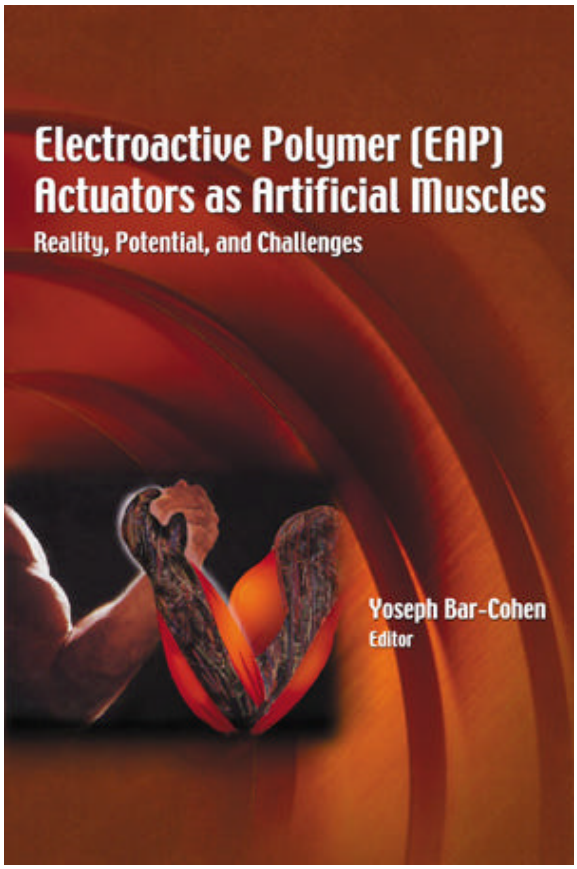

ELECTROACTIVE POLYMER (EAP) ACTUATORS AS

ARTIFICIAL MUSCLES

Reality, Potential and Challenges

Editor: Yoseph Bar-Cohen, JPL

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PREFACE

This book is reviewing the state-of-the-art of the field of Electroactive Polymers (EAP), so-called Artificial Muscles. In writing this book, efforts were made to cover the field of EAP from all its key aspects, i.e., its full infrastructure, including the available materials, analytical models, processing techniques, and characterization methods. It is intended to serve as a reference book, technology users guide, and tutorial resource, as well as create a vision for the future direction of this field.

For many years, the field of EAP has received relatively little attention since the number of available materials and their actuation capability were limited. The change in this view occurred in the last ten years, as a result of the development of new EAP materials that exhibit a large displacement in response to electrical stimulation. This characteristic is a valuable attribute, which enabled a myriad of potential applications, and it has evolved to offer operational similarity to biological muscles. The similarity includes resilient, damage tolerant, and large actuation strains (stretching, contracting or bending). Therefore, it is natural to consider EAP materials for application as biologically-inspired actuators to drive various manipulation, mobility and robotic devices. However, before these materials can be applied as actuators of medical aids (such as synthetic limbs or prostheses), their actuation force and robustness will need to be increased significantly from the levels that are currently exhibited by the available materials. On the positive note, there has already been a series of reported successes in demonstrating miniature manipulation devices including a catheter steering element, robotic arm, gripper, loudspeaker, active diaphragm, and dust-wiper. The editor is hoping that the information documented in this book will help stimulate the development of niche applications for EAP and the emergence of related commercial devices. Such applications are anticipated to promote EAP materials to become actuators of choice in spite of the current technology challenges and limitations. The commercial introduction of EAP will eventually evolve into improved products and can lead to a wide range of technology transfers to other practical uses.

Chapter 1.0 of this book provides an overview and background to the various EAP materials, and their potentials. Since biological muscles are used as a model for the development of EAP actuators, Chapter 2.0 describes the mechanism of muscles operation and their behavior as actuators. Chapter 3.0 covers the leading EAP materials and the principles that are responsible for their electroactivity. Chapter 4.0 covers such fundamental topics as computational chemistry and nonlinear electromechanical analysis enabling to predict their behavior as well as design guide for the application of one example EAP material. Modeling the behavior of EAP materials requires the use of complex analytical tools and it is one of the major challenges to the design and control of related mechanisms and devices. Efforts are currently underway to model their nonlinear electromechanical behavior and to develop novel experimental techniques to measure and characterize EAP material properties [see Chapter 6.0]. These efforts are leading to a better understanding of the origin of the electro-activity of various EAP materials, which, in turn, can help in improving and possibly optimizing their performance. Processing methods are also being covered describing fabrication, shaping, electroding and integration techniques of producing fibers, films and other shapes of EAP actuators [see Chapter 5.0].

Generally, EAP actuators are highly agile, lightweight, low power, and mass-producible, can be made inexpensive, and they have inherent capability to host embedded sensors and micro-electro-mechanical-systems (MEMS). Their many unique characteristics can make them a valuable alternative to current actuators such as electroactive ceramics and shape memory alloys. The making of miniature

insect-like robots that can crawl, swim and/or fly may become a reality as this technology evolves [Chapters 7.0 and 8.0]. Processing techniques, such as ink-jet printing, may potentially be employed to make complete devices that are driven by EAP actuators. A device may be fully produced in 3D details, thereby allowing rapid prototyping and subsequent mass production possibilities. Thus, polymer-base EAP-actuated devices may be fully produced by an ink-jet printing process enabling the rapid implementation of science fiction ideas (e.g., insect-like robots that become remotely operational as soon as they emerge from production line) into engineering models and commercial products. Potential beneficiary of EAP capabilities include many fields such as commercial, medical, space, and military that can impact our life greatly.

In order to exploit the highest benefit that EAP materials can offer, a multidisciplinary international cooperation is needed among scientists, engineers, and other experts (e.g., medical doctors, etc.). Experts in chemistry, materials science, electro-mechanics, robotics, computer science, electronics, etc. need to join together to develop improved EAP materials, processing techniques and applications that can benefit from EAP technologies. Effective feedback sensors and control algorithms are needed to address the unique and challenging aspects of EAP actuators. If EAP-driven artificial muscles can be implanted into a human body, together we can make a tremendously positive impact on many human lives.

Yoseph Bar-Cohen, JPL

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21.5.3.1 Garments and Clothing
21.5.3.2 Anti G-Suit
21.5.4 Robotics, Toys and Animatronics
21.5.4.1 Biologically-Inspired and Insect-Like Robots
21.5.4.2 Toys and Animatronics
21.5.4.3 Agriculture and Ecology
21.5.4.3 Rapid Prototyping Miniature Robotics Using Stereo-Lithography
21.5.5 Medical Applications
21.5.5.1 EAP for Biological Muscle Augmentation or Replacement
21.5.5.2 Miniature in-Vivo EAP Robots for Diagnostics and Microsurgery
21.5.5.3 Catheter Steering Mechanism
21.5.5.4 Tissues Growth Engineering
21.5.5.5 Interfacing Neuron to Electronic Devices Using EAP
21.5.5.6 Active Bandage
21.5.6 Liquid and Gas Flow Control and Pumping
21.5.7 Noise Reduction
21.5.8 Electromechanical Polymer Sensors and Transducers
21.5.9 Micro-Electro-Mechanical Systems (MEMS)
21.5.10 Other Potential Applications
21.6 EAP Characterization
21.7 Future Expectations
21.7 Acknowledgement
21.8 References