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Electroactive Polymers (EAP)

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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 (~ 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.

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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

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