INNOVATIVE *with*

THE MAGAZINE WITH THE IDEAS OF THE FUTURE #01

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SPOTLIGHT

ELECTROACTIVE POLYMERS: A NEW ERA OF ELECTRONICS

Interview with Fabrice Dominique Dos Santos, Head of Development for the Piezotech® range at Arkema.

ARKEMA
INNOVATIVE CHEMISTRY

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GLOSSARY: Find explanations of some of the technical terms used in our articles (underlined) at the back of the magazine.

WORKSHOP 4.20 *by Arkema*

+ Take four minutes to understand how electroactive polymers work with our scientific guide

Editorial

You're looking at the very first issue of *Innovative with!* This new magazine showcases Arkema's incredible ability to innovate in partnership with leading experts in a number of fields, against the backdrop of growing demand for both sustainability and performance. In this issue, we take a closer look at electroactive fluoropolymers. Developed by our Advanced Materials business segment, they are used in organic and printed electronic systems. Find out how they pave the way for high-tech solutions for tomorrow's retail and industrial applications, thanks to their special qualities. Electroactive fluoropolymers are set to revolutionize our daily lives and bring about major progress in electronics, medicine, and the automotive industry. As a leader in specialty materials, Arkema operates at the heart of an international ecosystem that is focused on bringing this promising market to fruition. In *Innovative with,* we talk to people in industry and startups, as well as academics and researchers, about their innovations and the ways in which we are working together towards success.

WE HOPE YOU ENJOY IT!

CHRISTIAN COLLETTE
R&D Vice President, Arkema

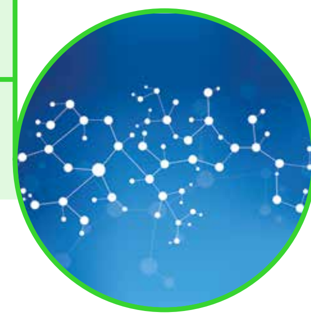
ELECTROACTIVE POLYMERS: Smart Materials

With its Piezotech® range, Arkema designs, produces and markets unique electroactive fluoropolymers. But what exactly are they, and what opportunities do their amazing properties open up? From materials science to real-world applications, we lead you through five steps to understand the potential of this promising field of research.

FROM THE FLUORINE ATOM...

1 SYNTHESIS

FLUORINATED MONOMERS



↑ Small reactive polar molecules, the basic unit of polymers.

2 POLYMERIZATION

ELECTROACTIVE FLUOROPOLYMERS

↑ A range of electroactive polymers that can, depending on their structure, convert electrical energy into mechanical or thermal energy and vice-versa.

3 FORMULATION

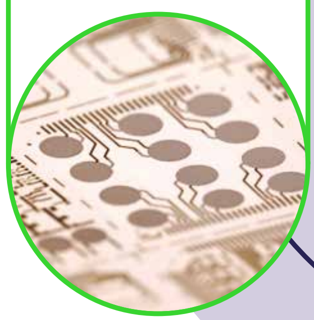
INKS, THIN FILMS, POWDERS

↑ Arkema's products incorporate electroactive fluoropolymers and are used to make electronic systems for its customers.

4 PRINTING

ORGANIC AND/OR PRINTED ELECTRONIC COMPONENTS

These use electroactive materials to function: pressure and thermal sensors, haptic and microfluidic actuators, flexible transistors, printed speakers, energy recovery systems, and more.



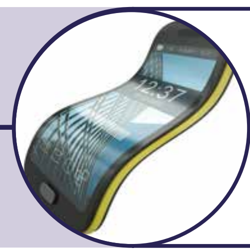
5 INTEGRATION

BUSINESS OUTLETS FOR THESE HIGH-TECH SYSTEMS

Health, electronics and smart devices, cars, housing and home automation, security, wearables, leisure, product traceability in the logistics chain, and more.

PROFESSIONAL APPLICATIONS

Smart labels and packaging, police border controls, medical imaging, catheters and surgical guides, road surfacing, organic photovoltaics, etc.



RETAIL APPLICATIONS

Smartphone screens, car dashboards and seats, virtual reality gloves, smart textiles and footwear, health tracking bracelets, video game controls, flexible screens and OLED* televisions, smart pill dispensers.

...TO NEW INVENTIONS

— Designed and manufactured by Arkema
— Designed and manufactured by partners of Arkema

GLOSSARY SEE P.20
Haptic and microfluidic actuators, pressure and thermal sensors, wearables, etc.
Go to the back of the magazine for explanations.

*Organic Light-Emitting Diode

SPOTLIGHT

A NEW ERA OF *electronics*

Fabrice Domingues Dos Santos,
Head of Development for the Piezotech® range

INTERVIEW WITH...
FABRICE DOMINGUES DOS SANTOS

As the world leader in fluoropolymers, Arkema believes in the development potential of applications that use electroactive polymers. Fabrice Domingues Dos Santos, Head of Development for the Piezotech® range, fills us in.

"Electroactive polymers are fine, lightweight and flexible, and can be integrated using simple procedures. They cost very little in terms of energy and offer infinite opportunities."

Is there a market for electroactive materials?

Fabrice Domingues Dos Santos – Definitely! Electroactive materials, particularly piezoelectric ceramic materials, are all around us. Known since the late 19th century (see frieze below), they are used in watches and lighters, cars, printers (injectors), smartphones (sensors, accelerometers), hospital equipment such as ultrasound scanners, and ship navigation systems (sonars, etc.).

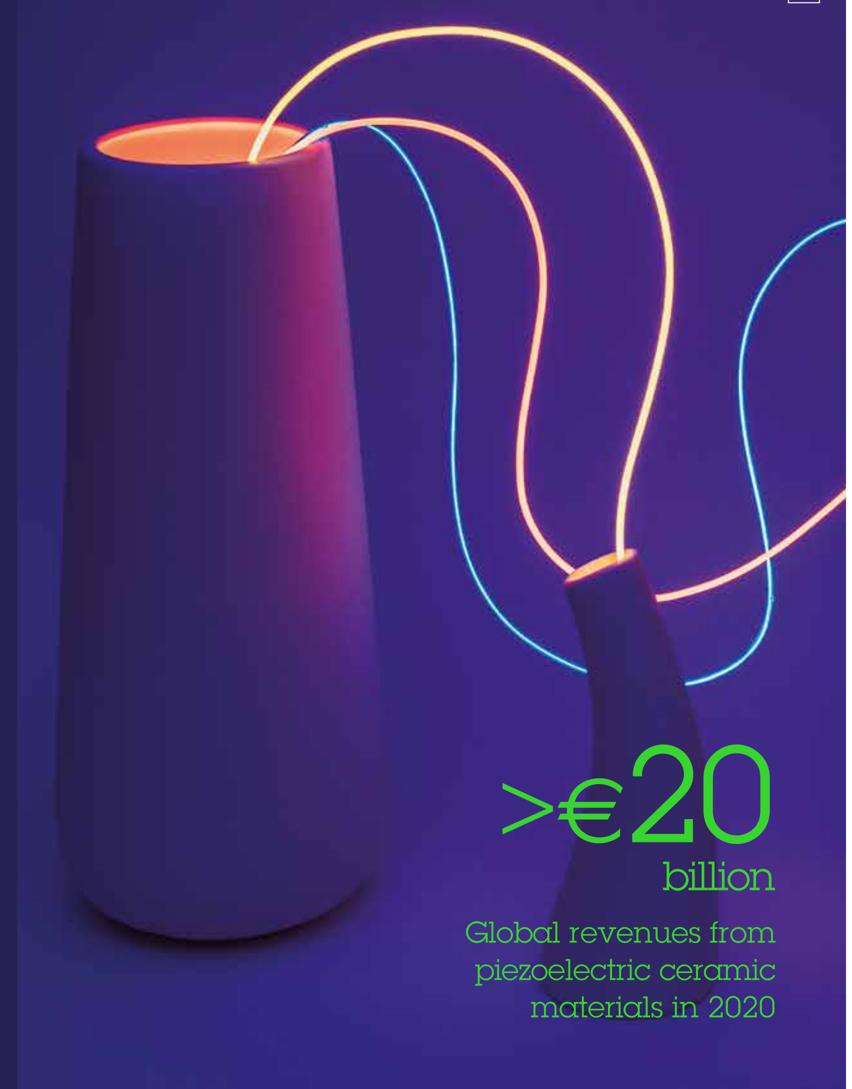
What makes electroactive polymers particularly useful?

F. D. D. S. – Piezoelectric ceramics are hard, sometimes toxic, materials that take a lot of energy to produce, and can only be used for small applications. Printable electroactive polymers can be used to make thin, flexible, lightweight objects with large surface areas, which can be recycled using environmentally friendly methods. Arkema supplies them to its clients in the form of powders, thin films and inks, which they use to make their products.

What do these products look like?

F. D. D. S. – They are electronic devices such as sensors, actuators and transistors that turn surfaces, objects and buildings into smart systems. For example, Arkema sells electroactive polymers to Novasentis, which uses them to make its actuators. These electronic parts communicate information to the user via touch. Next, a video

>>>



>€20 billion

Global revenues from piezoelectric ceramic materials in 2020

ELECTROACTIVE MATERIALS: FRENCH ORIGINS

1880
Piezoelectricity was discovered on Rochelle salt crystals by the brothers Pierre and Jacques Curie

1915-1918
The forerunner of sonar was developed by French physician Paul Langevin using piezoelectric transducers

1939-1945
Final developments in active sonar, which was used during World War II

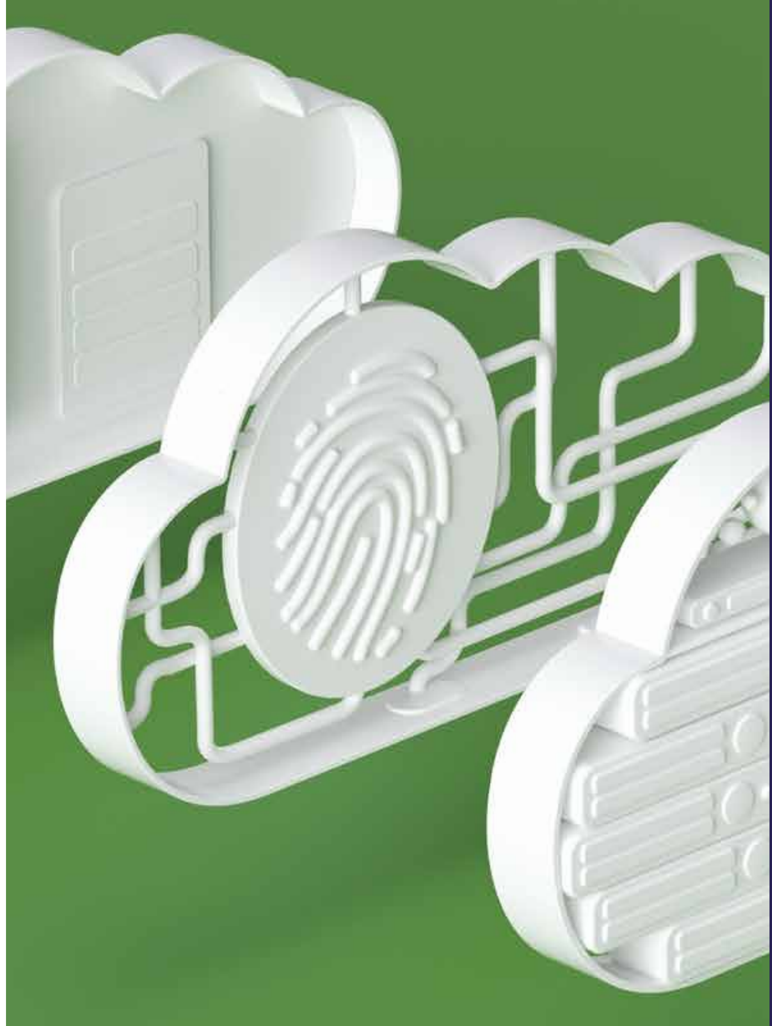
1949
The chemist Aharon Katchalsky discovered piezoelectricity in natural polymers (cellulose, collagen)

1969
In Japan, Professor Kawai demonstrated that fluoropolymers – PVDF in particular – could have electroactive properties (piezoelectric and pyroelectric) in certain conditions

1977
The Japanese chemist Hideki Shirakawa discovered the first conductive polymers

1980s
Development of a number of polymers with conductive or piezoelectric properties

2000s
Development of relaxor ferroelectric fluoropolymers



game manufacturer buys these actuators from Novasentis to make its video game joysticks. This improves the sensory realism in the game for the player.

Can you give other examples of mass market applications?

F. D. D. S. – The only limit is our imagination. We have already had successes in smartphones, musical instruments and defense. In the automotive industry, for example, we're working on integrating sensors and actuators into the surfaces of dashboards. In homes, we are developing smart flooring and beds that can detect things such as movement, heart rate or a person falling. Then there are smart fabrics that measure and transmit biomedical information about the wearer. Also in the health sector, we have catheters and surgical guides where we can adjust their direction to the nearest tenth of a millimeter, as well as health tracking bracelets, etc. Electroactive polymers will also be found in virtual reality applications that are set to be developed in many fields.

What is innovative about these examples? Did they not exist already?

F. D. D. S. – By playing around with their chemical composition, we can offer materials with a wide and unique range of properties, from extreme sensitivity to deformation, vibrations and heat to the creation of sensations, energy and even cooling. One of the major innovations is that they generate their own energy from vibrations or ambient heat. Take the bracelet I referred to, which gets its energy simply from the body's movement; or wireless, battery-free sensors integrated into floors, planes and wind turbines. These polymers bring a great deal of subtlety to applications such as haptic actuators in smart gloves, which can give the user the illusion of touching stone or velvet. This represents major progress compared with classic actuators, which vibrate like crazy.

What role does Arkema play in this market?

F. D. D. S. – Arkema is a driving force: As a designer and supplier of value-added polymer materials, we are at the base of the innovation creation chain in this market. Given the high number of sectors that demand organic and printed electronics – telephony, automotive, printing, medicine, home automation – the range of applications in which our products can be found is very wide. These are very promising markets, such as smart objects, printed sensors and wearables, estimated at nearly €52 billion by 2025. >>>

> "Our partnerships with manufacturers, academic institutions and associations in our sector are essential to the emergence of the organic and printed electronics industry."

€1,331 billion by 2025 [1]

Estimated global revenue for the smart object market.

(1) Sullivan 2017
Source: https://www.ictjournal.ch/etudes/2018-11-22/le-marche-des-objets-connectes-va-croitre-de-35-par-an-jusquen-2025

€8 billion by 2025 [1]

Estimated global revenue for printed sensors.

(1) Chansin, IDTECHEX 2015

SPOTLIGHT

Players who are bringing electroactive polymers into use

Arkema is a driving force within a structured ecosystem that brings together manufacturers, universities, colleges, research institutes, and professional associations in France, the European Union and worldwide. This impetus is essential in order to progress through the difficult stages between the invention and development of applications in organic and printed electronics.

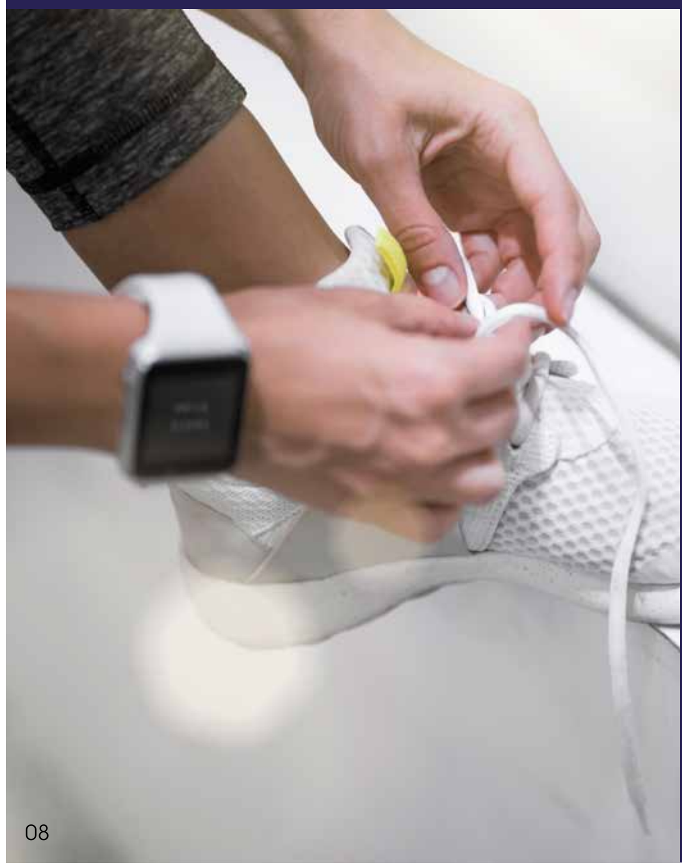
What means has Arkema put in place internally to develop these activities?

F. D. D. S. – Arkema already stands out thanks to its unique expertise in developing electroactive fluoropolymers, from design to fabrication. In 2010, we acquired the startup Piezotech, which specializes in developing sensors and electroactive materials, and integrated it into our research incubator for advanced materials. It really boosted this agile structure, supported by a global group, through our sales networks, research centers and partnerships.

Talking of partnerships, who has Arkema collaborated with to develop this market?

F. D. D. S. – Before naming them, I should say one thing: They are essential! Printed and organic electronics is an emerging sector. This stage between invention and innovation, when the product becomes commercially viable, is particularly delicate. To be successful at this research and development stage, the ecosystem of partnerships must be structured, targeted and solid, to ensure the market succeeds. This ecosystem brings together all parties in the innovation chain: manufacturers, the academic world, research institutes, professional associations and startups.

> "Recyclable, generating their own energy, our polymers are paving the way for a new era of electronics that is more sustainable and more responsible."



How would you sum it up?

F. D. D. S. – It is fascinating to be part of this adventure in which enthusiasm, creativity and partnership are key. Arkema is leading the way alongside manufacturers and academic research institutes, which are combining their efforts to develop more intelligent, more responsible materials. ■

€52 billion by 2025

Estimated global revenue for the wearables market.

Source: www.prnewswire.com/news-releases/world-market-for-wearable-devices-set-to-reach-62-82-billion-by-2025---increasing-penetration-of-iot--related-devices-drives-market-growth-300974593.html

A WORLD OF APPLICATIONS

Soon, our electroactive polymers will be all around us. In homes, in smart devices, in our cars. This technology opens up scope for new applications for electronics and completely recreates the experience of the man-machine interface. Here are a few examples that are not as futuristic as they seem!

SMART FLOORS

In future, smart floors will guide us: No need for indiscreet cameras to make our buildings intelligent. In offices, shopping malls and homes, piezoelectric, fine, flexible, standalone sensors will be embedded into carpets, tiles and floorboards. They will be able to count the number of people and detect their movements in order to adjust the lighting, air conditioning and heating. In hospitals or at home for those at risk, they will be able to alert the emergency services in case of falls or abnormal movements.

SENSORS FOR SUSTAINABLE ENERGY

The new sustainable energy revolution is here, in the form of batteries for electric vehicles, wind turbines, photovoltaic panels, and hydrogen tanks. Electroactive polymers incorporated into materials will be able to monitor wear and tear, faults, and impacts, and measure their temperatures or expansion so that they can be replaced at the right time. This will ensure a longer lifetime for these renewable energies and, importantly, keep us safer!

A SMART GLOVE TO FEEL WHAT YOU SEE

Progress in augmented and virtual reality is paving the way for new, highly realistic touch sensations in video games. Equipped with headsets and smart gloves which have electroactive polymers embedded in the materials, users will be able to feel the movements, vibrations, weight, and texture of objects that feature in their games. They offer an immersive experience that is more vivid than reality!

SENSORS TO MONITOR HEALTH

To read a pulse or measure blood pressure or temperature, these materials are incorporated into watches, bracelets, pillows, sheets, and clothing.

ACTUATORS EMBEDDED INTO THE SURFACE OF DASHBOARDS

No more need for controls and buttons on dashboards. They will soon become smooth, fully intelligent, ultra-sensitive surfaces, with thin, lightweight sensors and actuators incorporated directly into the material. To switch on the radio, air con or headlamps, you will simply need to touch the dashboard, which will provide haptic feedback – a vibration at the exact location touched, so that the driver knows all is well without needing to take their eyes off the road.

FOCUS

NOVASENTIS TOUCHES THE POTENTIAL *of haptics*

The Californian startup Novasentis specializes in haptic actuator technology, which adds a subtle touch sensation to electronic devices, from smartphones to video game consoles. Arkema has played a part in this performance. François Jeanneau, President of Novasentis, explains how it works and looks ahead to the benefits that can be expected in many applications.

Novasentis and Arkema go back a long way. Why?

François Jeanneau – That's right, we've been working closely together since the start of our adventure, to develop actuators until they become technically and commercially viable. We are seeing success in getting them to function thanks to the polymers with electrostrictive properties developed specially for us by Arkema. Arkema is more than a supplier, it is a key partner.

What is an actuator and how does electrostriction help it work?

F. J. – An actuator is an electronic component that makes something move. For example, it could make a smartphone vibrate in silent mode, or make a game console vibrate – it provides information or delivers sensations. When they are integrated into technologies that add the sense of touch to the user experience, we call this haptics.

In terms of electrostriction, it's very simple. A polymer with this property moves by about 5% when an electric field is applied to it, causing it to vibrate.

What applications have been developed using this technology?

F. J. – First of all, the user interface. Game consoles, surfaces with no mechanical buttons such as smartphones and car dashboards, and virtual reality gloves. Another example is wearables, where haptics is used to transmit information, such as a heart rate detector incorporated into a sports t-shirt so that the wearer can track their heart rate as it speeds up and slows down, or an actuator, which connects to the GPS on a smartphone and vibrates to indicate the direction to take. You target the step beyond; in other words, you aim to receive information automatically without having to find it on a touch screen.

> "With haptics, you target the step beyond; in other words, you aim to receive information automatically without having to find it on a touch screen."
>
> **François Jeanneau /** President of Novasentis

How do Novasentis actuators make a difference?

F. J. – They make the product move locally, on its surface, for example, and can vibrate at any frequency, even lower than traditional actuators. For example, we can go from an electric toothbrush that vibrates all over, from top to bottom, to one where just the head moves proportionally to the surface with which it's in contact (tooth or gum). "It's like switching from a sledgehammer to a pin".

Can you give an example of an existing product?

F. J. – A classic example is the video game joystick. Local vibrations refine the player's experience and make it more realistic, and the variation in frequencies provide subtle feedback on impacts experienced during the game. Take a game of pool, for example, where the force applied to the ball differs dramatically depending on whether you want to smash it into a pocket or knock it gently. In the context of this difference, our actuators offer a range of nuances that make the virtual experience more realistic. ■

SPOTLIGHT

FICTION 3.0: 2030, AUGMENTED DAILY LIFE

Paul is walking in the street, wearing his smart glasses and gloves. He feels a vibration near his right eye and a message indicator appears on the lens. Paul stops and taps at an invisible keyboard. It's nothing out of the ordinary: He's just replying to Sophie via the pop-up screen, which he also sees on his glasses, and feels the keys via vibrations on his fingertips. That's it – the message has been sent! They've arranged to meet in the restaurant in 15 minutes.

Once there, they order from virtual menus, where they can choose their dishes simply by pointing at them.

Now it's time to pay. The machine interface appears in their glasses and identifies their pre-registered payment methods. They authenticate the payment by entering their codes.

Sophie then spends an enjoyable afternoon playing her favorite game of virtual tennis. Using a sophisticated handheld device, which faithfully recreates the vibrations generated every time she hits the ball, she enjoys an incredibly life-like experience of a match against Cori Gauff, the world champion!

Novesentis, a Californian startup, was founded by former Apple executives. The company has developed actuator and haptic sensor technologies based on the world's thinnest films, which improve the sensory interactions of many applications. Thanks to the miniaturization of materials, its ultra-thin actuators are meeting growing demand for everyday devices that are lighter, slimmer, smaller and more flexible.

ARJOWIGGINS MOVES *towards paper 3.0*

A long-established paper-maker, Arjowiggins sees printed electronics as a source of future growth. The market is currently emerging and seems ready for electronic systems on paper, notably made using electroactive polymers. Gaël Depres, its R&D Manager, explains why.

"We can see the possibilities of this technology and we have invested in our equipment to produce high volumes."

Gaël Depres / R&D Manager at Arjowiggins France

What connection is there between the paper and electronics industries?

Gaël Depres – It's an opportunistic meeting of two worlds: Arjowiggins, known in particular for its retail stationery brand Conqueror, and printed electronics. This technology consists of using traditional printing methods (screen printing, flexography) but instead of using graphic inks, you print with conductive, insulating or active inks, to create electronic systems on paper.

What are these systems and what applications are they used for?

G. D. – We're talking about smart packaging, NFC antennas in passes to allow people to enter a building, payment cards, and specialist inks that can be used to make diplomatic or legal documents secure. These components are used to transmit information to initiate an action, authenticate a document or check the status of an object.

What is the purpose of a sensor on packaging or a smart label?

G. D. – There are several possibilities. A thermal sensor detects changes in a package's temperature, a pressure sensor measures impacts that could damage the content. These high-tech systems can be used on valuable goods that require a high level of monitoring: Impact sensors on fragile electronic items (TV screens, computers), thermal sensors on palettes of food products, and so on. The market can apply to retail and B2B.

How does it work?

G. D. – The smart label incorporates a sensor, an NFC antenna and a silicon chip. The sensor is made from polymers with piezoelectric properties. When pressure is applied to a material, it generates an electric current that corresponds to information being sent to the chip. The information is sent via the NFC antenna to an active reader – a smartphone for example – in a way that makes it intelligible for the user (see inset).

PowerCoat Alive is a creative paper with integrated NVC technology for graphic printing, available as sheets and stickers.

SPOTLIGHT

FID/NFC: HOW DOES IT WORK?

An offshoot of RFID technology, Near Field Communication (NFC) is a short-range wireless communications system. The NFC tag is made up of a chip and an antenna. It is a passive target that functions without wires or electricity.
When placed near an active reader—one with an energy supply (e.g. phone, card reader)—the antenna picks up its radio signal and uses its energy to allow the chip to function.
In this way, information is exchanged in less than a second. For example, it can be used in a pass to access a building or in a public transport terminal, when pairing two electronic devices (such as a smartphone and a wireless speaker), or in a contactless payment card.

So you are straddling traditional electronics and printed electronics?

G. D. – Absolutely. We are at the stage of hybrid electronics. Our pressure sensors use organic electroactive polymers and our NFC tags are made using metallic inks and silicon chips, which are traditional electronics components.

What is innovative about these systems?

G. D. – They are printed on high-performance paper from PowerCoat©, the brand dedicated to electronic printing by Arjowiggins. It's super smooth, but also very "sealed" so it doesn't absorb the conductive inks, which must remain on the surface and withstand the very high temperatures required for their application and functioning. Printed electronics represents major progress – most RFID/NFC antennas are made from chemically engraved aluminum incorporated into plastic.

So this procedure is more environmentally friendly?

G. D. – That's right. We are working actively on the recycling of our systems, drawing inspiration from technologies in our area of expertise, paper. Added to that are two other aspects—the production of electronics on paper consumes less energy than all-silicon electronics, and our systems are produced in Europe, whereas traditional NFC tags are mainly produced in China. These are significant factors for Arjowiggins, which sees this technology as a means of reducing the carbon footprint of its products.

Is this having an impact on interest in your products among manufacturers?

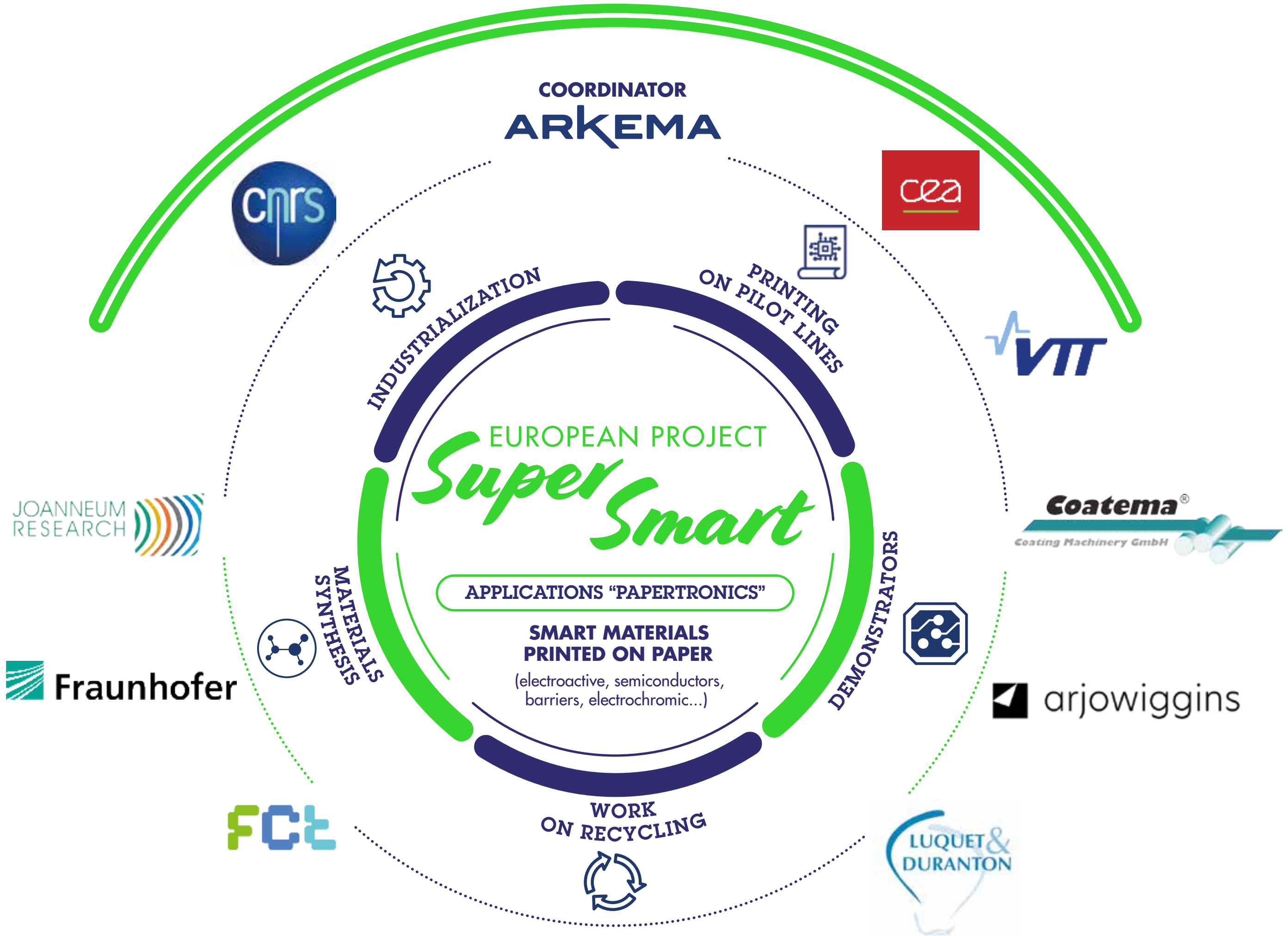
G. D. – Undoubtedly. The efficiency of the technology and its environmentally respectful quality make our systems a promising source of growth for the Arjowiggins group. What's more, it is economically viable, as the production costs of hybrid organic and printed electronics are much lower than those for all-silicon electronics. >>>

How does the collaboration between Arjowiggins and Arkema work?

G. D. – Arjowiggins and Arkema are working closely to develop the entire organic electronics industry. We are active members of AFELIM, the French association of printed electronics, and we have a number of shared technical projects. For example, there is SuperSmart, a European program funded by the European Institute of Innovation and Technology, led by Arkema. We are also working on pilot projects with the aim of using the chemicals group's electroactive polymer materials in systems with our products.

What innovations lie ahead for printed electronics?

G. D. – Smart paper could be used as a biosensor in the form of a disposable biological test to detect a pathology, which could be very useful in the current Covid-19 crisis. ■



OUR PARTNER INSTITUTES

CEA & CNRS, French public research laboratories.

FCT, science and technology university in Portugal.

FRAUNHOFER, German institute specialized in research in applied sciences.

JOANNEUM RESEARCH, Austrian research institute.

VTT, technical research center in Finland.

MANUFACTURERS AND SMALL/MEDIUM-SIZED COMPANIES

COATEMA, German manufacturer of printing and laminating equipment.

ARJOWIGGINS, paper manufacturer specialized in paper recycling.

LUQUET & DURANTON, French medical and administrative stationery printer.

ISORG, A FRENCH GEM IN *organic* ELECTRONICS

Isorg is a young company leading the way in printed electronics. Founded in 2010, it is now bringing its innovative products to market. We talk to its President and founder Jean-Yves Gomez about this disruptive technology and his vision of the industry, as well as collaborations with Arkema, manufacturers and universities.

What innovations does Isorg offer?

Jean-Yves Gomez – Isorg develops and produces large-area image sensors. Think about the smartphone, an essential object in our daily lives. Because more and more of what we do requires protected confidentiality – bank transactions, signing legal documents, medical information, etc. – Isorg offers device security through a fingerprint sensor that covers the entire surface of the screen. This means there is no longer just one method of biometric authentication. An operation could be validated by placing several fingers on the screen, even the fingers of different people.

What is the field of application for these sensors?

J.-Y. G. – It's vast! Everything that relates to security, of course, so borders and police checks, as well as medical imaging, tomography, cars, wearables, and so on. The potential fields are limited only by our creativity and our ability to imagine future needs.

For example, with cars, our sensors could trigger the release of airbags with a smart system, by adjusting the force of deployment according to the level of impact. In terms of wellbeing, rather than having warm air flowing through the cabin, as we do currently, imagine radiant printed electronic panels that warm the cabin evenly and regulate the temperature through sensors. >>>

"Thanks to electroactive inks, Isorg is introducing printing technologies to make these large-area sensors."

Jean-Yves Gomez / President-founder

"Isorg is producing fingerprint sensors for the smartphones of the future."

What is this technology based on?

J.-Y. G. – This technology is based on the electroactive properties of the organic materials we're developing, such as semiconductor inks which we use to make our sensors. When subjected to mechanical constraints, they generate electric currents that send information such as changes in pressure, or vibrations, in a very localized way. These inks can detect the temperature of the human body, which emits heat radiation in infrared, meaning they can be used in smart clothing, smartphones and presence sensors. With their ability to detect via our sensors this spectrum that's invisible to the naked eye, these inks differ from traditional organic materials.

Why are Isorg and Arkema working together?

J.-Y. G. – We are complementary. Arkema supplies us with electroactive fluoropolymers which we use to make our sensors, and Isorg is an expert in printing technologies and the development of organic electronic applications on an industrial scale.

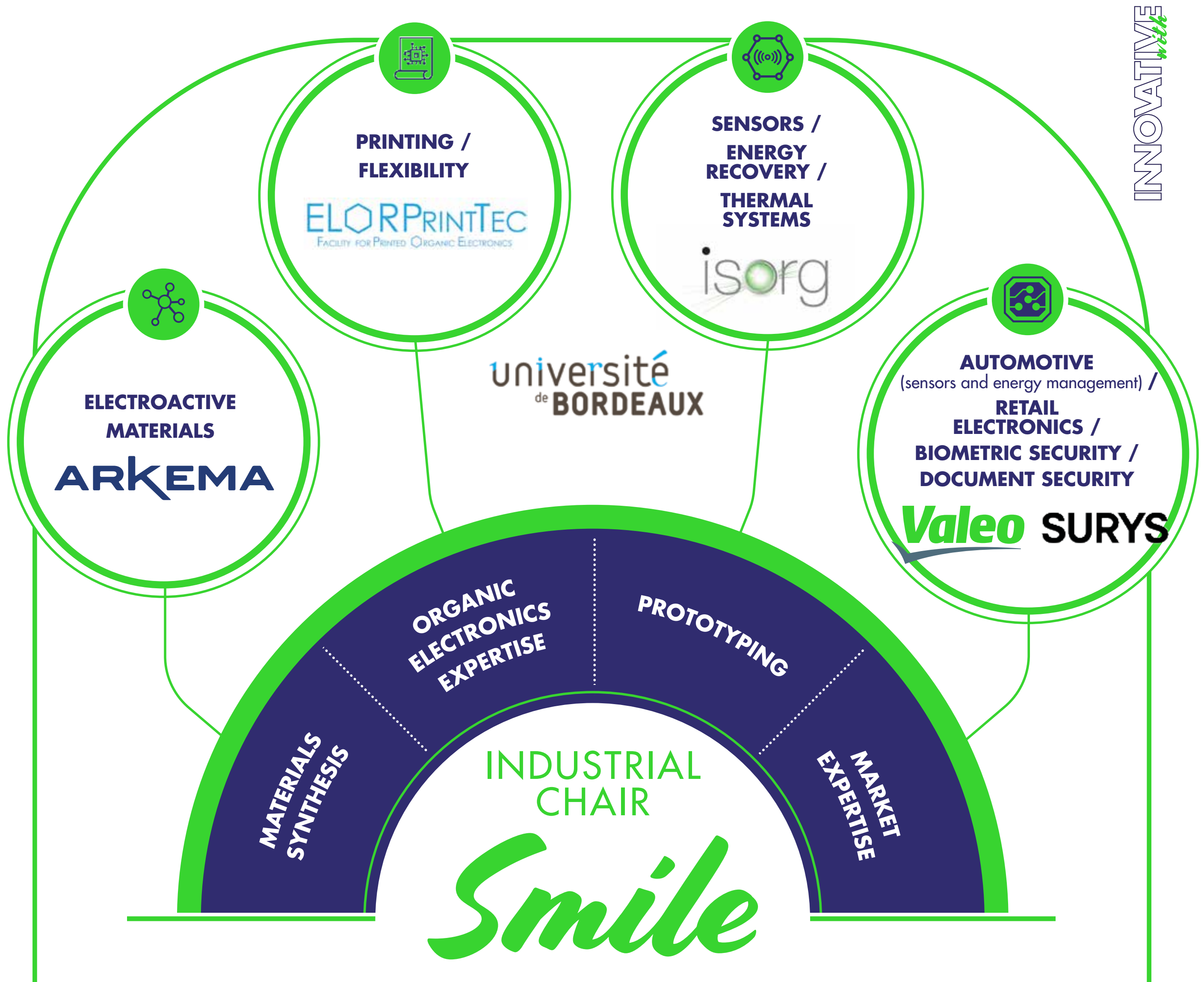
But we are also working together in the academic world, through the SMILE industrial chair at Bordeaux University, which focuses on smart polymer ferrotronic materials for environmental monitoring and energy conversion. It's a great example of a partnership in applied research between manufacturers and researchers.

Isorg is a young company. What do these collaborations represent?

J.-Y. G. – They are very important for us because they are enriching our knowledge so that we can develop our applications more quickly. Isorg has only been around for ten years and is starting to see the results of its research efforts. But to get here, we've had constant stress tests and have had to work hard to convince people of the potential of our sensors and the reliability of this technology!

What prospects for innovation lie ahead for printed electronics?

J.-Y. G. – This also relates to people's safety. I'm thinking of tiled floors made from electroactive materials that can detect when someone falls or can't move, which is a real lifeline for the elderly or people with disabilities; also urban lighting that switches on when a pedestrian is detected on the sidewalk; and road surfaces made from piezoelectric materials that could generate electricity when vehicles drive over it. There are so many possibilities. ■



OUR PARTNERS

BORDEAUX UNIVERSITY via its organic polymers chemistry laboratory (LCPO) is doing cutting-edge work on electroactive polymers.

ELORPRINTTEC at Bordeaux University is an equipment-sharing platform dedicated to printable and flexible electronics.

ISORG is a pioneering company in sensors based on organic printed electronics.

SURYS is a security solutions specialist for document authentication.

VALÉO, via its Thermal Systems Division (THS), designs components to optimize thermal management in vehicles and passenger comfort.

Arkema has **more than ten collaborative research** funded projects worldwide with industrial and academic partners on electroactive polymers. Such as **SMILE** project in France or **SUPERSMART** project at European level.

An ecosystem OPERATING ON AN INTERNATIONAL SCALE

As a manufacturer of electroactive polymers, Arkema is at the base of the innovation creation chain in organic and printed electronics. The company is a driving force within a closely woven network of universities, manufacturers and professional associations in France, the European Union and worldwide. We take a closer look at the academic world.

Guillaume Fleury / Assistant professor and researcher

"We develop electroactive materials and optimize their properties to suit the end demonstrator devices in which they are used (pyroelectric sensors, energy recovery systems, actuators, etc.). The performance of these solutions can be optimized through the intelligent use of the materials.

"Our approach is part of an ecosystem that brings together multiple areas of expertise. Arkema, with its electroactive polymers that are the cornerstone of systems tested in our research laboratory, and the manufacturers which, by using the organic electronic systems in their end applications, guide us on the course to take. This is the aim of the SMILE industrial chair (see p. 17) and ELORPrintTech, a French research equipment sharing platform dedicated to printable and flexible electronics.

"Our partnership with Arkema has crystallized in recent years around the development of electroactive materials with a view to accelerating the printed electronics revolution. The foldable screen is a significant example of the benefits of the materials it uses (lightweight, flexible). They are also less costly to produce and less harmful for the environment than traditional electronic components (silicon), both in the end application and during manufacture."

Bordeaux University, France

Field of research: Electroactive materials and organic electronics

Applications: Sensors, actuators, energy recovery systems

Seung Tae Choi / Associate professor in mechanical engineering

"Since 2015, Arkema has been funding one of our research programs on electroactive polymers and their applications in haptic systems. Since we started, we have made remarkable progress in flexible systems, including ferroelectric polymers. We share this with Arkema, and we are positioning ourselves as a bridge between this international specialist in materials and polymers and the leaders in electronics who are interested in our innovations. These include actuators that transmit localized touch vibrations on large surfaces, and an audible touch-sensitive button that reproduces the recognizable click sound in the latest electronic objects.

"The other aspect to our collaboration consists of providing Korean companies with know-how about the manufacture of systems that use piezoelectric polymers. These materials and systems have a massive future potential due to the growth in demand for retail electronics—smartphones of course, but also cars, and health (smart clothing, medical systems) —all aimed at improving the user experience."

Chung-Ang University, South Korea

Field of research: Haptic systems

Applications: Actuators

Dr Shizuo Tokito / Emeritus professor at the organic electronics research center

Yamagata University, Japan

Field of research: Organic, flexible and printed electronic technologies

Applications: Sensors, actuators, etc.

"We have been working with Arkema for four years to strengthen our knowledge of fluoro-copolymers with the aim of developing new applications. For example, the development of medical wearables that can detect the heart rate and measure perspiration using pressure sensors.

"We use these materials for this purpose, but our relationship goes further. Arkema is a partner we communicate with about our respective work and our results. We are also working on an applied research project for which one of the company's researchers is working in our laboratory.

"Yamagata University is at the cutting edge of this field of expertise in Japan and is recognized internationally for its innovations. It shares with Arkema its belief in the importance of the market for flexible printed sensors and their applications in medicine, health, agriculture, logistics, and robotics. Also, its belief in the emergence of the new 'Society 5.0' in which our sensors will collect information on people and objects, then, once analyzed using artificial intelligence, will allow us in return to innovate and optimize the environment in which we live."

Gregor Scheipl / Department of Marketing and Commercial Development of Materials, Institute of Surface Technologies and Photonics

"We created PyzoFlex®, a printed sensor that responds to pressure, temperature changes, and sounds. It is flexible, ultra-thin, economic in terms of energy, durable, and easy to handle. This printed electronic part is found in many applications: electronics (smartphones, etc.), cars (dashboards, seats, etc.), street furniture, smart textiles, etc.

"This technology would not exist without Arkema's electroactive polymers, which allowed us to improve our sensor. This specialist in advanced materials is a close partner with whom we are constantly communicating in order to optimize their developments.

"Since 2012, we have had a close and rich relationship. We have taken part in research projects (Horizon 2020[1], SuperSmart – see p. 14), sourced polymers from them, and have been part of a development partnership that led to the joint marketing of PyzoFlex®, with a strong emphasis on consulting for our clients to identify the optimal way to use it in applications for the end consumer."

Joanneum Research Institute, Germany

Field of research: Printed electronics

Applications: Sensors

(1) Horizon 2020: Launched on January 1, 2014 and running until 2020, the Horizon 2020 program brings together funding from the European Union for research and innovation and focuses on three key priorities: scientific excellence, industrial leadership and societal challenges. .

Source: https://www.horizon2020.gouv.fr/cid74427/horizon-2020-clic.html

GLOSSARY

A

Actuator: An electronic device that turns energy into another physical phenomenon (movement, heat, light, sound, etc.).

D

Dielectric: An electrical insulator that can store electrostatic energy.

E

Electroactive: Property of a material that converts electrical energy into a different form of energy (mechanical, thermal, etc.) and vice-versa.

Electrocaloric: The property of a material with a temperature that varies (heating, cooling) under the influence of an electric field (the inverse effect of pyroelectricity).

Electrostriction: The elastic deformation of a nonconductive or dielectric material under the effect of an electric field.

Energy recovery system: Used to generate and/or recover energy from external conditions (mechanical vibrations, pressure, temperature, etc.) to which the system is exposed. The use of electroactive polymers is a particularly innovative means of generating and recovering energy.

F

Ferroelectric: The phenomenon of spontaneous electric polarization takes place in certain materials and is reversible in the presence of an electric field.

Flexography: A relief printing process used particularly in packaging for different applications such as printing on films, papers and cardboard.

H

Haptics: The scientific study of touch; describes interfaces that produce sensations via touch.

Home automation: Technical systems used to automate different features of the home in terms of security, energy management, communication and so on.

I

Inkjet: The inkjet printing method projects droplets of liquid ink from nozzles on a moving print head. Typically used in office printers.

Infrared: In the electromagnetic spectrum, infrared refers to the radiation between visible light and microwaves.

Internet of Things (IoT): Refers to smart physical objects with their own digital identity that can communicate with one other. Technically, the IoT consists of the digital identification of a physical object by a wireless communications system (RFID/NFC chip, Bluetooth, WiFi).

N

NFC antenna: A passive electronic component that functions without wires or electricity. When placed near an active reader (supplied with energy, such as a phone, card reader, etc.), the antenna picks up its radio signal and uses its energy to power a chip, in order to communicate information (to pair two electronic devices, authenticate a card payment, etc.).

O

Offset: A major trade printing process (all types of publication, packaging, etc.). It can also be used to print on materials such as polymers and metals.

Organic electronics: General electronic component which uses organic materials (polymers) to move electrical charges. These organic conductors, semiconductors, ferroelectric materials, etc. are being used to develop new electronic systems that are thin, lightweight and can be integrated directly into many applications.

P

Piezoelectric: The property of a metal that generates an electric current when it is subjected to mechanical pressure or is deformed, and inversely, which deforms or vibrates when subjected to an electric current.

Printed electronics: A technology in which complete electronic circuits are printed onto a substrate (polymer, paper, fabric, etc.).

Polymer: a molecule with a high mass that is generally organic or semiorganic (e.g. wood, collagen, starch, thermoplastics, elastomers).

PVDF: PVDF (polyvinylidene fluoride) is a high-performance fluoropolymer that combines strong chemical and UV resistance with ease of use. It is used in many applications such as batteries, coatings, offshore industry, cables, filtration membranes, and wiring for the chemicals and electronics industries. Arkema is the world leader in the production and sale of PVDF under its Kynar® brand.

Pyroelectricity: The property of a material that generates an electric current when it is heated or cooled.

R

RFID: RFID labels consist of an electronic chip and an encapsulated or printed antenna. They are used to transmit information automatically to trigger an action (e.g. between a card and a card reader to authenticate a payment).

S

Screen printing: A system based on a mesh fixed in a frame that is used to print onto different types of materials.

Sensor: An electronic device that turns a physical input such as pressure, temperature, electrical current, etc. into useful data. It can be used to gather data that is read and stored by a measuring instrument (barometer, thermometer, voltmeter, etc.).

T

Tomography: A medical imaging technique used to measure the metabolic activity of an organ in three dimensions.

Traditional electronics: The main branch of electronics based on inorganic materials, mainly silicon, an essential semiconductor of components in equipment based on transistors, integrated circuits, etc.

Transducer: An electronic device that converts a signal in one form of energy (pressure, temperature, etc.) into another form of energy, e.g. loudspeaker, microphone, piezoelectric crystal, actuator.

Transistor: An electronic device used to restore, modulate or amplify electrical currents.

W

Wearable: A garment or accessory that incorporates information technology and electronics, allowing it to communicate, be connected, and receive information (e.g. clothing, watches, glasses).

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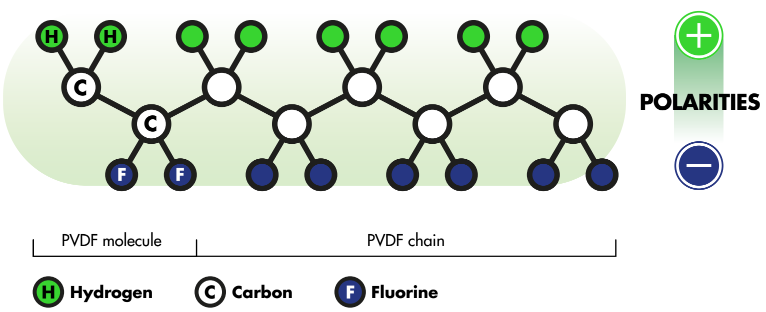
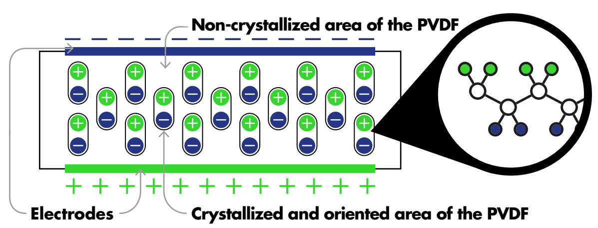
ELECTROACTIVE POLYMERS: HOW DO THEY WORK?

SPOTLIGHT

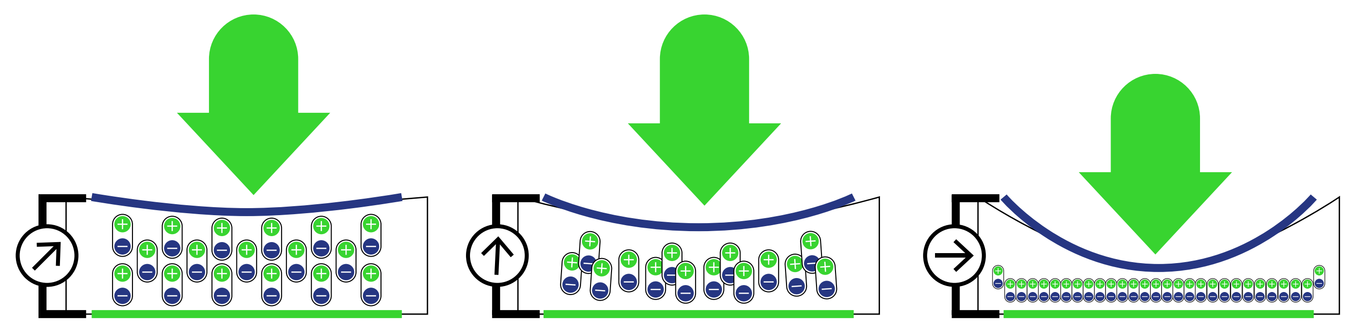
1. Fluorine (F) is extremely electronegative. Fluorinated electroactive polymers are therefore highly polar.



2. To make a sensor or actuator from electronegative polymer, you print an ink containing the polymer onto a substrate and an electrode. You dry the ink, then print another electrode over the top. When an electric field is applied, the polymer molecules align themselves in the same direction. You end up with a polarized film.



3. When the film is deformed, the density of its polarization is modified, which creates an electric current between the two electrodes. Inversely, when you apply a current between the two electrodes, the film becomes deformed.



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