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The Brain Behind Plastic Muscle

NASA scientist Yoseph Bar-Cohen is a pioneer in the field of artificial musculature, in which energized plastic flexes like the real thing

BY ALEX SALKEVER

Yoseph Bar-Cohen is an atypical arm-wrestling aficionado. A senior research scientist at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, Calif., Bar-Cohen is a rotund, voluble fellow with crinkly eyes and an easy smile -- the stereotypical happy, slightly mad scientist. So it's no surprise that Bar-Cohen would rather spend his free time riding a bike or playing with his shih-tzu than going wrist-to-wrist with the sweating behemoths of the arm-wrestling world.

Yet the 50-something Bar-Cohen is the primary instigator of a much anticipated contest that one day will pit a human strongman against a simulated human arm -- one made of artificial muscles. That means no hydraulics, no gears, no levers -- only strands of material that can contract and expand, just like the muscles in the human body.

Bar-Cohen is the dean of artificial-muscle research, a little-known field that appears to be on the verge of great things. He issued his arm-wrestling challenge four years ago at a professional conference. Today, a team of researchers from SRI International in Menlo Park, Calif., claims it's ready to build such a machine as soon as it gets funding.

CONTRACTION ACTION. The artificial muscle will consist of extremely thin layers of common materials, such as silicone insulation, coated with tiny carbon tubes that transmit electricity. That explains the complex name of this most advanced branch of artificial-muscle research: electroactive polymer actuators (EAP).

These actuators consist of pliable pieces of plastic that flex or contract under the influence of electrical charges applied to one side of the plastic. The other side is electrically drawn to the opposing charge. That squeezes the plastic and causes the strand to flex or contract, producing an eerie resemblance to natural motion. Says Bar-Cohen: "Our muscles are driven electrically. The reason these systems are called artificial muscles is because they functionally resemble the real thing."

Bar-Cohen regularly chairs conferences on the topic and maintains a comprehensive Web site linking the several hundred EAP researchers around the world. Not that he's a scientific slouch himself. The long-time NASA scientist has his name on 15 patents and has published 233 papers while scooping up a raft of prestigious awards.

DEN MOTHER. He has built EAP systems for NASA to wipe the lenses of cameras on explorer robots, as well as claw-like mechanisms that can pick up rocks using groups of EAP filaments. His current role in the field is more like den mother: Bar-Cohen serves as adviser and mentor to numerous EAP researchers spanning the globe, from Tokyo to New Mexico.

As a graduate student in his native Israel, Bar-Cohen studied physics and material science before working in applied materials and physics for the Israeli aircraft industry. He went on to work as a researcher at the U.S. Air Force Materials Lab and aerospace company McDonnell-Douglas (now a Boeing (BA) subsidiary) before landing at JPL in 1991. A scientific chameleon, Bar-Cohen has done research into drills that use sound waves to burst blood clots, ways to evaluate aircraft for damage without opening them up, and new systems for obtaining geophysical data.

Bar-Cohen's vision for a world powered by artificial muscles took shape more than a decade ago, when scientists began to understand that even simple, nonmetallic materials could be caused to move under the right electrical-charge conditions. Unlike traditional actuators or motor-driven devices used to deliver physical force, electrically driven polymer actuators have no moving parts aside from the flexible strands. They apply power directly, with no intermediate steps. For these reasons, EAPs are much simpler and cheaper to make -- and also far less likely to fail.

LIGHT AND LIVELY. EAP actuators also have an energy efficiency (the percentage of molecular energy translated into physical energy) of 70% -- well above the efficiency of traditional electrical motors. And since plastic is on average one-quarter the density of metal, EAPs could be a big help in situations where weight counts for a lot, such as on space missions. Best of all, scientists have found that many common plastic adhesive substances make fabulous EAP mediums. "The key words are lightweight, low-power, low cost," says Bar-Cohen. "We can make polymers at a very low cost."

That could help not only NASA but lots of industries that rely on small electric motors to move levers and gears. Take the auto industry: "A typical car has between 50 and 100 actuators, whether they be little motors or solenoids. If they could be replaced by these artificial-muscle actuators that last longer and work more efficiently,

Continued on next page

From previous page

the savings could be big," explains Ron Pelrine, a top EAP researcher at SRI and the man who'll oversee the arm-wrestling machine. Pelrine says commercial applications for EAP in the automotive sector may be closer than most researchers imagine -- perhaps only a few years off.

EAP's more exotic uses could dramatically alter the field of robotics and human locomotion. Bar-Cohen says prosthetic legs for humans driven by EAP systems are an obvious possibility. Pelrine has eight-inch robots shaped like bugs walking around his laboratory that are so life-like he gets the urge to squish them, he says. Adds Bar-Cohen: "We are the changing the paradigm of making robots. I don't need gears. I don't need bearings. All I need is material that conducts electricity."

FISH AND CHIPS. The first commercial product using EAP hit the market in January, when Japan's Eamex began selling battery-powered plastic fish that swim around aquariums and look practically indistinguishable from the real thing.

Bar-Cohen notes that the first-ever convention of research scientists from companies interested in EAP was held last month in San Diego. He's entertaining an offer from the 2004 Olympic Summer Games in Athens to build a display of how EAP muscles work. And sometime in the next two years, he hopes to host that man-against-artificial-muscle arm-wrestling smackdown.

It's all evidence of the impact a muscular mind can have on a promising field.