Building the eco-system of Canada's printable, flexible and wearable electronics industry

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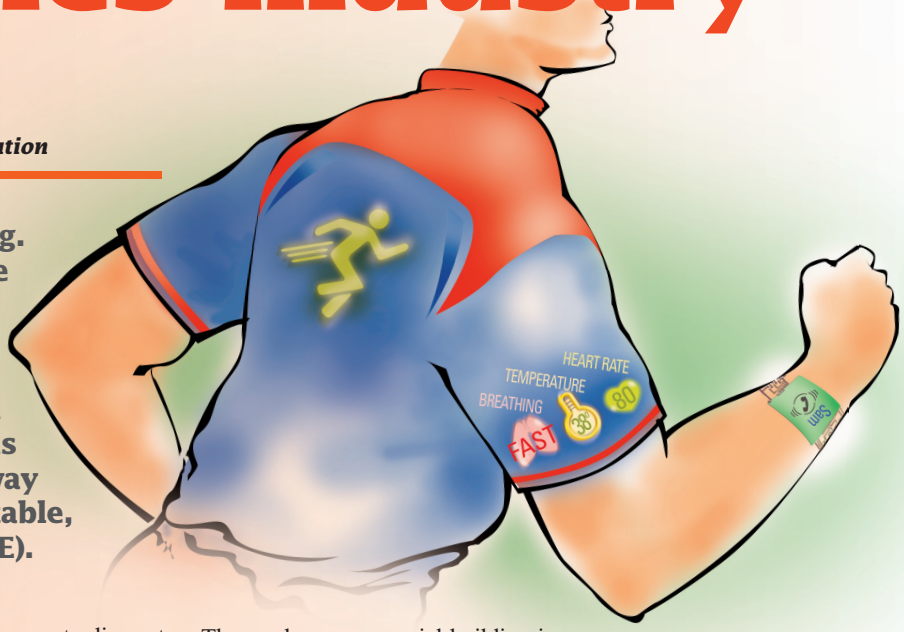

Flexible displays and lighting. Smart packaging. Wearable technology. Intelligent buildings capable of low-cost energy harvesting with organic photovoltaics. These are only a few examples of the applications taking hold today that in some way require or can benefit from printable, flexible and wearable electronics (PE).

What is PE?

Printable Electronics transfer conductive inks onto a substrate at high enough density to form a complete electronic circuit, but thin enough to have negligible impact on the substrate thickness. The substrate can be rigid, flexible or even stretchable, for instance: paper, plastic, fabric or glass. Inks can be made from materials such as graphite, silver or copper.

These inks can be applied through traditional printing processes such as flexo, screen, inkjet, gravure, and offset, as well as through coatings. This can be done through fast and inexpensive automated processes, such as those used in the commercial printing industry for newspapers and magazines. These electronic components can also be embedded through additive manufacturing processes, such as 3D printing or in-mould electronics. A related field involves conductive yarns that can be used to create smart garments.

PE can be used to create discreet components such as displays, conductors, transistors, sensors, light emitting diodes, photovoltaic energy capture cells, memory, logic processing, system clocks, antennas, batteries, and low-voltage electronic interconnects. These can be integrated into simple systems that, for example, can record, store, and then transmit temperature information. Fully functional electronic systems can be created in this way, or discreet components and sub-systems can be produced to function as part of a hybrid solution with conventional silicon-based integrated circuits or components.

Creating more intelligent buildings and connected homes

PE can redefine and enhance many of the conventional systems that are allowing intelligent homes and connected buildings to achieve new levels of energy efficiency, automation and occupant comfort.

The modern commercial building is morphing into an intelligent building at a rapid pace. Sensors, analytics, and controls using conventional electronics are already mainstream to improve efficiency, services, occupant comfort and safety. PE's advantages over conventional electronics in terms of form factor, flexibility and cost are driving research and commercial development into new applications for lighting, HVAC, fire, access and safety systems (see *The Office Remade* on page following). The same technology drive is happening in the connected home.

Both ends of the real estate market are looking at PE-related areas such as organic LED lighting and organic photovoltaics for low-cost energy harvesting (see sidebars on page 30).

Smarter parts for transportation and industrial applications

PE is ideal for additive manufacturing processes like 3D printing and in-mould electronics, to embed functionality inside a part or assembly. This reduces the bulk and expense of external hard wiring to connect electronic systems and assemblies.

By the same token, intelligence can be added to a part with low-cost printed electronic tags, labels and serialized sensor matrices. These are digital fingerprints that can be used to identify and authenticate a part.

But the practical uses go beyond these passive applications. With PE tags and sensors, parts and assemblies can collect and transmit data on their use and usage conditions, heat, humidity, stress and so forth. All this data can be collected and stored in the cloud, for remote monitoring and predictive analytics to carry out preventative maintenance and repair.

Wearables, including smart garments for health and wellness

Wearable technology has gone mainstream in a few short years. Many of us are taking advantage of devices worn on our person to enhance our athletic performance, monitor health and fitness indicators such as heart rate and breathing, and ensure the well-being and safety of the elderly. Wearable devices already on the market include bracelets, watches and necklaces, as well as athletic wear such as sports bras and shirts. We even have smart temperature stickers that monitor a child's vital signs during sleep.

The discrete form factors, flexibility and cost advantages of PE versus conventional electronics are crucial to make these devices and applications more practical and affordable. Another rapidly growing application area is smart garments and textiles.

Take, for example, Vagalume—a kind of electroluminescent technology that's incorporated into athletic apparel for greater visibility and safety at night. Unlike other electroluminescents, it is paper-thin, flexible, fully

The office remade

The conventional intelligent office

A typical office space has both ambient lighting and task lighting that can be adjusted to meet specific needs. The office also includes a light sensor that reduces the intensity of artificial light in response to natural light, an occupancy sensor that shuts the lights off when no one is present, and a thermostat.

In addition, there is a smoke/fire detector and an alarm annunciator to provide indication of a fire. Traditionally, each of these is a discrete component, hard-wired to a controller that provides localized control, as well as to a building-wide system for global control (for example, to set minimum and maximum allowable temperatures, to turn off the lights at night, and for the safety and security system).

All this requires a relatively large amount of labour to install, wire and commission all the separate components.

That office remade with PE

Ambient lighting is replaced with a thin sheet of light (using either organic LEDs or an array of inorganic LEDs). The substrate containing the light-emitting layer also includes a daylight sensor, a printed occupancy sensor, and a printed temperature sensor.

Local controls for providing daylight harvesting and occupancy control are printed on the substrate. This simplifies installation and wiring, and greatly reduces the local control burden on the central control system.

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Printed temperature sensors are tied into the heating, ventilation and cooling system and can also provide information to the safety system. The lighting is tied into the safety system and is programmed to change colour and provide directional exit information in case of fire.

Because functional electronics for these applications are printed, installation is simplified and costs are reduced. A further advantage is that the printed components are much thinner than conventional components. This allows for more usable space to be created within the building.

How close to market is an integrated system such as this today? Flexible sheet lighting technology is already on the market. The sensors and other discreet PE components are in various phases of development with one-to-five-year time horizons. ■

More than 250 organizations in Canada are involved in the printable electronics supply chain. Below are some examples.

END USERS	SMART PACKAGING	LIGHTING	WEARABLES	MANU-FACTURING	SWITCHES	SENSORS	R&D	EQUIPMENT	INKS, PASTES	SUB-STRATES	TESTING, QUALI-FICATION
Molson Coors Unilever Bank of Canada	Jones Netpak TUKU	Myant Cooledge	Myant OM Signal	CGI Memtronik ICI Canadian Bank Note	Memtronik CGI ClickTouch	Myant Memtronik Tangio	3M, NRC, INO CRC, UWaterloo UBC, UCalgary UQAM, McGill ULaval	NovaCentrix Fujifilm, Xenon MGI Ceradrop Optomec Nano Dimensions	Du Pont NovaCentrix Xerox	Du Pont 3M Corning	CSA NRC

machine washable, and emits its own light using flexible electronic components.

Vagalume, which means "firefly" in Portuguese, is the creation of CPEIA Member company Myant & Co. Myant made waves last year at the Canadian Printable Electronics Symposium (CPES) when it took home the Product Innovation Award.

Other innovators have brought to market smart garments for health and wellness that use embedded biometric sensors wirelessly connected to a software platform. The benefit for users is that they can track and enhance their athletic performance. CPEIA Member OMSignal is one such company. It's known for the OMbra sports bra, as well as Ralph Lauren's PoloTech collection—smart shirts that can track vitals like heart rate and breathing.

The opportunity for Canada

Global revenues for products using PE in 2016 is estimated at US$ 26.9 billion, an annual increase of 31.8 per cent since 2010. Consulting firm Smithers Apex expects the market to grow to an estimated US$ 43 billion by 2020.

A separate forecast from market research firm IDTechEx predicts a US$ 70-billion market by 2024, for applications ranging from organic LEDs (OLEDs) to conductive inks for a variety of applications.

Canada's PE sector has the expertise, innovation and opportunity to revolutionize the electronics industry, for substantial socio-economic benefits across Canada and abroad. More than 250 domestic organizations that we know of are active in the space. Researchers at academic and government labs across the country are busy with the fundamental and applied research that supports innovation by industry in a number of key areas.

And yet, significant challenges remain to get PE technology to market.

What is an organic LED?

An organic light-emitting diode (OLED) is an LED in which the emissive electroluminescent layer is a film of organic compound that emits light in response to an electric current. Conventional inorganic LEDs are point sources while OLEDs naturally emit light over large areas as sheets or panels. At present, LEDs have higher efficacy, lower cost and a longer lifetime. But OLED performance continues to increase. OLEDs can produce comfortable, uniform, non-glare light in a very thin and potentially flexible form factor.

The scale-up challenges of an emerging market

Last November, we convened in Toronto our first Sector Leadership Council to take the pulse of this industry in Canada through the eyes of our diverse membership—startups, young SMEs, established mid-sized companies and multinationals with Canadian operations, as well as government organizations that support innovation and commercialization.

According to our members, significant challenges remain in scaling up the sector in Canada. This is still an emerging industry, fragmented and dominated by a roster of startups and earlier stage companies in need of help to bring compelling products to market. There are currently no geographically concentrated technology clusters, government-funded centres of excellence for industry or dedicated incubators/accelerators.

The core group of larger Canadian and global companies that can help early-stage companies overcome their R&D and scalability hurdles face their own challenges to remain competitive. They are working to understand how they can incorporate the advanced features supported by PE into their products.

The Council identified four key challenges for the growth and development of this emerging sector in Canada that impact in various ways upon startups, young SMEs, established mid-sized companies and multinationals with Canadian operations:

The Market Challenge: Defining applications and products with large and profitable markets in partnership with world-class end users. Critical in this is accessing such end users globally and getting them to work with Canadian companies.

The New Product Development Challenge: Prototype development towards commercialization with lead end users/customers for trials and early adoption. Critical in this is conducting trials of new technologies at sufficient scale to prove the business case for profitable commercial adoption. Depending on the application, it can be quite difficult to get the unit cost low enough for prototype production, in order for trials to be economically feasible. End users can face challenges in getting the product to market, e.g., in the case of retail, procuring shelf space.

The Manufacturing Challenge: Resources for SMEs to invest in their own facilities before the market and business case have been proven for manufacturing scale up. Critical in this is creating and accessing sufficient scale-up manufacturing resources, including equipment, skilled people and production lines.

What are organic photovoltaics (OPV)?

The OPV group refers to organic solar cells or plastic solar cells that use organic electronics—a branch of electronics that deals with conductive organic polymers or small organic molecules—for light absorption and charge transport to produce electricity using the same photovoltaic effect used by conventional solar cells. Although OPV solar cells aren't as efficient as their inorganic counterparts, they have advantages in terms of flexibility, weight, ruggedness and cost. They can be more readily embedded in other materials, such as window blinds, roofing and plastics.

Who do we mean by end users for PE?

Two examples are Unilever and Molson Coors. These global consumer brands want to better engage with consumers and protect their products from tampering and counterfeiting by embedding intelligent functionality into packaging and retail displays.

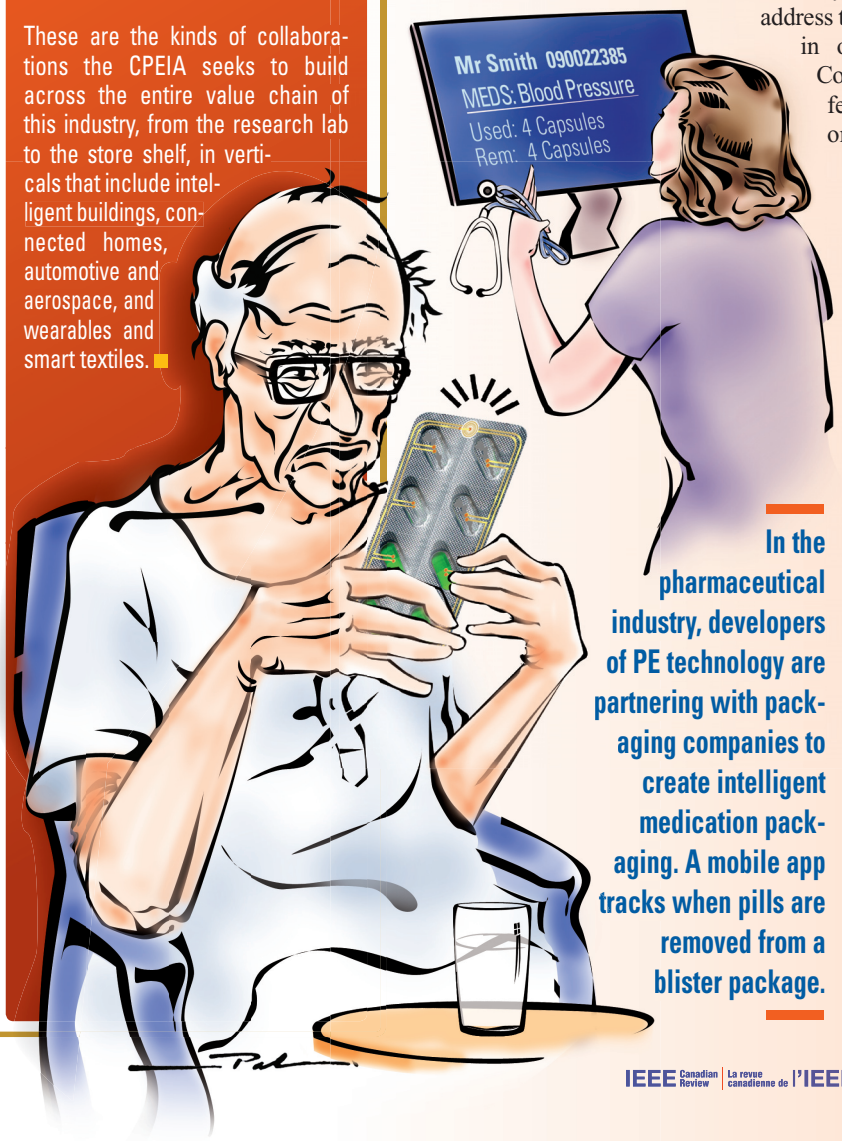
In the pharmaceutical industry, developers of PE technology are partnering with packaging companies to create intelligent medication packaging and market this solution to pharmaceutical companies—the end users. The goal again is brand protection and consumer engagement, along with the means to ensure safe and appropriate medication usage. A mobile app tracks when each pill is removed from a common blister package.

These are the kinds of collaborations the CPEIA seeks to build across the entire value chain of this industry, from the research lab to the store shelf, in verticals that include intelligent buildings, connected homes, automotive and aerospace, and wearables and smart textiles. ■

The Financing Challenge for Scale Up: Access to capital for startups and SMEs at various stages of growth. Critical in this is lack of access to traditional VC funding for materials, electronics or new emerging cross-sector ventures. Printable electronics is largely an unknown commodity for tech investors. Many of the application areas fall into the hardware segment, which overall are a harder sell to investors than a software product.

Why we convene CPES

Held this year May 24-26, CPES is Canada's sole conference and trade show exhibition dedicated to printable, flexible and wearable electronics. It arose from an annual conference held by the National Research Council of Canada, which has its own flagship research program in PE.



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By working together across the entire eco-system, we can build a robust PE sector befitting Canada's track record for innovation.

Our objective with CPES is to serve as Canada's common meeting ground for technology developers, industrial companies and end-users to meet and discuss how they can work together to commercialize new products and applications for PE. Academic researchers can showcase their research and discover how they can link it to market needs and opportunities.

New this year, we have added a third day of programming to help address the challenges identified in our Sector Leadership Council last November. It features Master Classes on various technical subjects, a Financing Panel to help companies engage with private and government funding sources, and Mentoring Sessions for startups, where they can tap into the support they need to rise to the next level.

CPES, along with the workshops and webinars the CPEIA develops throughout the rest of the year with its strategic partners, rests on the principle that a rising tide floats all ships. Only by working together across the entire eco-system, from the R&D lab to the end-use product, can we build a robust PE sector befitting Canada's track record for innovation. ■

FOR IEEE MEMBERS

As an IEEE member, you are invited to attend CPES2017 at 15 per cent off the standard rate. Please use the discount code: cpeia-partner2017b. Visit **www.cpes2017.ca** to learn more about the conference and to register.

Please note this offer cannot be combined with the CPES2017 student rate. It only applies to Day 1 and Day 2 of the conference. If you wish to attend the Master Classes or Mentoring & Financing Sessions on Day 3, you must pay the regular fee for those activities.

Learn more about PE with our white papers, which can be downloaded for free by IEEE members. Please visit **http://cpeia-acei.ca/cpeia-whitepaper-series/** and use the code ieee!@$2016

CPES 2017
PRINTABLE FLEXIBLE WEARABLE ELECTRONICS SYMPOSIUM

About the Author

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Peter is a senior high-tech management consultant who has worked extensively for leading companies, research organizations and growth-stage companies in the National Capital Region. He has consulted with more than 100 companies and government organizations, and served on various boards and committees.

Peter has been involved with the creation and growth of many startup and growth-phase technology companies. Most recently as VP of Strategic Analysis & Global Marketing, he helped a TSX-listed global communications company grow from $3.2 million to $100+ million in revenues. For the three years prior to the founding of the CPEIA, Peter played an integral role in the National Research Council's efforts to prove the value of the PE opportunity for Canada and to create the PE Consortium.