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PROJECT TITLE:

Silicon Friendly Materials and Device Solutions for Microenergy Applications

FP7-NMP-2013-SMALL-7 GA 604169

WEBSITE:

http://www.sinergy-project.eu/

Editorial - General Sinergy Topics

The **SiNERGY** project focuses on silicon and silicon friendly materials and technologies to explore energy harvesting and storage concepts for powering micro sensors nodes.

This project aims to select a number of examples on the themes of micro power and storage (thermoelectric generators, vibration harvesters and batteries micro structured) and aims their development and increase their performance.

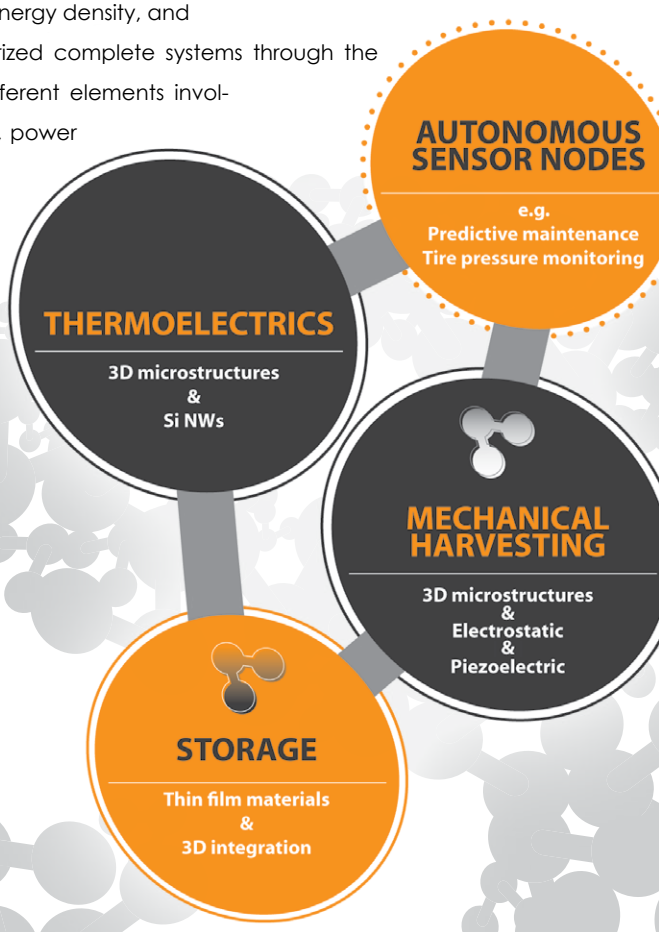
With this **goal in mind**, very important are the use of materials and the integration of technologies that are able to have more mature solutions and exploitable.

For this reason, we believe silicon technology compatible materials innovative as our starting point. The combination of these materials with device-making silicon micro and nanotechnology is particularly well positioned to do innovative developments in the micro domain relating to the collection and storage of energy.

This approach enables:

- Nanostructuration of the materials themselves
- Dense device architectures by means of 3D high aspect ratio microstructures -which increase the resulting energy density, and
- Open the path for miniaturized complete systems through the compact assembly of the different elements involved (e.g. harvesters, batteries, power control electronics, and devices to be powered) by means of hybrid or monolithic integration strategies.

Can be identified **two application scenarios**, engine/machinery fault prevention and tire pressure monitoring systems, relying on self-powered wireless sensor networks, have been chosen as frame of reference for our microenergy developments since they offer different harvesting opportunities (vibrations and waste heat) to work.

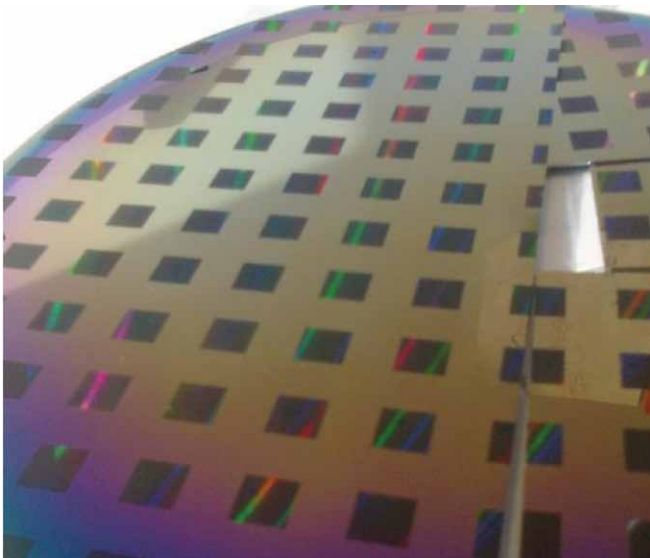


Inside Sinergy - Work programme

WP1 System Concept & Continuous Technical Evaluation	At the beginning of the project (first two months), an initial critical review of the scenario detailed in the proposal will be made and the corresponding technical specifications will be updated and validated for the different approaches contemplated. All along the project, the actual project progress will be compared with the initial objectives, and, if needed, technical reorientations will be introduced
WP2 Thermal micro harvesting	The activity will focus on silicon and silicide nanowires integrating material optimization with device design. The final deliverable is a micro generator capable to supply power to an autonomous wireless sensor network. Both bottom-up and top-down approaches will be explored,tailoring the different fabrication process parameters.This will imply a full characterization of material properties (thermal conductivity, electrical conductivity, and Seebeck coefficient).
WP3 Mechanical micro harvesting	To increase the power output and reliability of the vibration energy harvesters and the integration of nanostructures for high throughput nanogenerators (NGs). The aim is to improve the electret material to increase the charge and with this the power output. Another goal is to integrate the electret in a reliable way
WP4 3D thin film micro batteries	To carry out the fabrication of a functional thin-film microbattery for on-chip or on-package storage.To achieve this goal, planar thin-film devices for interface optimisation and 3D microbatteries for increased contact area will be fabricated and electrochemically characterised. The specifications of the final microbattery will be targeted and aligned to the extent possible to the specifications of the integrated device with micro harvester in WP5
WP5 Integration feasability	To advance in the integration of the developed new technologies into an application feasibility proof of concept. Different applications will be chosen best suited for the devices developed in WP2-WP4, related to machine monitoring and automotive. The proof of concept devices will consist of the new technologies developed in this collaboration in combination with off-the-shelf components where needed
WP6 Dissemination & Exploitation Strategy	To disseminate and exploit the results of the project through awareness activities in close relation with all the technical activities. In this way, the promotion of the knowledge and use of micro- and nanotechnology (MNT) based miniaturised energy autonomy systems will be addressed. The main part of the dissemination activities will take place when first results of the project will be available.
WP7 Administrative and financial management	The two activities, administrative management actions and the set-up of the consortium bodies, fully complement the work done in WP1 concerning technical management and in WP6 concerning the management of Dissemination and Exploitation horizontal activities.

SiNERGY Project first Workshop. September, 30th 2014, Bologna - Italy.

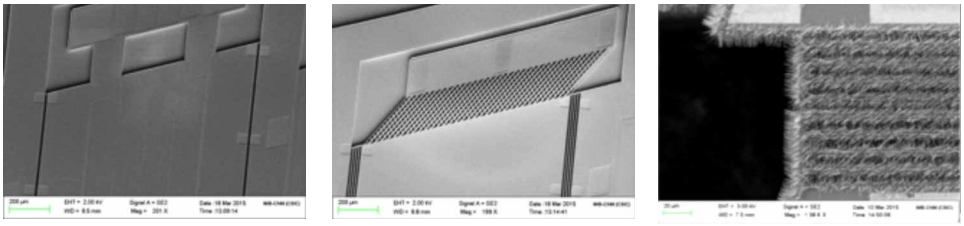
The SiNERGY project has celebrated its first workshop the 30th of September. It was in Bologna within the framework of the **LET'S** event (Leading Enabling Technologies for Societal Challenges).
For more information and for download the presentation of the event go to the project website (http://www.sinergy-project.eu/)



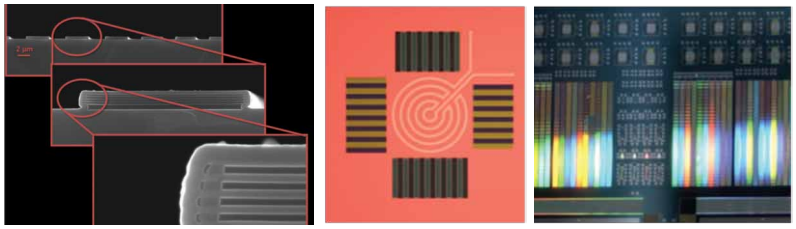
First Achievements ATM18

WP2 A technological route has been defined for improving the thermal isolation of planar thermo-generators based on silicon suspended platforms connected with Si nanowires. Conventional bulk silicon bridges have been substituted by sieve-like thin dielectric membranes. Dense arrays of bottom-up SiNWs have been grown laterally in such platforms by means of VLS-CVD after a galvanic displacement process for Au-nanoparticles seeding. Several trenches separating the hot and cold parts of the device were defined for even better thermal isolation and successfully filled with NWs, so that arbitrarily long nanomeshes could be obtained with just one short CVD process.

Figure :
Suspended silicon platform linked by bulk bridges (left) or by a thin perforated membrane (center). Multiple trenches filled with bottom-up SiNWs (right)

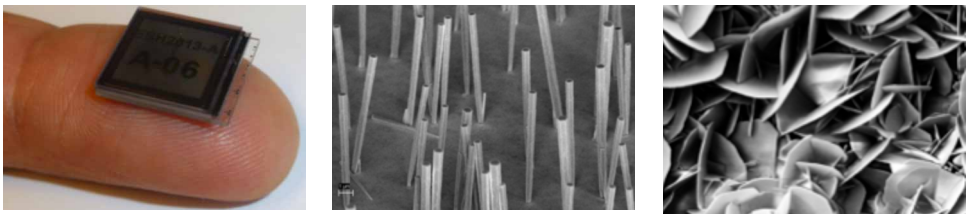


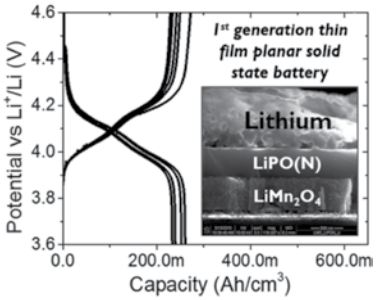
WP2 Top-down approach to the making of nanowire arrays. Alternate stacks of silica and silicon nitride are grown and lithographically defined onto a suitable substrate. Then transversal niches are obtained by chemically etching silica. Nanowires are then made by filling niches with silicon using chemical vapor deposition. The technology is scalable as it fully complies with microelectronic standards.



WP3 Two types of mechanical energy harvesters are being developed in parallel, able to convert vibrations into usable electric energy via a silicon spring-suspended proof mass and a variable capacitor. The piezoelectric harvester makes use of high performance piezoelectric ZnO nanostructures, synthesized by a newly developed, low cost, silicon friendly growth method. The electrostatic energy harvester uses a permanently charged high voltage inorganic electret material. Clever integration of cappings and stoppers limits the maximum displacement of the mass and improves the mechanical reliability of the devices.

Figure:
Electrostatic harvester with glass cappings (left);
Piezoelectric ZnO nanowires (centre) and nanosheets (right)





WP4 The SiNERGY 1st generation thin film solid state micro-battery has been fabricated and characterized. The battery stack consists of a LiMn2O4 cathode layer prepared by RF-sputtering and post treatment annealed, an electrolyte layer of LiPON prepared by RF-sputtering using N2 flow which has been known to have the maximum ionic conductivity and an anode layer consisting of a lithium metal thin film prepared by thermal evaporation. Cyclic voltammetry and charge-discharge measurements show that the device can obtain 250mAh/cm3 with high Coulombic efficiency of the stack showing high performance on kinetics.

Figure: 1st generation battery stack showing 250 mAh/cm3 of capacity

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WP5 Leading the research towards energy efficient wireless autonomous sensors (EEWAS), thus aiming to meet the challenges referred to the specific technical requirements, the 2 proof of concepts devices will be engineered and based on the innovative micro.sp technology patented by STE. Micro.sp technology adopts an advanced concept of data transmission taking the advantages of an innovative modulation scheme capable to generate 2µs wide high peak power RF pulses.For the proven robustness, flexibility, economical scale and system's scalability, along with the intrinsic ultra low energy absorption, the micro.sp opens up an innovative and previously unthinkable approach to EEWAS that is particularly proved to be suitable for the Tire Pressure Monitoring System and "white goods" commodities, that are representative products of the growing world of Internet of Things.

WP5, Electrolux Gas-powered appliances are excellent candidates for a «thermal harvesten» proof-of-concept. The reason is tied to the fact that such appliances usually do not have electricity on-board and are controlled by devices operated by fluid expansion (e.g. thermostatic gas control valve). Such types of appliances are quite diffused, particularly in the countries of the Mediterranean area where combustible gas (methane or LPG) has always been extensively used. As an example, a professional kitchen has a power consumption ranging between a few tens to a few hundred kilowatts. A thermal energy harvester capable to provide enough power to supply a sensor and a RF transmitter would give the great advantage of digitally managing a totally mechanical appliance.

The system will be able to read the oil temperature and to send its reading through the RF module to a remote controller along the entire working cycle of the fryer. Data transmission frequency will be typically of 0.1 Hz.

Calendar: upcoming events

Events	Date	Place
Smart System Integration	11-12/3/15	Copenhagen (DK)
2015 MRS Spring meeting	6-10/4/15	San Francisco (US)
Energy Harvesting & Storage 2015	28-29/4/15	Berlin (DE)
SPIE Microtechnologies 2015	4-6/5/15	Barcelona (ES)
E-MRS Spring meeting	11-15/5/15	Lille (FR)
Transducers	21-25/6/15	Anchorage (US)
IEEE Nano 2015	27-30/7/15	Rome (IT)
ICT 2015 & ECT 2015	28-6 2-7/15	Dresden (DE)
Eurosensors 2015	6-9/9/15	Freiburg (DE)
Sensors and Their Applications XVIII	6-9/9/15	Kingston (UK)
European Congress and Exhibition on Advanced Materials and Processe	20-24/9/15	Warsaw (Poland)
IUMRS-ICAM 2015 Meeting	25-29/10/15	Jeju-do (Korea)
2015 MRS Fall Meeting	29-11 4/12/15	Boston (USA)

Upcoming SiNERGY releted events include:

- **18 month review meeting**

Leuven, April 28-29

- **Dissemination workshops**

Next workshop a Dresden, 25-26 June 2015

To find out more

For more information, go to the project website (http://www.sinergy-project.eu/)

Consortium

Consejo Superior de Investigaciones Científicas (CSIC) is an autonomous multisectorial, multi-disciplinary public research body affiliated to the Spanish Ministry of Science and Technology. CSIC is composed of around 110 research institutes in all research areas, and is the major Public Research Body in Spain, and the third inEurope.

Confindustria Emilia-Romagna Ricerca (CERR), is the company of Confindustria Emilia-Romagna specifically created to support the associated enterprises network in the area of research, innovation, technology development and technology transfer. It assists enterprises in their innovation, plays a key role in the governance of the regional High-Technology-Network

Electrolux Italia S.p.A., with 5.000 employees, is a historic European leader in household appliances for Research, Design and Manufacturing. The Company is controlled by the Swedish Electrolux AB which is a global leader in household appliances and similar equipment for professional use, selling more than 40 million of products in 150 countries

Catalonia Institute for Energy Research (IREC) is a research institution under the trust of different governmental and private organizations. IREC is organized in two Applied Research Areas: Advanced Materials and Bioenergy and Biofuels and three Technological Areas: Electrical Engineering, Energy Efficiency and Offshore Wind Energy.

IMEC is a world leading R&D lab for nano-electronics. Imec scientists and engineers research and develop exploratory and emerging technology in ICT, healthcare and energy for a better, healthier life in a sustainable environment through innovations in nano electronics. Imec has its headquarters in Leuven, Belgium, where the main labs and state-of-the-art Clean Rooms are located.

Stichting IMEC Nederland (IMEC-NL) is the Dutch research branch of the independent nano electronics research center imec, is together with TNO, one of the two pillars of the Holst Centre. Its research focuses on next generation wireless autonomous transducer solutions.

STE Engineering was established earlier in the 1965: founder Guido Moiraghi is recognised has one of the pioneer of radiofrequency in Italy were, among the few, introduced radio communication products for voice and data transmission for civil and military applications (aircraft, ground and naval)

The **University of Milano-Bicocca** was established in 1998 to serve Northern Italy. The University is a gateway to professionalism and educates scientists and technicians from Italian industries, as Milan is historically open to competition, innovation, and internationalism.

Consiglio Nazionalle delle Ricerche – CNR. IMM (Institute of Microeletronics and Microsystems) includes 5 Departments, located in Bologna, Rome, Naples, Lecce and Catania. IMM belongs to the National Research Council of Italy (CNR), which is a nonprofit, partially government-funded research organization, and the organisation with legal entity to act as partner in EU Framework Programmes .