NanoElectronics Roadmap for Europe: Identification and Dissemination

2nd General Workshop

Athens, April 6-7, 2017

WP4/Sub Task.4.2 Energy for autonomous systems

New!

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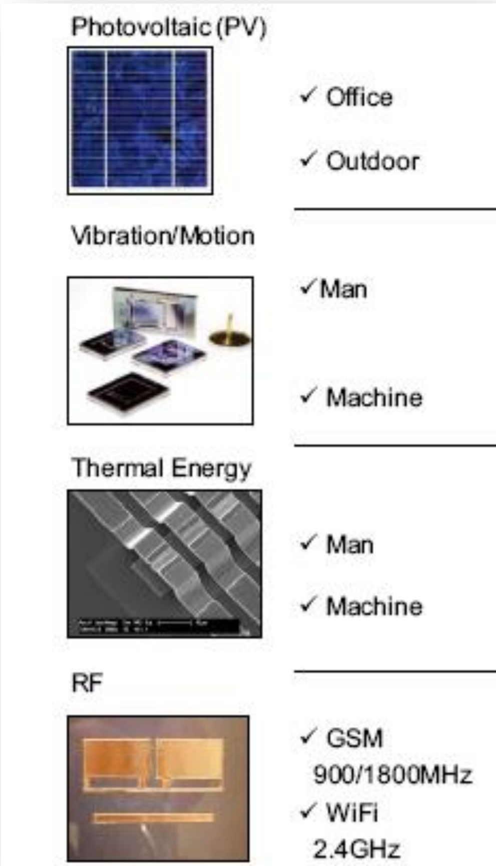
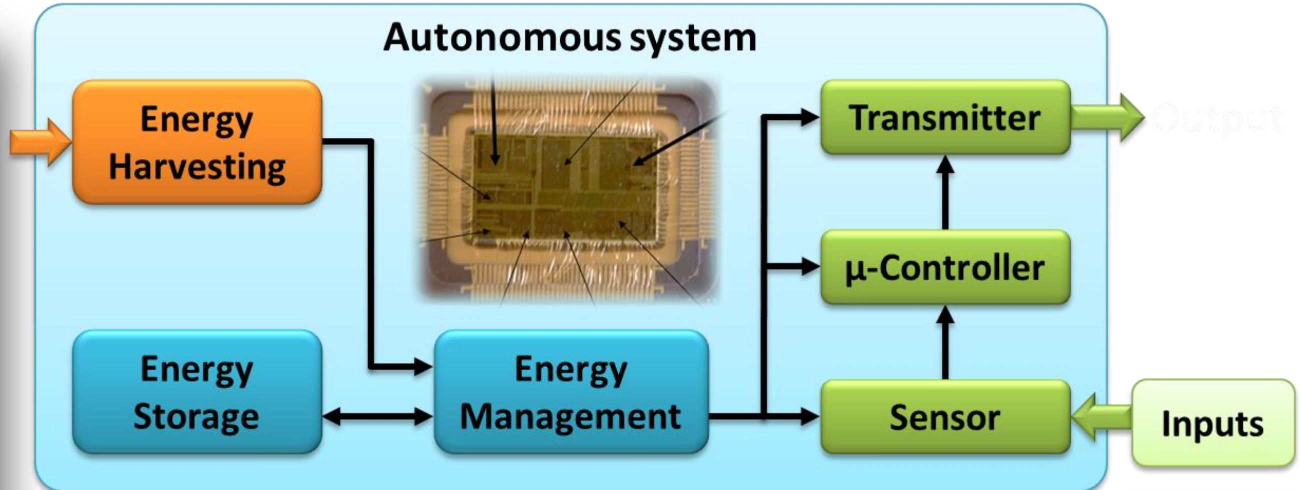
HORIZON 2020

Context & Objectives





Demonstration Platform

- Roadmap on energy harvesting technologies…
- Identify material and technological issues, challenges, applications…

1st domain workshop

- October 19th at Bertinoro, Italy.
- 4 expert presentations (40’ each):

- **Stephane Monfray** – STMicroelectronics,
  “Innovative thermal energy harvesting for future autonomous applications”
  + electrostatic conversion

- **Anne Kaminski-Cachopo** – Grenoble INP,
  “Solar cells for energy harvesting”

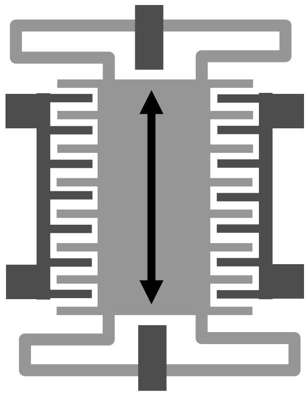
- **Aldo Romani** – University of Bologna,
  “Energy Management”

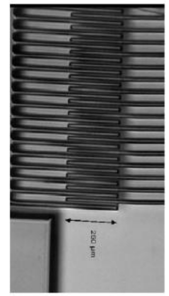
- **Gustavo Ardila** – Grenoble INP/Grenoble Alpes University,
  “Mechanical energy harvesting using piezoelectric materials”

Concept #1: *« Electrostatic conversion »*

- Principle

One electrode of the capacitor is charged (electret, tribolelectricity…) and the relative movement between the two electrodes causes a variation of electric capacity
-> charges movement





- Applications are linked to mechanical vibrations harvesting (movements)
- Energy density is low at macro level but increases at micro scale (relative capacitor variation increases)
- Power is proportional to the surface potential
- Main challenge is related to the reliability of the material to keep the charges

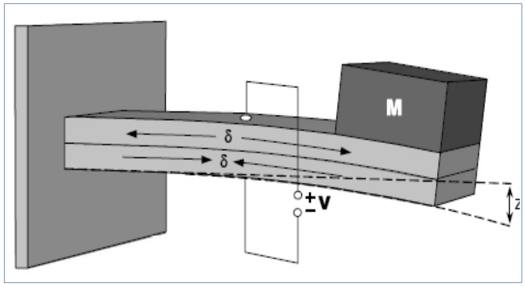
❖ General recommendations

- ❖ For vibration based harvesting, enlarge the frequency bandwith (>50Hz) around low frequency target (below 100Hz) is key to fit with applications.
- ❖ Develop dedicated power management circuits.
- ❖ Reliability of Material is the key to maintain the charges over 10 years.
- ❖ Flexible and low cost approaches for wearable (body) applications should be developed.

Concept #2: *« Piezoelectric conversion »*

- Principle

Resonant cantilever covered by a piezoelectric layer and a inertial mass attached. As the cantilever is bent, strain is transferred to the piezo layer -> asymmetric charge distribution (Voltage)



- Applications are linked to mechanical Vibrations harvesting (movements)
- Devices tuned at a specific vibration frequency
- Devices are easy to fabricate
- Macro-devices and MEMS (new) are actually on the market

❖ General recommendations

❖ From material point of view, new sustainable materials should be considered to avoid PZT and lead containing piezoelectric materials.

❖ Development of micro and nanocomposites

❖ New concepts leading to performance increase: frequency-up converters, hybrids.

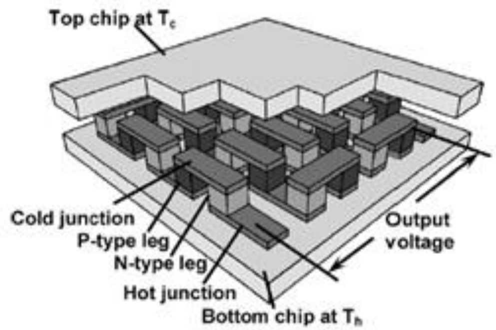
❖ Miniaturization will lead to new applications, wearables, IoT.

❖ Packaging is also a key to improve performance and reliability, in particular with vacuum.

Concept #3: « Thermal EH »

- Principle

Seebeck effect: generation of a voltage along a conductor when it is subjected to a temperature difference
Low voltage : elevator circuit needed
r (working at Vteg>75mV)



- Fast thermalization (need for a big heat sink)
- Non-flexible
- Bi_2Te_3 Expensive/rare/toxic material
- Low output voltage
- Power proportionnal to available temperature gradient

❖ General recommendations

❖ New sustainable materials should be considered to avoid Bi2Te3.

❖ Cost is a key point for energy harvesting: miniaturized solutions should focus on Si or SiGe material (nanostructured materials, phonon engineering) for compatibility with standard semi-conductor industries to reduce production costs.

❖ For non-miniaturized solutions, low cost/flexibles materials should be developed, with optimized thermal engineering at the product level to reduce the size of the heat sink.

❖ Improvement of ZT will allow heat sink size reduction

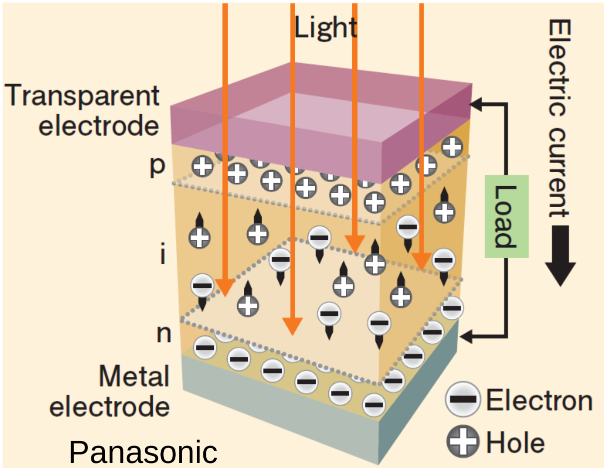
❖ New thermal energy approaches (non Seebeck) needs also to be developed (i.e. phase change of liquid, thermomechanical approaches, thermodynamic cycles…)

Concept #4: « Photovoltaic EH »

Principle :

Photovoltaic effect:

- Absorption of light by the semiconductor
- Electron-hole pair generation, separation and collection
- Power delivered



- A market dominated by the Si (mature technology):
  - For *outdoor* applications, crystalline Si solar cells
  - For *indoor* applications, amorphous Si photovoltaic cells
- Solar cells spectral sensitivity and efficiency differ depending on the light spectrum which is very different for artificial and sun light
- Indoor standard characterization procedures and norms are not defined

❖ General recommendations

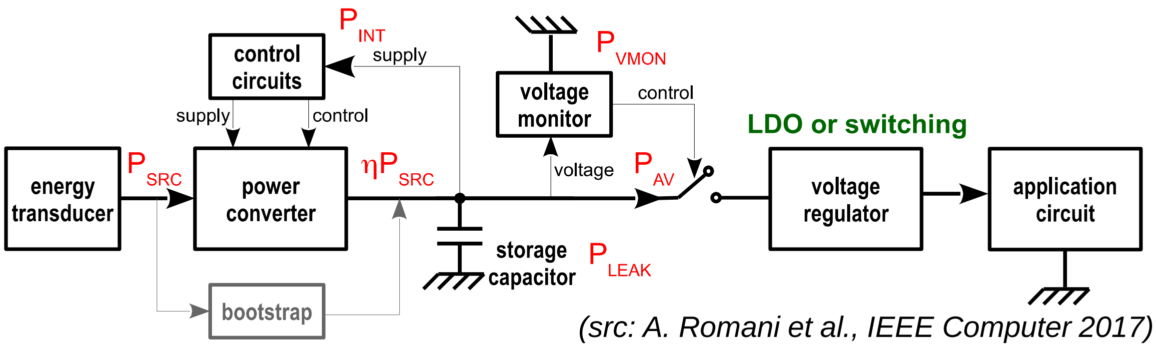
❖ Define standard procedures for indoor photovoltaic cells characterization (light intensity and spectra, direct and diffuse light, temperature…).

❖ Design and optimize structures for outdoor or/and indoor light and for different type of application: sensitivity to different light sources (sun, artificial light, diffuse and/or direct light), flexibility if necessary, cost, output power, material abundance (especially for mass production such as outdoor applications).

❖ a-Si and c-Si are the most used material for indoor/outdoor EH PV. However other materials and structures (organic, perovskite, dye, III-V compounds, nanostructured materials, multijunction…) provide flexibility, high output power, etc. For those materials it is recommended to decrease cost and increase lifetime, stability, efficiency.

Concept #5: *« Micro-power management »*

- Principle



(src: A. Romani et al., IEEE Computer 2017)

- Essential to store and deliver the harvested energy to circuits
- Must consume less than the input power
- Efficiency must be traded with self-consumption
- Should keep sources in the MPP

❖ General recommendations

- ❖ Refinement of energy-aware nano-power design techniques for µpower management circuits, in order to define adequate trade-offs between intrinsic power consumption, efficiency and performance.
- ❖ Power-constrained re-design of WSN circuits is recommended. This is key for application compatibility and to further reduction in intrinsic power of converters
- ❖ In order to devise mm-scale autonomous systems and dramatic reductions in system size, the recommendations include: size reduction of inductors; enhancement of efficiency of inductor-less power converter circuit topologies; develop planar alternative to inductors
- ❖ Tune microelectronic process parameters to reduce leakage and to allow lower activation voltages, improve the quality of the switches (low-voltage electromechanical switches)

Perspectives

- Continue the roadmap
- 2nd Domain workshop
- Include other technologies/concepts not included yet on roadmap
  - RF harvesting
  - Batteries / supercapacitors
  - Mechanical energy harvesting (Electromagnetic approach)
  - Other approaches?

Thank you for your attention!