Miniaturised Energy Harvesting @ RISE

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Miniaturised Energy Harvesting @ RISE

- Introduction
- Examples of applications
- Conclusions
Miniaturised Energy Harvesting @ RISE

• Introduction
• Examples of applications
• Conclusions
Sweden's research institute

Business and innovation areas

- Digitalisation
- Energy and bio-based economy
- Sustainable cities and communities
- Health & life science
- Mobility
- Material transition

More than 30 research institutes and ca. 130 test beds in one organization
Smart hardware dept. - Expertise
MEMS inertial sensor

IMUs for unmanned vehicles

High dynamics, high bandwidth
Inertial Navigation
World-leading MEMS gyro systems

Data processing, motion classification, wireless

MEMS accelerometers for navigation and seismic applications

Magnetic simulation
AC susceptometry
Magnetic Sensor System
Magnetic analysis

Magnetic analysis

Bio & Chemical

From protocols to complete systems

What to detect
Toxicology
Analytical

How to detect
Optical
Magnetic
Electrochemical

Solution / Prototype
Energy Harvesting vs Cables / Batteries

- Too much weight
- Inaccessible
- Ultra-low power
- Large quantities
- Low data rate
- Low duty cycle
- Not easily accessible
Energy Harvesting technologies @ RISE

**Kinetic energy** – Piezo, Electromagnetic, Triboelectric

- **Industry**
  - Automotive
  - Mining
  - ....

- **Maintenance**
  - Pump, compressor
  - Gas turbine, engine
  - ..... 

- **Life science**
  - Pacemaker
  - Textile, wearable

UDI-2 ‘Energy Toolkit’, Sephmet
ECSEL ‘Energy ECS’; H2020 ‘Symphony’
Energy harvesting for automotive

H2020 ‘Smart Memphis’
FP7 ‘WIISEL’
Energy Harvesting technologies @ RISE

**Thermal**
- Gas turbine, engine
- Hydraulics
- ...  

**RFID**
- Recycling, Identification
- Environment
- ...  

FP7 Stargate
Digitalisation based on energy harvesting (HSP Gripen)

Robust identification
Climate control in greenhouse

AFarCloud
Printed electronics & sensors

Triboelectricity in cellulose & lignin

PVDF

DIODES

Ag
C

NbSi₂:SU8
Si:SU8
Al
PET
• Introduction
• Applications examples - Piezo
• Conclusions
Our prototypes for Energy Autonomous Sensors

Harvester

Ambient energy (Pump)

Kinetic energy

AC voltage

Power management

DC for storage

DC for powering

Supercapacitor/Battery
(Energy storage)

DC for powering

Bluetooth/ Wi-fi

Data

Sensor

PZT

PVDF-TrFe

Tribo

Narrow ambient frequency peak

Broad ambient frequency peak

DC for powering

DC for powering

DC for powering

PZT

PVDF-TrFe

Tribo

EnerHarv 2022

PSMA
Ex #1: Proof of Concept: Pump maintenance

- Pump characteristics for harvester design and tuning
  - Correct mounting of measurement device for vibration spectra

Raw acceleration
Y-led on pump

Amplitude spectrum over frequency

Tuned harvester setup attached to pump
Ex #1: Proof of Concept: Pump maintenance

- **Piezo element**
  - MIDE /Piezo

- **Power management**
  - Analog Devices/Linear Technology LTC3588

- **Communication**
  - LED
  - Bluetooth beacon (RSL10 SIP) + Samsung App
  - Pokit multimeter + Samsung App
  - Modified for harvester application

- **Sensing**
  - Turn on LED
  - Harvested voltage
  - Vibration frequency
  - Vibrations changes
Ex #1: Proof of Concept: Pump maintenance

Pump vibration

PZT harvester (Mide/ Piezo)

BLE module

Power management module

LED lights when enough energy is harvested

Voltage charging / discharge on supercap

Harvester POWER Harvester VOLTAGE

Ex #1: Proof of Concept: Pump maintenance

Pump vibration

PZT harvester (Mide/ Piezo)

BLE module

Power management module

LED lights when enough energy is harvested

Voltage charging / discharge on supercap

Harvester POWER Harvester VOLTAGE
Piezo harvester powering wireless sensor on Gas Turbine

Many, different resonances and in diverse directions on a gas turbine

Measurements fan rig

MIDE EH (80-175 Hz)
Gas Turbine

- Harvested tested up to 100°C
- Cables → Multi core (damps vibrations)
- Mounting support - eigenfrequency

Open circuit voltage output from a backfolded harvester on ex-service engine
4 supercapacitors connected in series
- Discharge while powering Wi-Fi ↔ Rechargeable battery
RISE

- MEMS-based PZT harvester simulation / design
- Mechanical & electrical harvester characterisation
Ex #3: Pacemaker

Resonance frequency: 10-30 Hz
Acceleration: < 1 g
Size: 0.3 - 1 cm³
Needed power: 10 – 20 μW

MEMS PZT
1 – 2 μm

Bulk PZT
30 – 60 μm

(Vermon)

Proof-mass: 0.5 – 1 g
Ex #3: Pacemaker

Challenge

- MEMS design ↔ thin PZT, low
- Damping, pressure encapsulation
- Heart measurements ↔ EH position
- Excitation data ↔ shaker pre-compensation
Ex #3: Pacemaker

- Reproducibility
- Reliability
Ex #4  EU H2020 - Symphony -
Smart Hybrid Multimodal Printed Harvesting of Energy

RISE: Magneto electric harvester characterisation

www.symphony-energy.eu
Ex #4

EU H2020 - Symphony -
Smart Hybrid Multimodal Printed Harvesting of Energy

**Sensor** skin for wind turbine condition monitoring
*(Copyright: Eologix sensor technology GmbH)*

**Smart floor**
*(Copyright: Joanneum Research–MATERIALS)*

**Automated pressure monitoring of bike tubes**
*(Copyright: Tubolito GmbH)*
Ex #4

EU H2020 - Symphony -
Smart Hybrid Multimodal Printed Harvesting of Energy

DIODES
Laminated
Magnetoelastic coupling

Non-contact capacitive coupling electrode

\[
\alpha_{ME} = \frac{dE}{dH} = \frac{V_{\text{piezo}}}{tH_{ac}} = 950 \text{ V/(cm.Oe)}
\]
Develop **technologies** to improve **digitalization** of **e-mobility systems** and related **energy solutions**, forming the basis for future businesses and services.

H2020 ECSEL – Energy ECS -
Smart and secure energy solutions for future mobility

https://energyecs.eu
Ex #5

H2020 ECSEL – Energy ECS -
Smart and secure energy solutions for future mobility

UC1 Drone Zones: Autonomous Drone Ecosystem on Mobile platforms
UC2 Smart containers in intermodal transport
UC3 Smart grid with e-mobility
UC4 Vehicle to grid

**UC5 Self-powered system in tyres**
UC6 Autonomous driving of EV to charging station
Harvester system Challenges

• A component is not a system
• Very light & small size
  − Flexible energy harvesters (piezo, tribo)
  − Enough energy
• Robustness
  − Electrical contacts
  − Mounting
Our Conclusions

- In many applications: energy harvesting won’t replace batteries but… there is interest to increase battery lifetime and/or reduce cables.

- Market acceptance is very much application dependant:
  - Chosen harvester solution ↔ Energy source
  - Component is not a system
  - Implementation is complex

- Energy Harvesting application is still new & requires significant progress & robustness
  - Power density
  - Ultra low power electronics (e.g. high voltage input)
  - Energy storage devices (e.g. current leakages)
  - Wireless communication consumption

- Collaboration with industry
Thank you

Questions?

Acknowledgment: All my colleagues and financiers

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