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Electro-Active Polymer Actuators - Types, Applications, new Developments, Industry Structure and Global Markets

https://marketpublishers.com/r/E9D1E37F4B0EN.html
Date: February 2008
Pages: 119
Price: US$ 2,650.00 (Single User License)
ID: E9D1E37F4B0EN

Abstracts

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Electro-active polymers (or EAPs) are polymeric materials whose shapes are modified when a voltage is applied to them. They can be used as actuators or sensors. As actuators, they are characterized by the fact that they can undergo a large amount of deformation while sustaining large forces. Due to the similarities with biological tissues in terms of achievable stress and force, they are often called artificial muscles, and have the potential for application in the field of robotics, where large linear movement is often needed.

When certain types of electro-active polymers are physically flexed, they produce a voltage output. This effect allows EAPs to be used as potential sensors in various types of equipment. With EAPs’ inherent flexible and durable nature, long sensor life is expected. EAPs such as ionic polymer metal composites (IPMCs) are active materials that exhibit interesting bidirectional electromechanical coupling phenomena, e.g., by bending an IPMC strip, a voltage output is obtained, while a voltage input is able to cause the strip to bend. Thus, they are also large motion sensors. The output voltage can be calibrated for a standard-size sensor and correlated to the applied loads or stresses. EAPs can be manufactured and cut in any size and shape. For example, for a structural health monitoring of a bridge such as the San Francisco Golden Gate Bridge against all vibrational, aerodynamics or natural disturbances, a completely integrated and distributed computer-controlled package of quickly installed, user-friendly IPMC sensor elements numbering 100,000 are required.

Electro-active ceramic actuators (for example, piezoelectric and electro-strictive) are effective, compact actuation materials, and they are used to replace electromagnetic motors. However, while these materials are capable of delivering large forces, they produce a relatively small displacement, on the order of magnitude of a fraction of a percent. Since the beginning of the 1990s, new electro-active polymer (EAP) materials have emerged that exhibit large strains, and they have led to a great paradigm change with regards to their capability. The unique properties of these materials are highly attractive for bio-mimetic applications such as biologically inspired intelligent robots. Increasingly, engineers are able to develop EAP actuated mechanisms that were previously imaginable only in science fiction. Electric motors tend to be too weak, while hydraulics and pneumatics are too heavy for use in robotics or prosthetics. EAPs, in comparison, are lightweight, quiet and capable of energy densities similar to biological muscles.

In ionic EAPs, actuation is caused by the displacement of ions inside the polymer. Only a few volts are needed for actuation, but the ionic flow implies a higher electrical power needed for actuation, and energy is needed to keep the actuator at a given position. Examples of ionic EAPS are conducting polymers, ionic polymer metal composites (IPMCs), and responsive gels. Yet another example is a Bucky gel actuator, which is a polymer-supported layer of polyelectrolyte material consisting of an ionic liquid sandwiched between two electrode layers consisting of a gel of ionic liquid containing single wall carbon nanotubes. The name refers to Buckyballs.

This study reports new concepts in mechanism design and digital mechatronics, which have the potential to significantly impact a wide variety of systems and devices, including medical devices, manufacturing systems, toys and robotics, among others. The survey mainly targets dielectric elastomer actuators, conductive polymers actuators and ionic polymer metal composites (IMPC) actuators as the most likely candidates to act as EAP devices, on the basis of material characteristics, maturity of technology, reliability, and cost to meet design requirements of applications considered.

STUDY GOAL AND OBJECTIVES

The markets for EAP devices are strongly driven by the expanding medical market, E-textiles and robotics with its demand for a novel class of electrically controlled actuators based on polymer materials. Almost any laboratory for molecular biology has to be equipped with a dextrous robotic gripper. The artificial muscle envisioned is a low-cost actuator capable of being accurately electrically controlled, expanding or contracting

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linearly, and performing in a manner that resembles the natural skeletal muscles. Such an actuator has potential applications in areas where flexibility of a moving system goes together with a need for accurate control of the motion: robotics, advanced consumer products like smart fabrics, toys and medical technology. Totally new design principles and novel products highly visible in everyday life and having a large economic potential can be anticipated.

In addition, new and much larger markets will open up if micro-fluidic devices using micropumps and microvalves can enter the arena of clinical and point-of-care and even the home diagnostics market. This study focuses on electro-active polymers and devices, types, applications, new developments, industry and global markets, providing market data about the size and growth of the application segments, including a detailed patent analysis, company profiles and industry trends. Another goal of this report is to provide a detailed and comprehensive multi-client study of the market in North America, Europe, Japan and the rest of the world (ROW) for electro-active polymers and devices and potential business opportunities in the future.

The objectives include a thorough coverage of the underlying economic issues driving the electro-active polymers and devices business, as well as assessments of new advanced electro-active polymers and devices that are being developed. Another important objective is to provide realistic market data and forecasts for electro-active polymers and devices. This report provides the most thorough and up-to-date assessment that can be found anywhere on the subject. The study also provides extensive quantification of the many important facets of market developments in electro-active polymers and devices all over the world. This, in turn, contributes to the determination of what kinds of strategic responses companies may adopt in order to compete in this dynamic market.

REASONS FOR DOING THE STUDY

Electro-active polymers and devices exhibit many qualities that make them ideal for a low cost actuator capable of being accurately electrically controlled, expanding or contracting linearly, and performing in a manner that resembles the natural skeletal muscles. Such an actuator has potential applications in areas where flexibility of a moving system goes together with a need for accurate control of the motion, such as robotics, advanced consumer products like smart fabrics, toys, and medical technology.

Development of EAP fields will benefit companies that use EAP components to add value to products and services, companies skilled in using EAP to design new products and services, and materials processors that add value to raw materials. The small volumes of EAP consumption likely will have little impact on raw materials suppliers. Near-term returns on investments by EAP suppliers generally will be modest, because most EAP fields still are building infrastructure and knowledge bases for efficient and effective production, marketing and use of EAP. The specialized knowledge necessary to produce EAPs and to incorporate them effectively into products will slow the spread of EAP use, but it also has led to high market valuations for companies developing products for high-value applications.

Smart structures, which fully integrate structural and mechatronic components, represent the most refined use of EAPs and might eventually enjoy very large markets. Only a very simple EAP-based smart-structure product is in commercial use today. Other important areas of opportunity include applications in which designers desire performance improvements or new features but are unwilling to accept the compromises necessary to use conventional mechanisms and products (including non=mechanical devices) that must operate in a variety of conditions but have rigid designs optimized for a single operating point. Though improvements in EAP performance would increase the range of possible applications, the major barriers to widespread EAP use are users' lack of familiarity, the need for low-cost, robust production processes, and the need for improved design tools to enable non-experts to use the materials with confidence

Therefore, iRAP felt a need to do a detailed technology update and analysis of this industry.

CONTRIBUTIONS OF THE STUDY

The study is intended to benefit the existing manufacturers of robotics, advanced consumer products like smart fabrics, toys, and medical technology, who seek to expand revenues and market opportunities through expanding to new technology such as low-cost electro-active polymers and devices, which are positioned to become a preferred solution over conventional actuator applications.

This study also provides the most complete accounting of electro-active polymers and devices growth in North America, Europe, Japan and the rest of the world currently available in a multi-client format. The markets have also been estimated according to the type of materials used, such as dielectric elastomer actuators, conductive polymers and ionic polymer metal composites.

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The report provides the most thorough and up-to-date assessment that can be found anywhere on the subject. The study also provides extensive quantification of the many important facets of market developments in the emerging markets of electro-active polymers and devices, such as China. This, in turn, contributes to the determination of what kind of strategic response suppliers may adopt in order to compete in this dynamic market.

SCOPE AND FORMAT

The market data contained in this report quantify opportunities for electro-active polymers and devices. In addition to product types, the report also covers the many issues concerning the merits and future prospects of the electro-active polymers and devices business, including corporate strategies, information technologies, and the means for providing these highly advanced products and service offerings. It also covers in detail the economic and technological issues regarded by many as critical to the industry's current state of change. The report provides a review of the electro-active polymers and devices industry and its structure and the many companies involved in providing these products. The competitive position of the main players in the electro-active polymers and devices market and the strategic options they face are also discussed, as well as such competitive factors as marketing, distribution and operations.

TO WHOM THE STUDY CATERS

The study will benefit existing manufacturers of robotics, advanced consumer products like smart fabrics, toys, and medical technology. The electro-active polymer (EAP) materials exhibit large strains and they led to a great paradigm change with regards to their capability. The unique properties of these materials are highly attractive for biomimetic applications such as biologically inspired intelligent robots.

This study provides a technical overview of the electro-active polymers and devices, especially recent technology developments and existing barriers. Therefore, audiences for this study include marketing executives, business unit managers and other decision-makers in robotics, advanced consumer products like smart fabrics, toys, and medical technology as well as those in companies peripheral to these businesses.

REPORT SUMMARY

Electro-active polymer technology could potentially replace common motion-generating mechanisms in positioning, valve control, pump and sensor applications, where designers are seeking quieter, power efficient devices to replace cumbersome conventional electric motors and drive trains. An EAP actuator is not only completely different from conventional electromechanical devices, but also separates itself from other high-tech approaches that are based on piezoelectric materials or shape-memory alloys by providing a significantly more power-dense package and, in many instances, a smaller footprint.

Shape-memory alloys contract with a thermal cycle, and piezoelectric technologies expand and contract with voltage at high frequencies. While both these technologies provide direct displacement, they are usually limited to a 1% direct displacement. Electromagnetic solutions typically consist of a motor that rotates an output shaft, so there is no direct displacement from the motor itself. The output shaft connects to a "drive train," gear reducer transmission or other mechanical device that has several touching and moving parts, which create an "indirect" displacement.

This iRAP (Innovative Research and Products, Inc.) study segmented markets into four applications for electro-active polymer devices and products. These are medical devices, smart fabrics, digital mechtronics, and high strain sensing in construction. Manufacturers of electro-active polymers expect competition to persist and intensify in the future from a number of different sources. EAP devices are facing competition in a new rapidly evolving and highly competitive sector of the medical market. Increased competition could result in reduced prices and gross margins for EAP products and could require increased spending by research and development, sales and marketing, and customer support.

According to the iRAP study, during 2007, there is low key activity in the manufacturing of EAP devices. Companies are catering to specific orders of low to medium volumes. Low penetration of EAP technology in the fragmented market is partly due to lack of standardization of product specifications among manufacturers. Adaptation of EAP technology during the period of replacement of bulky conventional actuators by OEMs will depend upon, besides cost, reliability and durability of the EAP devices.

The global market for EAP actuators and sensors reached $15 million in 2007. This will increase to $247 million by 2012. Medical devices will have the largest share in 2007, as much as 77.3%, followed by smart fabrics with 13.3%, digital mechtronics with 6.7%, and high strain sensing in construction as the remaining 2.7% of the market. While the medical devices will continue to maintain the lead in 2012, that sector will see the largest growth rate as well, as much as 92 % AAGR from 2007 to 2012.

Major findings of this report are:

There is low key activity in the manufacturing of EAP devices. Companies are catering to specific orders of low to medium volumes. Low penetration of EAP technology in the fragmented market is partly due to lack of standardization of product specifications among manufacturers.

Adaptation of EAP technology during the period of replacement of bulky conventional actuators by OEMs will depend upon, besides cost, reliability and durability of the EAP devices.

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While the medical devices will continue to maintain the lead in 2012, that sector will see the largest growth rate as well, as much as 92 % AAGR from 2007 to 2012.

Regionally, North America has about 66% market in 2007, followed by Europe at 21.3%, Japan at 9.3%, and rest of world at 3.3%. The AAGR growth rate is expected to be 71.3% to 91.8% for the four major regions surveyed for the period 2007 to 2012.

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Contents

INDUSTRY STRUCTURE AND DYNAMICS

TECHNOLOGY OVERVIEW OF EAP ACTUATORS AND SENSORS

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NEW DEVELOPMENTS AND PATENT ANALYSIS

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Surgical Instrument Incorporating EAP Blocking Lockout Mechanism
Non-uniform Thickness Electro-active Device
EAP Devices for Moving Fluid
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Electro-active Based Artificial Sphincters and Artificial Muscle Patches
Electro-active Polymer Actuated Medical Devices
Electro-active Polymer Actuator and Diaphragm Pump Using the Same
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Energy Efficient EAPs and EAP Devices
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EAP Transducers and Actuators
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Elastomeric Actuator Devices for Magnetic Resonance Imaging
Polymer-polymer Bilayer Actuator
EAP Fabrication
EAP Animated Devices
EAP Thermal Electric Generators

APPENDIX I - COMPANY PROFILES

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Vivometrics

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