

Design News

Fabrics Get Smart

Electro-active textiles serve as switches, sensors, and more

Joseph Ogando, Senior Editor -- Design News, May 14, 2006

If your idea of "smart fabrics" is a pair of khaki pants that sheds food stains, think again. The smartest fabrics are becoming electro-active, allowing them to address far more important engineering problems than whether you wear your lunch to an afternoon meeting. These textiles can help you build flexible sensing systems, detect chemicals, generate mobile power and perform other tasks. "More than 70 percent of the surfaces we interact with daily are textiles. Once those textiles can carry data and electrical power, it opens up a huge new world of applications," says Stacey Burr, president of Textronics Inc., a developer of smart fabric technology.

Rather than just a single material, electro-active smart fabrics encompass many combinations of textiles and electrically conductive materials. Though often based on elastomeric fibers, like Lycra, smart fabrics can be created from a wide variety of synthetic and even natural fibers. Various knit, woven and non-woven fabrics can all be made smart too. As for the electrical properties, smart fabrics most commonly contain fine metal wires, either in the yarn used to make the fabric or woven into the fabric alongside ordinary textile fibers. Other smart fabrics get their electrical properties from inherently conductive polymers or nanocomposites deposited as coatings on the fabric's fibers.

All of these electro-active smart fabrics have a way to go before they become commonplace engineering materials. Some of the textiles, particularly those that rely on nanotechnology, are available only in quantities suitable for development work. Others, while fully commercial, may not have enough of a track record to alleviate the kinds of technical concerns that design engineers bring up within minutes of evaluating a technology. "Smart fabrics are still something of a black art," says Maggie Orth, president and founder of International Fashion Machines, a developer of smart fabric products.

Smart-fabric suppliers, for example, all make compelling arguments for the use of their technologies in various sensing systems. But only one company, Nanosonics Inc., would provide technical data related to sensor performance — in this case, strain range, linearity and hysteresis.

This lack of basic engineering information may limit the use of smart fabrics somewhat. Spyros Photopoulos, an analyst who studies smart fabric market for Venture Development Corporation (VDC), recently surveyed OEMs regarding their plans for using smart fabrics and found that many expressed doubts about the durability and performance of smart fabrics. "Price is also a big

issue," he says. "Many OEMs wouldn't consider smart fabric technology without strong consumer demand."

Smart fabrics may also suffer from a disconnect within the design community. As Burr notes, "electrical engineers and textile designers don't speak the same language." And bringing these two groups together goes beyond semantics. Engineers need to know how to physically integrate fabrics with traditional rigid electronics, which requires new approaches to interface and interconnect designs (see sidebar on page 82).

SWITCHES AND CONTROLS

The smart fabric applications that have currently moved along the furthest in a commercial sense have involved switches and controls for consumer electronics. The leader in this field, Eleksen Ltd., has supplied touch-sensitive fabric controls for products ranging from electronics cases to ski jackets with integrated, machine-washable controls for audio players. The company also developed portable wireless fabric keyboards that you can roll, fold or even crumple.

Eleksen makes these fabric controls from a multilayered fabric containing three electro-active layers. Two outer conductive layers surround an inner resistive layer that separates the conductive layers until someone presses them together. As Andrew Newman, one of the technology's developers, explains, "the fabric is basically an open circuit until someone presses the fabric." Eleksen then measures the voltage drop at various points on the surfaces to determine where and how hard someone presses the fabric. "We measure the interaction in the x, y and z directions," says Newman, who adds that the z-axis measurement gives a relative, rather than an absolute, pressure reading.

The company can supply a variety of configurations, including single switches or arrays of switches on a given fabric surface. The company's keyboards, for example, take the latter approach. Newman notes that Eleksen's fabric, which it calls Elek Tex, and the related electronics, output an analog signal. So the same technology can also be used for sliding control buttons, such as those used for volume or scrolling on a computer display.

While current Elek Tex applications have focused squarely on consumer electronics, Newman sees some potential for a variety of human-machine interface applications. In automotive interiors and appliances, the technology could be used for software-configurable control panels that can cover even deeply curved surfaces. In one of the only real indications of smart fabric durability, Eleksen has carried out extensive mechanical testing of its products, including subjecting them to 10 million press cycles and hysteresis tests after 30,000 roll-ups and folding cycles. "That's far in excess of what they would see in real life," says Newman. (see <http://rbi.ims.ca/4922-562> for the company's reference designs).

Another switch application comes from International Fashion Machines. Orth has re-imagined the ordinary household light switch as a capacitive touch sensor in the shape of a pom-pom. At first glance, pom-pom switches may seem too frivolous for *Design News*' practical readers. But consider this: Orth gets \$129 for her light switch, which has appeared in museum shows, compared to about two bucks for the ugly plastic commodity versions down at the hardware

store. "Smart fabrics allowed me to create a premium product," she says. She's also managed to get UL approval for her switch, no easy task.

SENSE STRAIN AND MORE

For engineers, one of the biggest technical potentials for smart fabrics relates to their ability to sense strain and serve as the basis for pressure monitoring systems. Both broad types of smart fabric — those based metal wires and those based on inherently conductive polymers or nanocomposites — can perform some sensing. Whatever the type of fabric, they tend to operate on the fabric equivalent of the piezoresistive principle. With fabrics based on metal wires, such as those offered by Textronics, the movement of the fabric itself brings conductive metal fibers closer together or further apart, altering the resistance of the fabric. Something similar happens with fibers infused with ICP or nanocomposites, in that strain changes the electron transport between conductive clusters on the fabric fiber. With some signal processing, these resistance changes can be translated into pressure measurements. "In theory, you can turn all kinds of resistive materials into strain sensors," says Orth.

Two of the newest ways to create fabric sensors rely on nanotechnology to make polymer fabric fibers conductive to varying degrees. Nanosonic Inc. recently developed smart fabrics based on an electrostatic self-assembly process (see <http://rbi.ims.ca/4922-563>). Initially developed to make free-standing elastomeric sensor films, the self-assembly process can infuse the surface of textile fibers with various nanocomposites — combinations of polymers and metals or metal oxides. Fabrics made from these fibers have high conductivity, with bulk resistivity values down to 10^{-5} ohm cm, according to Andrea Hill, the Nanosonics researcher who helped develop the conductive fabrics.

At the same time, they also can tolerate extreme elongations. Rick Claus, Nanosonics president and founder, notes that the original sensor films, called Metal Rubber, can measure strains up to 1,000 percent with full scale linearity of 1 percent. At lower strains, they can tolerate thousands of flex cycles and exhibit low mechanical hysteresis, he adds. The brand new fabric versions, dubbed Metal Rubber Textiles, can tolerate similarly large strains.

Another twist on inherently conducting fibers comes from Eeonyx. The company has a proprietary process for coating textiles with inherently conductive polymers based on doped polypyrrole. The company polymerizes the materials in situ — or on the surface of the fabric itself — so that the coating material fills interstices in the surface and forms a physical bond with the fibers. Jamshid Avloni, the company's president, reports that the ICP doesn't offer conductivity near the level offered by metal wires. But, then again, it doesn't have to.

"There are orders of magnitude of difference between the conductivity of, say, polyester and copper," says Avloni. "We occupy a middle ground." The company can deliver fabrics, for example, with surface resistivities ranging from 10 to 10^6 ohm/sq, controllable to within 10 percent. Avloni says the textiles have seen some use in piezoresistive pressure sensing applications, including a dynamic pressure sensor for biomedical applications and the design of custom footwear.

Neither the Nanosonic nor the Eeonyx technology changes the fabric properties much, if at all. "You still get the drape and feel of a fabric," Avloni says of Eeontex. The conductive treatments can also be translucent enough to avoid much of a visual impact — though some versions of the Eeonyx coating formulations are black.

The two nanotech approaches have a downside too. Metal Rubber Textiles and Eeontex are currently available in quantities that many large OEMs would consider developmental. What's more, Eeontex has issues with long-term stability owing to the hydrolysis of polypyrrole when exposed to elevated temperatures and humid conditions. The company recently developed a third-generation product that improves stability by a factor of 20, according to Avloni. And the fabrics can be protected with a laminate. But environmental conditions still represent the chief failure mode for the ICP and need to be accounted for by design engineers, he acknowledges. "Metal wires have their problems too," he adds. "If you bend them enough, they'll break."

In many sensing applications, smart fabrics won't likely represent a low-cost alternative to an array of pressure transducers. Yet even if they aren't cheapest way to sense pressure, fabric sensors can potentially offer value by brining more freedom to the design of sensing systems. Fabrics can covering very large areas, including civil structures. They can conform to a wide variety of surfaces, including the human body while it's moving. And they may be able to measure very large strains. Textronic's Burr notes that elastomeric smart fabrics tolerate repeated elongations up to a few hundred percent.

These fabric attributes may result in other types of unique sensors in the future. Textronics, for example, is working on electro-optical movement sensors for medical monitoring applications. As Burr explains, these sensors integrate a light source and photodetector into the fabric. As the fabric stretches and returns to its initial shape, different amounts of light would pass through the fabric's woven or knit structure. Burr says one application for such an optical sensor would be a garment that monitors a patient's breathing. Textronics also recently introduced a biomonitoring product for the consumer market.

She also sees the potential for both optical and strain-based measurements of movement and vibration. And Nanosonic's Claus reveals that the company has come up with a proprietary chemical sensors based on smart fabrics. He's not ready to publicly disclose much about it, other than to say that it works based on electro-chemical reactions of a nanoclusters on the fabric surface.

Smart Fabric Sources and Applications

Supplier	Technology	Uses
Eeonyx (http://rbi.ims.ca/4922-556)	Inherently conductive polymer coatings for fabrics offers surface resistivities between 10 and 106 ohm/sq.	<ul style="list-style-type: none"> • Pressure Sensor • Motion sensors • Vibration sensor • Switches
Eleksen Ltd. (http://rbi.ims.ca/4922-557)	Pressure sensitive textiles and related control electronics.	<ul style="list-style-type: none"> • Radiation Sensors • Artificial horizon
International Fashion Machines	Proprietary capacitive textile switches. Also consults on	<ul style="list-style-type: none"> • Radar absorbing composites

<http://rbi.ims.ca/4922-558>

Nanosonic Inc.

<http://rbi.ims.ca/4922-559>

product development using many other types of smart fabrics. Electro-static self assembly process builds conductive layers on fabrics. Bulk resistivity values to 10^{-5} ohm cm.

- Textile antenna systems
- Ground penetrating radars
- Static control garments and laminates
- Radar shielding curtains and camouflage netting
- Aircraft edge cards and R-cards
- Resistive heating
- Warming textiles
- Elastic interconnects
- Wiring harness structures
- Signal and power pathways
- Inductance change materials
- Industrial warming wraps
- EMI shielding

Textronics

<http://rbi.ims.ca/4922-560>

Offers textiles that incorporate a variety of metal wires and inherently conductive polymers.

- Mobile power generation
- Large surface area photovoltaics
- Photo detectors

Konarka

<http://rbi.ims.ca/4922-561>

Nanotech coatings turn fabric and thin films substrates to act as photovoltaic cells.