SYMPHONY

AIMS TO DEVELOP A COST-EFFICIENT AND ENVIROMENTALLY FRIENDLY REALIZATION OF ENERGY HARVESTING

FIRST RESULTS

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MONTH 18 – WHAT HAS HAPPENED

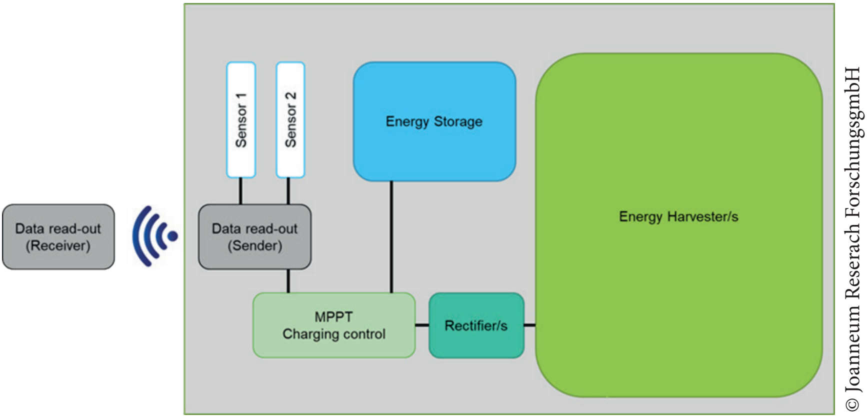

Figure 1: Schematic representation of the SYMPHONY Energy Autonomous Sensor System building blocks

The 21st century has been dominated by an ambient digitalization and the increasing use of electronics in everyday objects. Current IoT scenarios expect around 75 billion connected devices by 2025, and the powering of these devices by batteries will result in a considerable amount of potentially hazardous waste. Besides the predicted billions of smart objects require a proportional number of distributed and interconnected sensors that allow monitoring of the objects' inner state or the outer environment. The spread of electronic systems in remote locations requires a change in power generation, making use of dislocated and disordered energy sources.

A cost-efficient and environmentally friendly realization of energy harvesting (EH), however, is still a challenge, as the required input of functional material and electronic components in comparison to the energy output is high and often involves lead-based materials, manufacturing methods that consume high amounts of energy and costly assembly steps.

SINCE THE PROJECT STARTED?

The SYMPHONY project is addressing all these challenges with the development of an innovative energy autonomous sensor system. The energy supply in this system is completely made of printed, recyclable, and non-toxic materials including the ferroelectric polymer P(VDF-TrFE), printable Si-based rectifiers, redox polymer batteries and cellulose-based supercapacitors.

The SYMPHONY project develops cost effective and scalable methods to print these materials on flexible films and to combine them with energy efficient electronics and sensor technologies. With the scalable and low-cost processing in combination with optimized ICs for energy harvesting the SYMPHONY project strives the goal of a specific cost below 1€/mW harvesting power.

In the first 6 months of the project the Work Package specifications served to find a common understanding of the system to be developed among the partners and to address the limitations regarding the available processes and expectations regarding energy output, integration requirements and durability requests for the use cases.

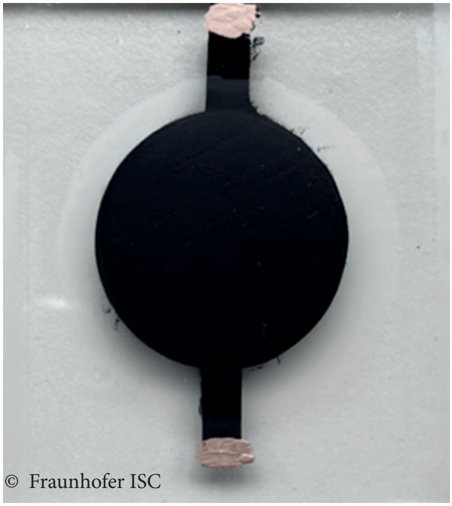

Figure 2: PVDF-TrFE multilayer stack with stretchable electrodes based on Carbon Black/PDMS

Many parallel activities were performed in the material development. Several project partners collaborated on the development of P(VDF-TrFE) based composites either to form a stretchable piezoelec-

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tric material or to incorporate magnetic particles to form magnetoelectric materials. To prepare triboelectric nanogenerators tailor made electropositive and electronegative materials were created and 237 µC/m2 were achieved, which is close to the electrical breakdown in ambient conditions. The efficient rectification of the generated current is crucial for the bipolar actuation of the nanogenerators. The mixing of silicon or zinc oxide particles in a flexible binder was investigated and showed the possibility to fabricate flexible rectifiers on solution-based processes.

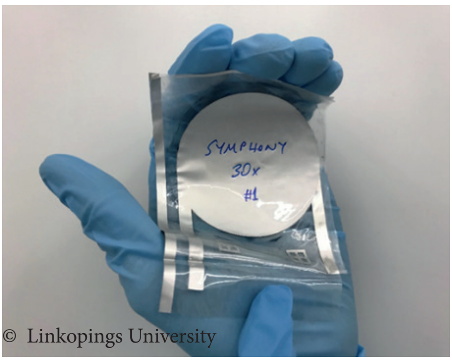

Figure 3: Spray-coated and laminated supercapacitor

The components for energy storage had great progress with the development of batteries based on redox polymers in different printing layouts leading to single cell and multicell structures in a co-planar and vertical design by screen-printing. To achieve this, perfectly adjusted materials were synthetized for anode cathode and electrolyte and, after encapsulation on flexible PET foil, a capacity of 0.2 mAh/cm2 was reached.

The printable or spray coatable supercapacitors based on a "power paper" consisting of nanofibrillated cellulose and PEDOT:PSS reached the goal of a specific capacity of 10mF/cm2 and an ESR of 0.55 Ω.

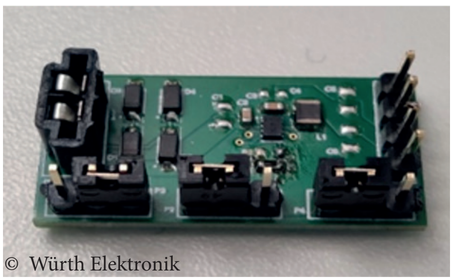

Figure 4: Prototype of discrete power management system

SINCE THE PROJECT STARTED?

The development of electronic components for the fabrication of energy autonomous sensing systems has started integrating an energy harvesting interface and Bluetooth Low energy communication into a general sensor chip and first prototypes are already fabricated for testing purposes within the consortium.
A miniaturized discrete circuit for rectification and output regulation allows to operate the nanogenerators close to the maximum power point and deliver a constant voltage for battery charging or sensor powering.

First integration trials in the use cases were started including the testing of nanogenerators in a wind channel and the bicycle tube was equipped with sensors and mounted on a demonstrator. This, goes hand in hand with the first steps regarding hybrid integration as investigation of stretchable conductors and/or lamination of piezo sensors.

Figure 5: serial arrangement of 3 cells in coplanar design

Figure 6: Hot press lamination of sensors on bicycle tube

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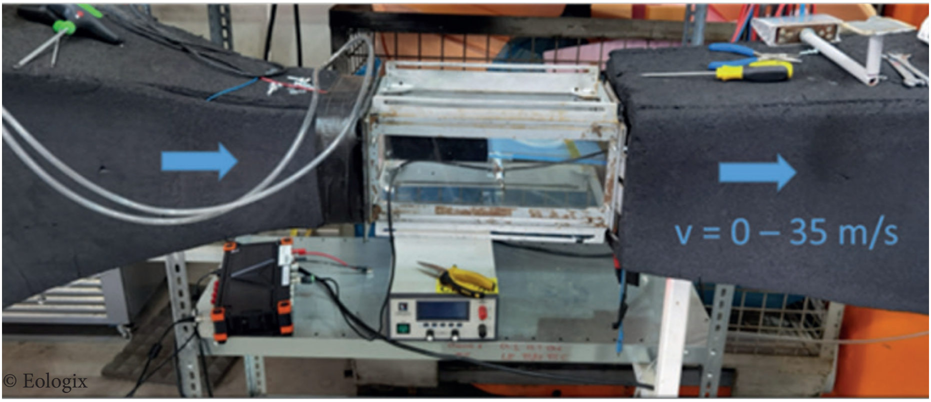

Figure 7: First measurements in wind tunnel of the energy harvested with the SYMPHONY triboelectric nanogenerator for the wind turbine use case

The first material parameters have been delivered for an LCA analysis of the use cases and the preliminary boundaries of the investigated system have been identified.

The use of EH modules is currently driven by the IoT sensor market. While thermoelectric and solar-powered generators are dependent on certain location factors (temperature differences, availability of sunlight), electrodynamic and piezoelectric energy converters can use almost omnipresent existing vibrations and deformations to generate the required energy. The energy-efficient and scalable printing processes used in SYMPHONY offer significant cost reductions and energy savings as compared to high-temperature processes needed in manufacture of piezoceramics. In addition, the materials used in the project have a considerably lower environmental impact (cellulose, polymer batteries, lead-free piezoelectrics).

The SYMPHONY energy autonomous sensor system will provide functionalities such as Condition Monitoring, Pre-

SINCE THE PROJECT STARTED?

dictive Maintenance or Energy Management in 3 application areas: renewable energy generation, room heating/cooling and mobility.

The SYMPHONY solution will significantly reduce CO2 emissions by increasing the lifetime of wind turbines, making room heating/cooling more efficient, through presence and motion tracking smart floors and decreasing the energy consumption in e-bikes, through remote tube pressure control.

The SYMPHONY printed technology can be integrated cost effectively in stretchable and flexible devices, representing a huge potential for usage in a wide range of further IoT-supported applications.

SYMPHONY will have impact not only in the field of applications for nanogenertors, but also at the material level since several material concepts developed in the project can also be applied for other purposes than energy harvesting. In fact the new printable and cross-linkable materials offer new processing routes such as UV-Nano Imprint Lithography, and inkjet printing, therby enabling new integration methods and applications.

Figure 8: First preliminary version of the SYMPHONY demonstrator for the pressure measurement in bicycle tubes

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