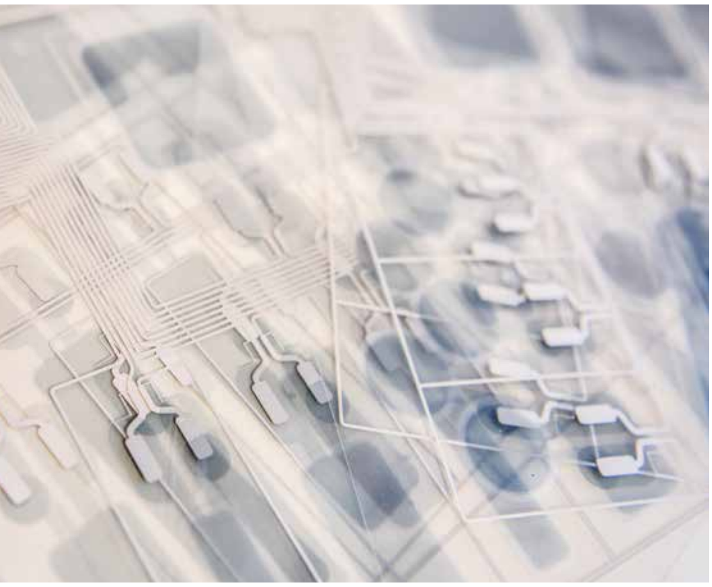
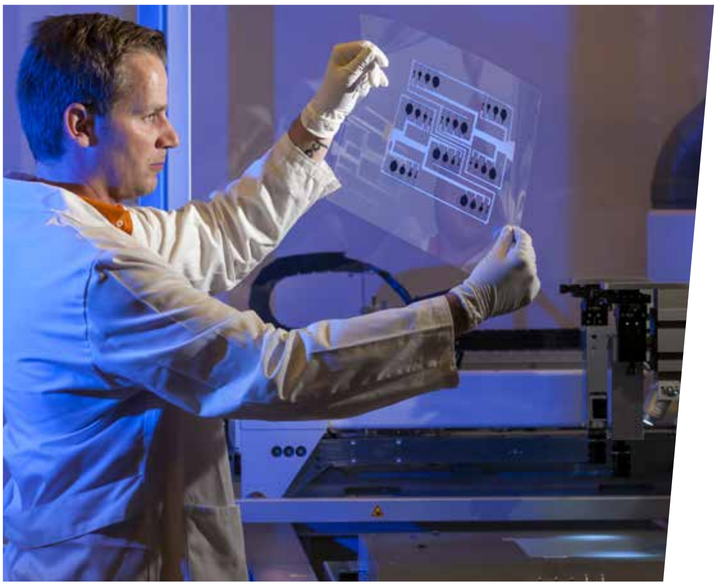
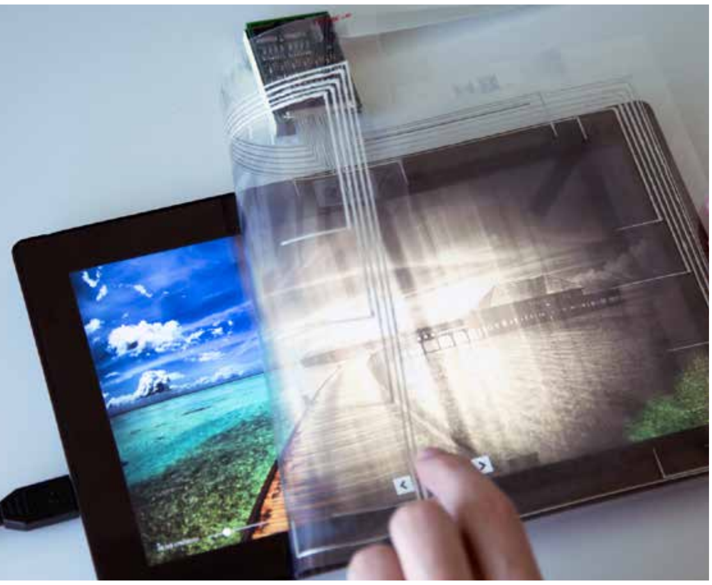
JOANNEUM RESEARCH
MATERIALS

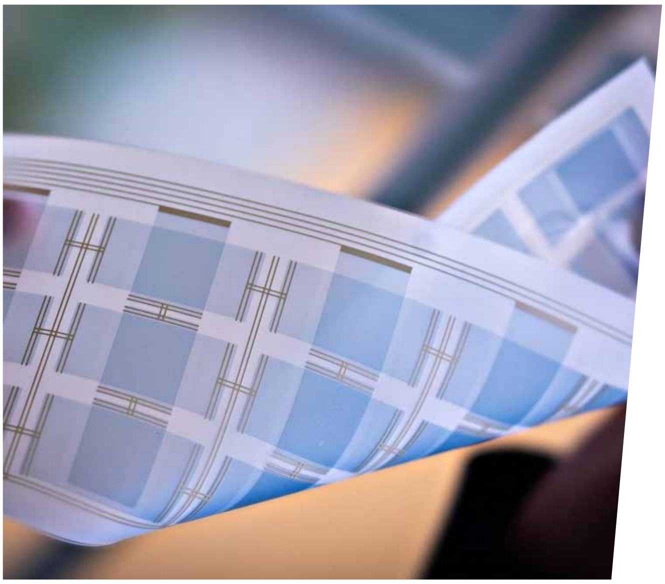
PyzoFlex®

sense your future









SHAPING THE FUTURE, TOGETHER

JOANNEUM RESEARCH MATERIALS

PyzoFlex®

Design-driven

- Any surface
- Any material
- Any design

Flexible

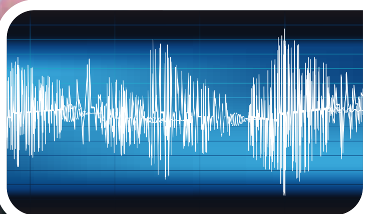
- Light and thin surface
- Formable
- Resistant against environmental damages

Intelligent

- Real-time
- Application specific
- Customized

Energy

- Passive
- Harvesting
- Low temperature processing

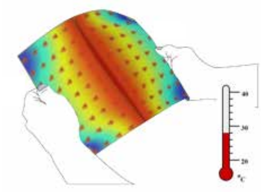


Dynamic

- Pressure
- Temperature
- Vibro-acoustics

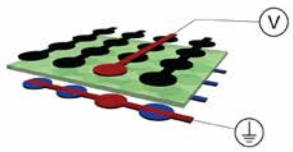
Sensor Applications

Piezoelectric sensing
- Pressure changes
- Acoustics / vibro acoustics
- Structure borne sound
- Impact analytics
- Force lines, threshold forces

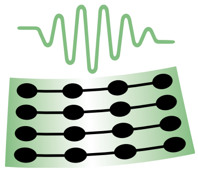


Pyroelectric sensing
- Temperature changes
- Waste heat detection
- Thermal gradients
- Laser detection
- Proximity sensing

Flexible sensors
- Bending
- Wavelike movements
- Curved surfaces
- Smart skin
- Wearables



Energy harvesting
- Body movement
- Vibrations
- Temperature changes
- Deformations
- Wind, tides



Vibro acoustic sensing
- Vibration Analysis
- Condition Monitoring
- Acoustic Event Detection
- Structural Health Analysis
- Vibration-based Interaction

... a wide range of markets

building control, energy- and security management, smart lighting for public and private spaces

control of light and air conditioning, burglar alarm, fall detection

monitoring of vital parameters, smart sports equipment, smart footwear, tracking and tracing products

seat occupancy, hands-on detection, energy harvesting, smart sensing interior

fingerprint sensor, pressure level location, switch/button/slide, knock sensor

predictive maintenance, condition monitoring, structural health analysis, acoustic event detection

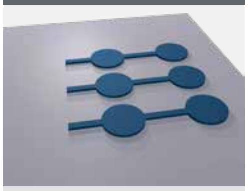
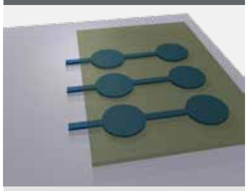
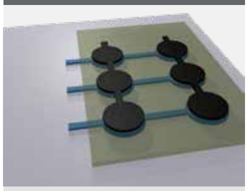
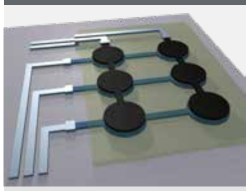
JOANNEUM RESEARCH MATERIALS

PIEZOTECH® ARKEMA

ARMOR SMART FILMS

Standard fabrication process by screen-printing

patented!

Substrate	1st Electrode	Active Material	2nd Electrode	Connections
				
Plastic, paper, textile, glass, metal, transfer foils …	PEDOT: PSS (conductive, transparent polymer)	Copolymer: PVDF:TrFE-Ink patented!	PEDOT:PSS (for semi-transparent sensors) Carbon	Ag lines for connection to read-out electronics

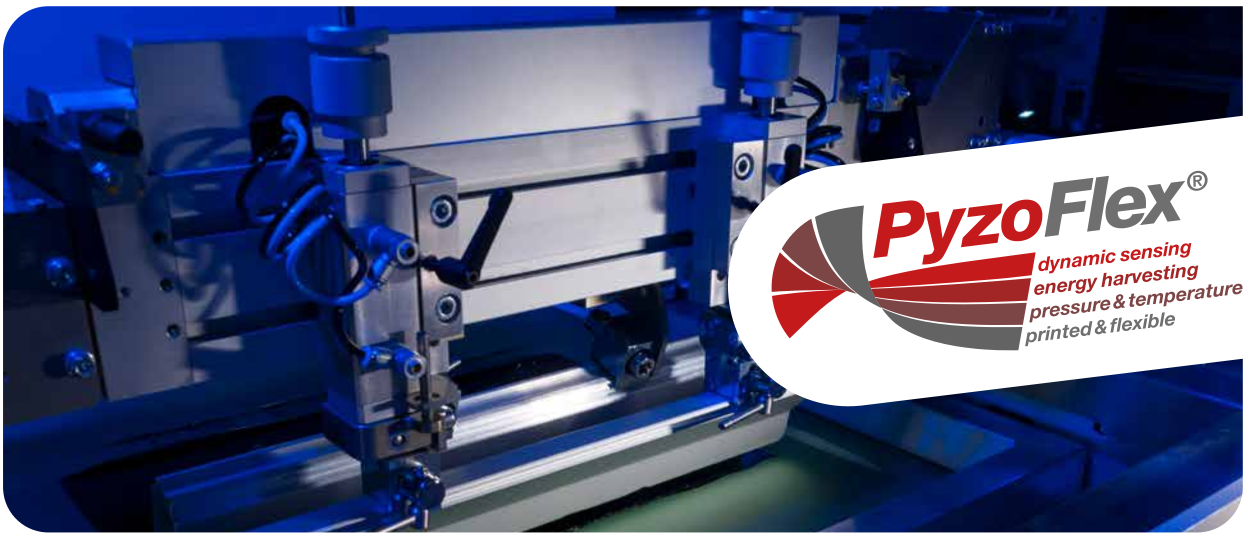
Key Facts: Sensor-Fabrication

- Minimal sensor thickness 6µm
- Quality control by poling process
- Printable on versatile substrates (low temperature fabrication < 100°C)
- Substrate sizes up to 420 x 420mm with a thickness ≤ 20mm
- Semi-transparent sensors if solely PEDOT:PSS is used as electrode material
- Cost efficient sheet to sheet manufacturing by industrial screen printing process
- Application specific sensor shapes based on CAD designed screen masks (max. resolution = 12000dpi)
- Feature sizes down to 100µm (depending on material and screen)

Key Facts: Printing Equipment

- Thieme LAB 1000
- Alignment accuracy: (±) 10µm
- Full camera alignment
- High reproducibility due to software control
- Monitoring of printing parameters
- Process transfer to industrial lines

READY FOR MASS-PRODUCTION



Key Facts Technology

Measured physical properties of screen-printed PyzoFlex® sensors based on PVDF:TrFE=70:30				
	min.	typical	max.	Unit
Recommended poling field	100	**150**	200	MV/m
Displacement	50	**60**	66	mC/m²
Coercive field @ 10Hz	46	**55**	60	MV/m
Pyroelectric coefficient @ 25°C	28,5	**34**	37,5	μC/m²K
Pyroelectric coefficient from –90°C to +90°C	12 — 52	**15 — 62**	16 — 67	μC/m²K
Piezoelectric coefficient d_{33}	-21	**-25**	-27,4	pC/N
Tested pressure range*	30m — 40k			N/cm²
Electromechanic coupling coefficient k_{33} (1Hz — 1kHz)*	0,15	**0,16**	0,17	-
Curie Temperature	103	**104**	130	°C
Standard PVDF:TrFE layer thickness	3	**5**	15	μm
Capacity at standard layer thickness	2	**1,33**	0,45	nF/cm²
Capacity (thickness normalized)	6,21	**6,64**	6,79	nF/cm²μm⁻¹
Permittivity @ 1kHz (poled)	7,2	**7,5**	7,9	-
Permittivity @ 1kHz (unpoled)	10,9	**11,4**	12,0	-
Frequency response**	100μ — 1M			Hz
Tunable properties based on polymer-composition				
VDF content of PVDF:TrFE	55, 70, 80			%mol
Curie temperature	62 – 132			°C
Coercive field (quasi-static)	46 — 57			mV/m
Displacement	48 — 80			mC/m²
Piezoelectric coefficient d_{33}	-26 — -30			pC/N

* Due to the flexibility of PyzoFlex®, the conversion of force to mechanical deformation can be enhanced by employing appropriate mechanical design.

** The parameter limits are determined by available measurement equipment and its measurement ranges.

The technology is based on electro-active polymers, which are applied using a cost-effective screen printing method. These films can detect localized pressure and temperature changes with high precision. The performance of the PyzoFlex® technology within specific applications strongly depends on the mechanical design (conversion of external stimuli into tiny mechanical deformations) and therefore cannot be generalised. All the data presented within this data sheet are based on measurements of PyzoFlex®-sensors composed of the ferroelectric copolymer PVDF:TrFE = 70:30 printed on PET-substrates.

Ageing analysis of PyzoFlex®

Test ID	Test name	Description
TS	**Temperature Storage**	Keeping samples at 105°C for 24 hours
HW	**Hot Water Test**	Keeping samples in water at 99.9°C for 1 hour
1000H	**1000 Hours Test**	Keeping samples at 85°C and 85% humidity for 1000 hours (42 days)
ThSh	**Thermal Shock**	The samples are kept at alternating low and high temperatures. During the cold phase the samples are kept at -40°C for 30 min. During the hot phase they are kept at +85°C for 30 min. The test lasts 11 days.
UP	**Uniaxial Pressure Test**	A static pressure of 0.1 MPa is applied for 240 hours (10 days) at 85°C
MA	**Multiple Mechanical Actuation Test**	106 actuations are performed at a frequency of 1Hz. Within each actuation the pressure of p=0.01MPa at room temperature is applied.
Shr.	**Shrinkage Test**	A sample of a fixed size is placed into an oven at 90°C for 30 min and the ratio of the size after and before the test is determined.
Fl.	**Flammability Test**	The sample stripe of a prescribed length is set afire; the speed of the flame front is measured and classified by integers from 0 to 5.
BC	**Bending Cycles**	4 million bending cycles (deflection ± 1cm) without degradation.
PC	**Pressure Cycles**	2.5 million pressure loads ($9N/cm^2$) without degradation.
QC	***Quality Control***	*Quality controlled process by quantitative poling procedure.*

According to the tested parameters PyzoFlex® has potential for automotive applications.

Measuring principle of PyzoFlex® – mechanical to electrical

Like all piezoelectric materials, the PyzoFlex® polymer transducer develops an electrical charge proportional to a change in mechanical stress. The amplitude and frequency of the signal is directly proportional to the mechanical deformation of the material, resulting in a change in the surface charge density of the material so that a voltage appears between the electrode surfaces. When the force is reversed, the output voltage is of opposite polarity. An alternating force therefore results in an alternating output voltage. PyzoFlex® is not suitable for static measurements as the electrical charges developed decay with a time constant that is determined by the dielectric constant and the internal resistance of the transducer, as well as the input impedance of the interface electronics to which the transducer is connected resulting in a minimal frequency measurable in the order of 0.001Hz. There are methods to achieve static measurement, but these require using PyzoFlex® as both an actuator and sensor, monitoring change in the actuation. The fundamental piezoelectric coefficients for charge or voltage predict, for small stress (or strain) levels, the charge density (charge per unit area) or voltage field (voltage per unit thickness) developed by the transducer.
A properly designed interface circuit plays a key role in the optimization of PyzoFlex® transducers.

LOPEC 2024 - piezoelectric energy harvesting & sensing

The project SYMPHONY receives funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 862095.

SYMPHONY (**S**mart H**y**brid **M**ultimodal **P**rinted **H**arvesting **o**f E**n**erg**y**) adresses three use cases to validate the impact of its new energy harvestig materials:

- wind turbines,
- smart floors and
- bicycle tubes

The project will develop an integrated sensor skin based on the SYMPHONY Energy Supply Platform and P(VDF-TrFE) sensors that allow Condition Monitoring of rotor blades of wind turbines to increase their lifetime and reduce downtimes. An automatic remote monitoring of the pressure of bike tubes will help to keep it, will reduce the maintenance costs for rental e-bike systems and will overall decrease the electrical energy consumption.

In the project SYMPHONY it was possible to develop use of dislocated and disordered energy sources with the development of an innovative energy autonomous sensor system. The energy supply in this system will be completely made of printed, recyclable, and non-toxic materials including the ferroelectric polymer P(VDF-TrFE), printable silicon-based rectifiers, redox polymer batteries and cellulose based supercaps.

The SYMPHONY will provide functionalities such as Condition Monitoring, Predictive Maintenance or Energy Management in three application areas:

- Renewable energy generation
- Room heating/cooling
- Mobility

In cooperation with:

https://piezotech.arkema.com/en

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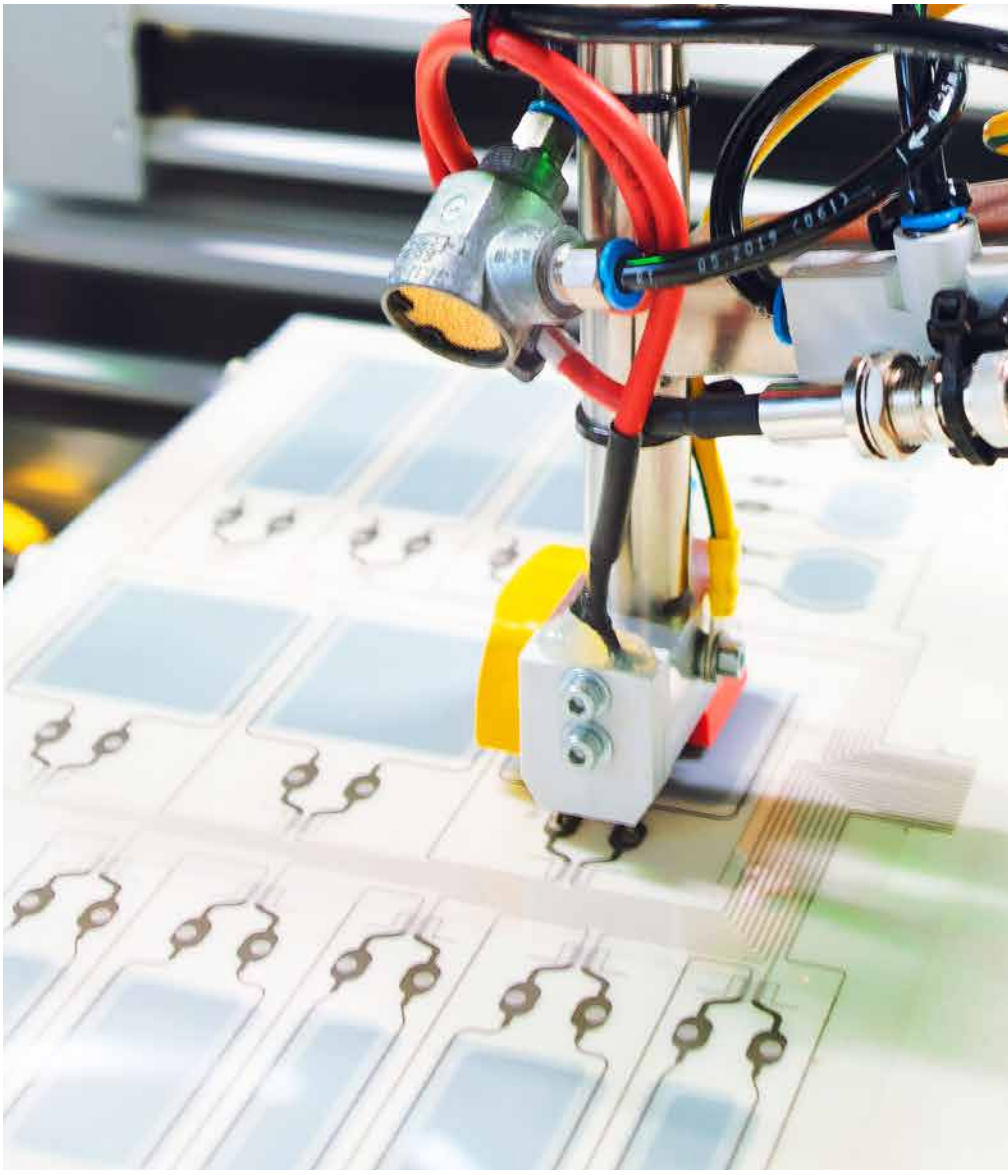

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