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Electroactive Polymers (EAP)

EDITORS

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Electroactive Polymers (EAP)

Symposium held November 29–December 1, 1999, Boston, Massachusetts, U.S.A.

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Electroactive Polymers (EAP)

PREFACE

For many years, electroactive ceramic, magnetostrictive material and shape memory alloys have been the primary source of actuation materials for manipulation and mobility systems. Electroactive polymers (EAP) received relatively little attention due to their limited capability. In recent years, effective EAP materials have emerged changing the paradigm of these materials' capability and potential. Their main attractive characteristic is the operation similarity to biological muscles where under electrical excitation a large displacement is induced. The potential to operate biologically inspired mechanisms using EAP as artificial muscles and organs is offering exciting applications that are currently considered science fiction.

This MRS symposium, "Electroactive Polymers," held November 29–December 1 at the 1999 MRS Fall Meeting in Boston, Massachusetts, was initiated for the first time this year in an effort to promote technical exchange of EAP research and development as well as provide a forum for progress reports. The symposium has the input from the international mix in participation. Eminent EAP researchers from the U.S.A., Japan, and Europe presented Invited Papers covering the cutting edge of their material state of the art capabilities and limitations. Generally, two groups of materials were covered: Dry - including electrostrictive, electrostatic, piezoelectric, and ferroelectric; as well as Wet - including IPMC, nanotubes, conductive polymers, gels, etc. While overall the dry types require high voltage for their operation, they provide larger mechanical energy density and they can hold a displacement under a DC voltage, and some of the DRY EAP are capable of operating to high frequencies (>10 kHz). On the other hand, the WET EAP are superior in requiring low actuation voltage ($\sim$ a few volts) with high strain generation capabilities, but are sensitive to drying, and some have difficulties holding a displacement under DC activation.

This proceedings volume brings together many of the oral and poster presentations at the symposium and includes papers on the following topics:

- ▼ EAP applications and their characterizations
- ▼ Ferroelectric based polymers
- ▼ Piezoelectric, electrostrictive polymers, and high strain dielectric elastomers
- ▼ Polymer gels and biological muscles
- ▼ Conductive polymers
- ▼ Polymer composites
- ▼ EAP synthesis and processing
- ▼ Models and analysis of EAP

We hope this volume can provide a resource for the future development in this exciting interdisciplinary field. Clearly, the EAP developed offer great potential in many applications, and also challenge to improve them further to meet the great expectations.

Q.M. Zhang
Takeo Furukawa
Yoseph Bar-Cohen
J. Scheinbeim

January 2000

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CONTENTS

Preface	xi
Acknowledgments	xiii
Materials Research Society Symposium Proceedings	xiv

APPLICATIONS

*Compliant Actuators Based on Electroactive Polymers	3
S.G. Wax, R.R. Sands, and L.J. Buckley	
Challenges to the Transition to the Practical Application of IPMC as Artificial-Muscle Actuators	13
Y. Bar-Cohen, S. Leary, A. Yavrouian, K. Oguro, S. Tadokoro, J. Harrison, J. Smith, and J. Su	

FERROELECTRIC POLYMERS

*Structure, Properties, and Applications of Single Crystalline Films of Vinylidene Fluoride and Trifluoroethylene Copolymers	23
H. Ohigashi	
*Structural Change in Ferroelectric Phase Transition of Vinylidene Fluoride Copolymers as Studied by WAXS, SAXS, IR, Raman, and Computer Simulation Techniques	35
K. Tashiro	
Effects of Sample Processing and High-Energy Electron Irradiation Conditions on the Structural and Transitional Properties of P(VDF-TrFE) Copolymer Films	47
Vivek Bharti, Z-Y. Cheng, H.S. Xu, G. Shanthi, T-B. Xu, T. Mai, and Q.M. Zhang	
Synthesis and Electric Property of VDF/TrFE/HFP Terpolymers	53
A. Petchsuk and T.C. Chung	

*Invited Paper

*Giant Electrostrictive Response in Poly(vinylidene-fluoride hexafluoropropylene) copolymer	61
Xiaoyan Lu, Adriana Schirokauer, and Jerry Scheinbeim	
Electro-Mechanical Properties of Electron Irradiated P(VDF-TrFE) Copolymers Under Different Mechanical Stresses	71
Z-Y. Cheng, S.J. Gross, V. Bharti, T-B. Xu, T. Mai, and Q.M. Zhang	
Electron Irradiated P(VDF-TrFE) Copolymers for Use in Naval Transducer Applications	77
T. Ramotowski, K. Hamilton, G. Kavarnos, Q. Zhang, and V. Bharti	
Dynamics of Pyroelectricity of a Copolymer of Vinylidene Fluoride With Trifluoroethylene	83
Y. Takahashi, J. Taniwaki, and T. Furukawa	
Analysis of Ferroelectric Switching Process in VDF/TrFE Copolymers	89
Kenji Kano, Hidekazu Kodama, Yoshiyuki Takahashi, and Takeo Furukawa	
Ferroelectric and Piezoelectric Properties of Blends of Poly(vinylidene fluoride-trifluoroethylene) and a Graft Elastomer	95
J. Su, Z. Ounaies, and J.S. Harrison	
Structural and Electronic Characterization of Epitaxially-Grown Ferroelectric Vinylidene Fluoride Oligomer Thin Films	101
K. Ishida, K. Noda, A. Kubono, T. Horiuchi, H. Yamada, and K. Matsushige	
Non-Electrical Poling in Novel Ferroelectric Polymers	107
S. Tasaka, O. Furutani, and N. Inagaki	

***PIEZOELECTRIC, ELECTROSTRICTIVE, AND
DIELECTRIC ELASTOMER***

*Ultra-High Strain Response of Elastomeric Polymer Dielectrics	119
Roy Kornbluh, Ronald Pelrine, Jose Joseph, Qibing Pei, and Seiki Chiba	

*Invited Paper

Electrostrictive Graft Elastomers and Applications	131
J. Su, J.S. Harrison, T.L. St. Clair, Y. Bar-Cohen, and S. Leary	

Dehydration Time Dependence of Piezoelectric and Mechanical Properties of Bovine Cornea	137
A.C. Jayasuriya, J.I. Scheinbeim, V. Lubkin, G. Bennett, and P. Kramer	

*Novel Polymer Electrets	143
G.M. Sessler and J. Hillenbrand	

Polarization Stability of Amorphous Piezoelectric Polyimides	153
C. Park, Z. Ounaies, J. Su, J.G. Smith, Jr., and J.S. Harrison	

A Study of Liquid Crystalline Elastomers as Piezoelectric Devices	159
A.G. Biggs, K.M. Blackwood, A. Bowles, S. Dailey, and Alison May	

CONDUCTIVE POLYMERS

*Poly(SNS) Electrochemical Synthesis and Processability	167
T.F. Otero, S. Villanueva, E. Brillas, and J. Carrasco	

<i>In Situ</i> Conductivity of Poly(3,4-ethylenedioxythiophene) Electrosynthesized in Aqueous Solutions in the Presence of Large Anions	173
H.J. Ahonen, J. Lukkari, and J. Kankare	

Hyperbranched Conductive Polymers Constituted of Triphenylamine	179
S. Tanaka, K. Takeuchi, M. Asai, T. Iso, and M. Ueda	

Conduction Behavior of Doped Polyaniline Under High Current Density and the Performance of an All Polymer Electromechanical System	185
Haisheng Xu, V. Bharti, Z-Y. Cheng, Q.M. Zhang, Pen-Cheng Wang, and A.G. MacDiarmid	

Comparative Study of Solvent Effect on the Electrochemical Deposition of Polythiophene and Polybithiophene	191
T.K.S. Wong and X. Hu	

*Invited Paper

EQCM and Quartz Crystal Impedance Measurements for the Characterization of Thiophene-Based Conducting Polymers	197
C. Arbizzani, F. Soavi, and M. Mastragostino	
Polythiophene Grafted on Polyethylene Film	203
N. Chanunpanich, A. Ulman, Y.M. Strzhemechny, S.A. Schwarz, J. Dornicik, M. Rafailovich, J. Sokolov, A. Janke, H.G. Braun, and T. Kratzmüller	
A Conductive Composite Film by Permeation Method	209
Jin Wei Wang and M.P. Srinivasan	
Electrochemical Investigation of 2,2'-diaminobenzyloxydisulfide	215
Y.Z. Su and K.C. Gong	
On the Nature of Heterogeneity in Vacuum Deposited Polyaniline Films	221
V.F. Ivanov, A.A. Nekrasov, K.V. Cheberyako, O.L. Gribkova, and A.V. Vannikov	

POLYMER GELS AND MUSCLES

*Polymer Electrolyte Actuator Driven by Low Voltage	229
K. Oguro, K. Asaka, N. Fujiwara, K. Onishi, and S. Sewa	
*Polymer-Gel Phase-Transition as the Mechanism of Muscle Contraction	237
Gerald H. Pollack	
Biochemical Synthesis and Unusual Conformational Switching of a Molecular Complex of Polyaniline and DNA	249
Ramaswamy Nagarajan, Sukant K. Tripathy, Jayant Kumar, Lynne A. Samuelson, and Ferdinando F. Bruno	
Enzymatic Template Synthesis of Polyphenol	255
Ferdinando F. Bruno, Ramaswamy Nagarajan, Jena S. Sidhartha, Ke Yang, Jayant Kumar, Sukant Tripathy, and Lynne Samuelson	
The Constitutive Response of Active Polymer Gels	261
S.P. Marra, K.T. Ramesh, and A.S. Douglas	

*Invited Paper

Electroactive Nonionic Polymer Gel—Swift Bending and Crawling Motion	267
T. Hirai, J. Zheng, M. Watanabe, H. Shirai, and M. Yamaguchi	

Effect of the Pore Formation on the Solution Flow Through Acrylamide Gel	273
H. Tamagawa, S. Popovic, and M. Taya	

COMPOSITES AND OTHERS

High Dielectric Constant Polymer Ceramic Composites	281
Y. Bai, V. Bharti, Z-Y. Cheng, H.S. Xu, and Q.M. Zhang	

The Voltage and Composition Dependence of Switching in a Polymer Current Limiter Device	287
Anil R. Duggal	

Smart Polymer Composite Thermistor	293
Ralf Strümpfer and Joachim Glatz-Reichenbach	

Fast Proton Conductors From Inorganic-Organic Composites:	
I. Amorphous Phosphate-Nafion and Silcophosphate-PMA/PWA Hybrids	299
Yong-Il Park, Jae-Dong Kim, and Masayuki Nagai	

Fast Proton Conductors From Inorganic-Organic Composites:	
II. Amorphous Phosphate-PTFE and ZrP-PTFE Composites	305
Yong-Il Park, Jae-Dong Kim, and Masayuki Nagai	

Dielectric Relaxation Spectroscopic Measurements on a Novel Electroactive Polyimide	
Saadi Abdul Jawad, Abdalla Alnajjar, and Mamoun M. Bader	

Computer Controlled Pulsed PECVD Reactor for Laboratory Scale Deposition of Plasma Polymerized Thin Films	325
P.D. Pedrow, L.V. Shepsis, R. Mahalingam, and M.A. Osman	

Author Index	333
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Subject Index	335
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Applications

COMPLIANT ACTUATORS BASED ON ELECTROACTIVE POLYMERS

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ABSTRACT

The field of Electroactive Polymers has experienced a considerable amount of expansion over the last decade. Much of this work has been concentrated on developing polymeric materials that mimic biological systems or that exhibit electronic and optical properties similar to inorganic materials. This paper briefly reviews some of the nearer term applications that electroactive polymers might impact: image processing and sonar. In addition, a review of compliant actuators based on the unique properties inherent in electroactive polymers is provided. Emphasis will be placed on the mechanisms responsible for actuation and on the limited mechanical, electrical and chemical data current available. A comparison between mammalian muscle properties and electroactive polymer actuator properties is provided.

INTRODUCTION

The interest in electroactive polymers (EAP) has grown significantly over the last several years, as indicated by the growing number of conferences that now address this topic. This interest seems to be due in part to the potential for EAPs to provide compliant actuation for use in biological or biomimetic applications. (Here the term “compliant” is used to describe the flexibility that emulates that of real muscles) The actuation promise of these materials is one of the major reasons the Defense Advanced Research Projects Agency (DARPA) has been sponsoring this technology. In addition, other applications that involve the unique electro-optic response of the materials are being pursued. Table I, modified from a previous paper [1], outlines the many possible applications being examined.

The primary focus of this paper is to discuss how the unique advantages of EAP for actuation drive the requirements for the performance of these materials and therefore the research needs. However, it is also illuminating to examine another biologically inspired application for EAPs in order to note how even simple control of the chemistry can make huge differences in capability.

There is a critical defense need for rapid signal processing of images, particularly important as a weapon attempts to identify and follow its target amid clutter of all spatial frequencies. Traditional sensors are pixel based and require a great deal of digital processing, costly in time and power. Conversely, our eyes and early visual system sort through scenes in an analog fashion, blending “pixels” as needed and sending only the critical

Table I: Defense Applications for Electroactive Polymers

Actuation and Sensing

- Artificial Muscles
- Smart Skins
- Acoustic (Sonar)
- Biomimetic Devices
- Bio-sensors

Electro-Optical Response

- Analog Processing
- Large Area, Flexible Displays
- Polymer FET's
- Sensor Protection