Robots will be of service with muscles, not motors

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Abstract
Purpose – Aims to project how electroactive polymer will replace conventional electromagnetic motor driven solutions for service and industrial robots.
Design/methodology/approach – Presents the ability of electro active polymer to provide higher power density for robot actuation over conventional approaches. Laboratory tests by DARPA compared electroactive polymer with conventional electromagnetic methodologies as well as shape memory alloy and piezo solutions.
Findings – Tests by DARPA and SRI International showed significant power density advantages for electroactive polymer artificial muscles (EPAM). Robot prototypes and well as early commercial prototypes developed by Artificial Muscle, Inc. in pumps, valves, and actuators prove superior performance over other actuation solutions.
Originality/value – Introduces a new low cost, low power consumption, light weight, and silent method for actuation for robots and other motion control devices.

Keywords Robotics, Actuators, Muscles, Polymers

Paper type Research paper

Introduction

Robots have been the topic of fantasy for decades as walking, talking, even running humanoids materialized in books and on the screen. The same fascination captured the minds of industrial and service industries in the last 30 years as robots began appearing on factory floors, as well as mobile service robots.

The challenges have been many in getting robots to perform closer to their human inventors and masters. Machine vision allowed robots to see first in two dimensions and more recently three. Software developments in artificial intelligence helped allow robots to make rudimentary decisions once vision information was captured. Developments in force sensing, CAD, simulation, and other fields improved the economics of implementing robots in automated assembly and other manufacturing applications while bringing them closer to reality in the service and personal use markets.

But one major impediment has remained for robots to reach the broadest potential in manufacturing while penetrating the service and personal markets – the cost and energy inefficiencies of conventional robots. While the industrial market made significant strides in transitioning from the early hydraulic driven arms to electric motors in the 1980's, heavy and inefficient electromagnetic actuation remains the convention not only for robots but also for motion devices in general.

In the early 1990s United States agencies approached SRI International in Menlo Park, California to address the inefficiency issues of electro-magnetic driven robots and funded development of technology that would drive robots with much more efficient, high power density actuation. What they wanted for military and other uses were robots that could walk, run and jump in the same way humans do. This funding led to a technology called electroactive polymer artificial muscle (EPAM) which is now being commercialized over ten years later. The promise of this technology is immense as electroactive polymers perform like human muscles, expanding and contracting based on variable voltage input levels.

This paper will focus on this EPAM technology and how it can change the world of programmable motion control and thus make service robots truly of service to mankind.

What is EPAM?

EPAM is an emerging "smart materials" technology that has significant differences from not only conventional electromagnetic actuators but also from other emerging technologies like piezo electric crystals and shape memory alloys. The most significant advantage EPAM has over electromagnetic actuators is energy density, that is, more energy created for the mass of the actuator itself (Figure 1).

With regard to shape memory alloy and piezo electric technology, EPAM has a significant direct displacement

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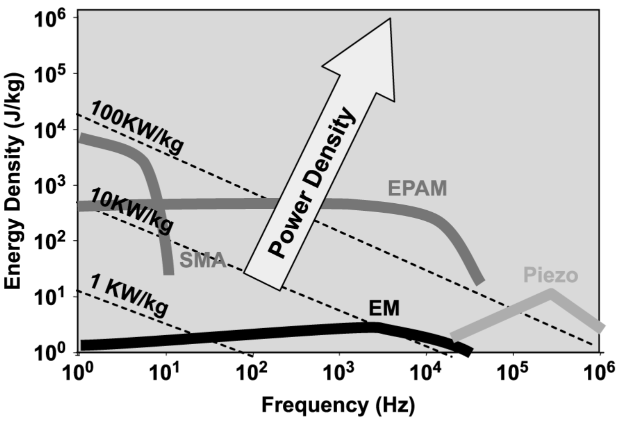
Figure 1 Actuators – energy density/frequency



Source: DARPA

advantage. While shape memory alloy and piezo electric technology might get an 1 per cent direct displacement, EPAM actuators can reach 20-30 per cent levels over long life cycles. With respect to conventional electromagnetic motors, EPAM has a significant advantage in power density. EPAM will provide the same level of power as an EM motor device but with a much smaller and lower weight form factor, much like the human muscle.

How does EPAM work?

The EPAM basic architecture is made up of a film of an elastomer dielectric material that is coated on both sides with another expandable film of a conducting electrode. When voltage is applied to the two electrodes a Maxwell pressure is created upon the dielectric layer. The elastic dielectric polymer acts as an incompressible fluid which means that as the electrode pressure causes the dielectric film to become thinner, it expands in the planar directions (Figure 2). Thusly, electrical force is converted to mechanical actuation and motion

As mentioned earlier, EPAM gets significant displacement from this electrostatic pressure as compared to other technologies but one can still "layer" EPAM to get additional displacement or stroke as well as getting higher exerted forces. These layers can be constructed in multiple planar configurations or in linear rolls. In addition, EPAM can be patterned to pinpoint actuation in multiple locations (Figure 3). This EPAM architecture along with configurations, applications, and fabrication processes was developed and patented by SRI International in Menlo Park, California, and then licensed exclusively to Artificial Muscle, Inc., an SRI spin-out company to commercialize. Today Artificial Muscle, Inc. is developing EPAM actuators under contract with OEM's as well as shipping development kits for evaluation and test.

Applications

The EPAM product road map clearly leads to programmable linear actuators, XY tables, assembly robots, and walking, running robots (Plate 1). The costs of EPAM actuators will be a fraction of that of electromagnetic solutions, will use less energy, and will be silent. Imagine an assembly robot that can easily be hand carried from one assembly station to another, or that can walk from one station to another based on a wireless command from factory control. The energy density gains from EPAM will bring mobility and flexibility to robots that combined with sensing and artificial intelligence developments will open up a huge range of industrial and service robot applications.

For a variety of economic and technical reasons, robotic applications are not the first stop in the Artificial Muscle, Inc. product roadmap. Several high volume commercial applications for EPAM that require high quality, high volume automated production are currently being funded and developed. All this commercial development will set the foundation for high performance EPAM-based robot actuator production. Sample development kit products are now being shipped in quantity with plans to be soon shipping high volume muscles specific to OEM partner specifications.

Among the early EPAM applications are valves, liquid pumps, small actuators, robotic grippers, and lens positioners (Plates 2-4). In the case of lens positioners, automatic focus

Figure 2 Electrical force is converted to mechanical actuation in the dielectric polymer

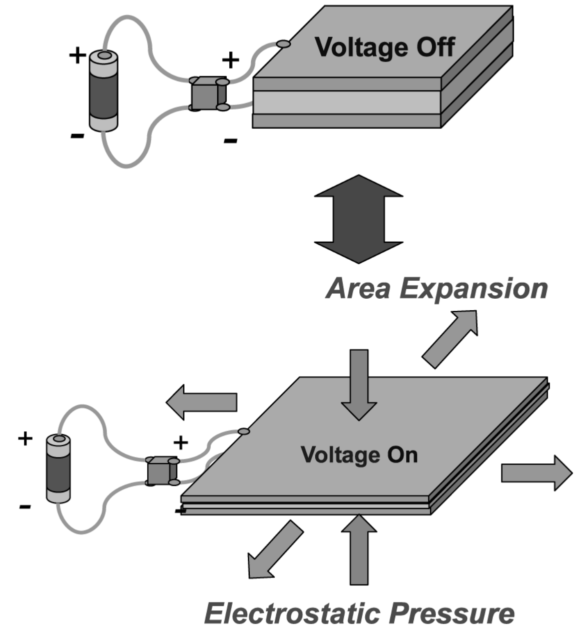


Figure 3 EPAM layers and patterns

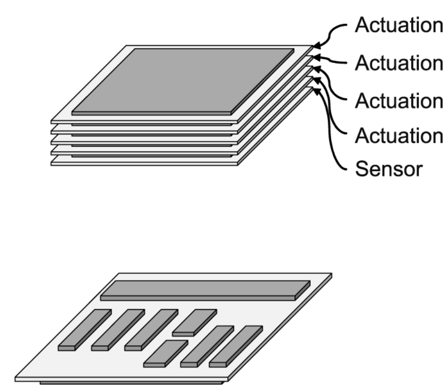


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Plate 1 Walking robot developed by SRI International

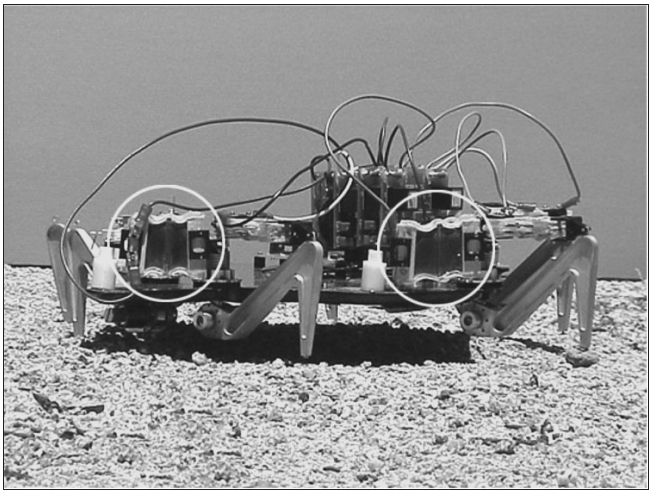
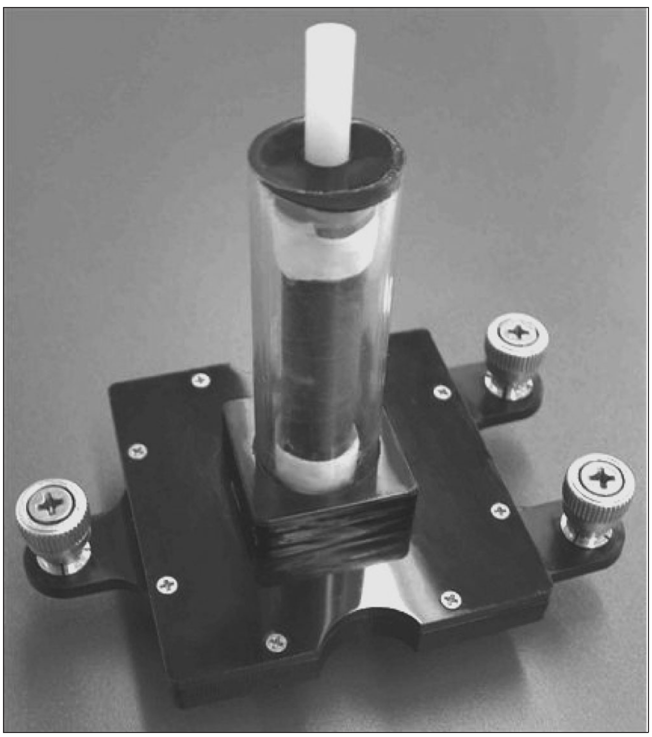


Plate 2 EPAM roll actuator



and/or zoom motion can be accomplished with silent EPAM actuators. The resolution of the actuator can be in the microns as actuator position is a function of voltage. In addition to actuation, EPAM can be used as a low cost, highly flexible sensing form factor. Since the muscle is in effect a capacitor, force and displacement sensing can be accomplished by measuring the change in capacitance or resistance of the EPAM material. EPAM can also be used for haptic feedback devices

Example of EPAM advantage over conventional electromagnetic solution

A good example of how EPAM can stack up against conventional technology is a hydraulic valve for a drive by

Plate 3 EPAM lens positioner

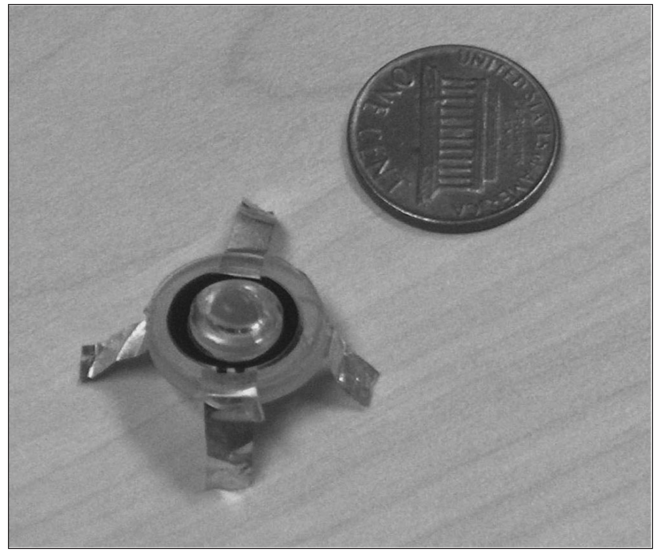
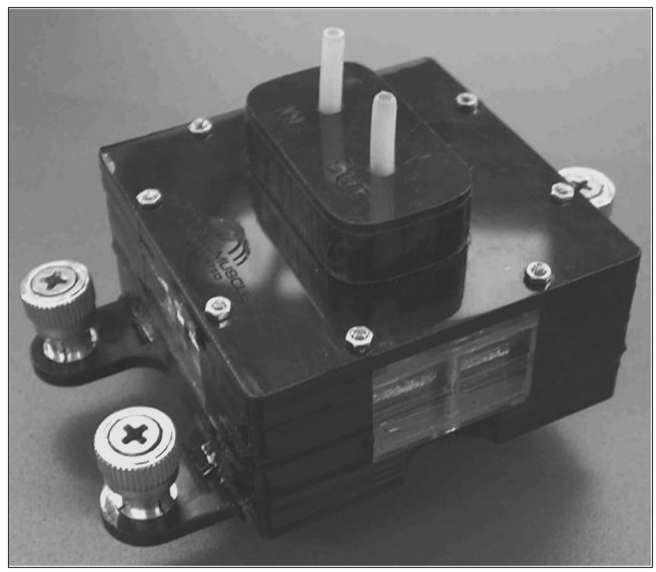


Plate 4 EPAM diaphragm pump



wire application for an off road vehicle. The conventional design for a control-by-wire hydraulic valve controller includes a motor, gearhead, belt drive and ball screw ... over 100 parts. The EPAM solution is a linear roll actuator which is an expanding/contracting cylinder that is controllable with a variable voltage input. It has significantly lower cost, is silent, and weighs than a tenth of the conventional electric motor actuator. This weight difference is a good example of how the advantage of EPAM power density plays out in a full motion solution.

The future

The applications for EPAM are endless. Virtually all existing electromagnetic actuators are targets for replacement with lighter, smaller, lower cost and more power efficient EPAM actuators. The initial applications at AMI are focused on the smaller, lower stroke and lower force applications than what will be needed for true humanoid robotic applications. But the product roadmap takes EPAM into high force, high

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displacement applications like linear modules and robotics. There might be a day when one drives a car with EPAM actuators for seat and mirror positioners, EPAM speakers, and an EPAM camless engine while getting a back massage from EPAM massaging pads. And all this in the car assembled by EPAM-based robots.

Sound far fetched? Most of today's actuators are based on electromagnetic technology that has had little change in 100 years. Piezo-electric and shape memory alloy have found niche applications. But EPAM's potential spans the broad range of almost all electromagnetic actuation. Perhaps after 100 years we will finally get a revolutionary change.