August 1996
Westin Resort, Vail, Colorado

This joint meeting will bring together two crystal growth communities and will encompass both bulk crystal growth and epitaxial growth. Special topics will include: nanocrystals,nitrides, microgravity, defects and characterization, as well as photovoltaic materials.
Contributions are solicited for all aspects of crystal growth, including novel crystal growth methods, materials, applications, and fundamental studies.

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Organizers

T.F. Ciszek and **J.F. Wenckus**, conference co-chairs for ACCG-10
D.W. Kisker, conference chair for ICVGE-9
K.A. Jackson, program chair for ACCG-10
J.M. Olson, program chair for ICVGE-9

Contact

Anthony L. Gentile, American Association for Crystal Growth
PO Box 3233, Thousand Oaks, CA 91359-0233

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MAILBOX .....

This space is reserved for inquiries and comments of our readers to colleagues in the field. It is designed as an additional vehicle to facilitate the exchange of information and answers to specific questions. Our sponsors mandate that all contributions must be ***noncommercial.***

My research activities as a PhD student focus on ferroelectric films for piezoelectric actuator devices. I would appreciate it if I could get names of other researchers in this field who would be interested in discussing certain aspects.

Frank Gugenberger
Institut für Materialsforschung I
Forschungszentrum Karlsruhe
PO Box 3640
D-76021 Karlsruhe
Germany

* * *

The section of the newsletter I like the most is the conference reports. In particular, I like Pierre-Yves Lesaicherre's reports on Japanese ferroelectric conferences.

Scott Summerfelt
Texas Instruments
Dallas, Texas

* * *

I am a physics student at the University of Osnabrück, Germany, writing a thesis on hydrogenchloride as ferroelectric matter. Unfortunately, I could not find any articles on that subject in the professional journals. I would appreciate any information on that matter.

Ulrich Solbach
e-mail:
usolbach@rz..uni-osnabrueck.de

	CALENDAR OF EVENTS 1996
Mar 17-20	• 8th International Symposium on Integrated Ferroelectrics (ISIF 96), Tempe, Arizona (see *Ferroelectricity Newsletter* Vol. 3, No. 3, p. 14 and this issue p. 13)
26-29	• 43rd Spring Meeting of the Japan Society of Applied Physics, Toyo University-Asaka Kosha, Asaka City, Saitama Prefecture, Japan. For information contact The Japan Society of Applied Physics, Kudanshita Bldg., 1-12-3 Kudan-kita, Chiyoda-ku, Tokyo 102, phone +81-3-3238-1044, fax +81-3-3221-6245.
Apr 8-12	• 1996 MRS Spring Meeting, San Francisco, California (see *Ferroelectricity Newsletter* Vol. 3, No. 3, p. 15)
May 21-23	• International Seminar on Relaxor Ferroelectrics, Dubna, Russia (see p. 15)
25-29	• International Symposium on Ferroic Domains and Mesoscopic Structures, Vienna, Austria, (see p. 15)
27-29	• 3rd Pacific Rim Conference on Applications of Ferroelectrics, Coop-Inn Kyoto, Japan. For information contact Prof. T. Shiosaki, Department of Electronics, Faculty of Engineering, Kyoto Univ., Kyoto 606-01, Japan, phone +81 75 753-5309, fax +81 75 753-5749, e-mail tshiosak@kuee.kyoto-u.ac.jp
May 29-**Jun** 1	• 13th Meeting on Ferroelectric Materials and Their Applications (FMA-13), Coop-Inn Kyoto, Japan. For information contact Prof. T. Shiosaki, Department of Electronics, Kyoto University, Kyoto 606-01, Japan, phone +81 75 753-5309, fax +81 75 753-5749, e-mail tshiosak@kuee.kyoto-u.ac,jp
Aug 4-9	• 10th American Conference on Crystal Growth, in conjunction with the 9th International Conference on Vapor Growth and Epitaxy, Vail, Colorado (see p. 15)
18-21	• IEEE International Symposium on the Application of Ferroelectrics (ISAF '96), Brunswick Hilton and Tower, East Brunswick, NJ/Rutgers University. For information contact Prof. A. Safari, Rutgers University, Dept. of Ceramic Engineering & Center for Ceramic Research, PO Box 909, Piscataway, NJ 08855-0909, phone (908) 445-4367, fax (908) 445-3258, e-mail safari@safari.rutgers.edu
Sep 2-5	• 3rd European Conference on Applications of Polar Dielectrics (ECAPD-3), Bled, Slovenia (see *Ferroelectricity Newsletter*, Vol. 3, No. 4, p. 13)
25-27 30	• 9th International Symposium on Electrets (ISE 9), Shanghai, China • Workshop at ISE 9: The Future of Electrets and Surveys on Ongoing Electret Research (see *Ferroelectricity Newsletter*, Vol. 3, No. 4, p. 14)
Dec 2-6	• MRS Fall Meeting, Boston, Massachusetts. For information contact Werner Lutze, University of New Mexico, phone (505) 277-7964, fax (505) 277-5433, e-mail brbl@unmb.unm.edu

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