MICRO-ENERGY GENERATION AND HARVESTING

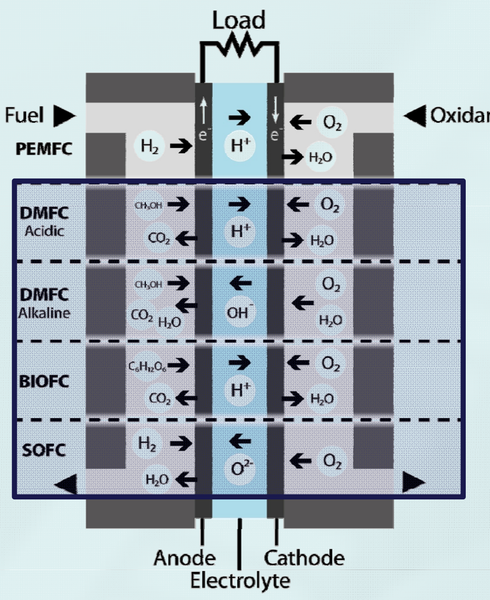
This research line deals with the adaptation of ***microtechnologies*** for the development of ***microdevices*** based on ***microstructures*** with an architecture that confers them an added value from a functionality point of view (free-standing resonant structures, thermally isolated platforms, three-dimensional topology…) and the synthesis of functional ***materials*** to be integrated in those microstructures.

Harvesting (thermoelectricity, mechanical) and **generation** (micro fuel cells - PEM, SOFC, microfluidic) are covered. Materials used are basically those related to silicon technology, but also alternative materials such as polymer and paper and their associated technology are being introduced. These other materials are flexible, low cost (even for low number of samples) and enable fast prototyping routes.

Another aim is the **microintegration** of some of those microdevices with **microenergy** sources to develop **autonomous systems**.

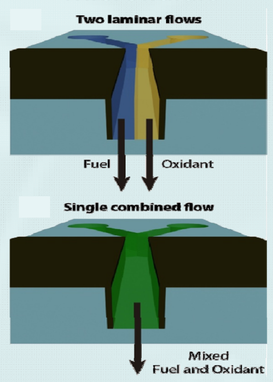
GENERATION

Fuel Cell Types



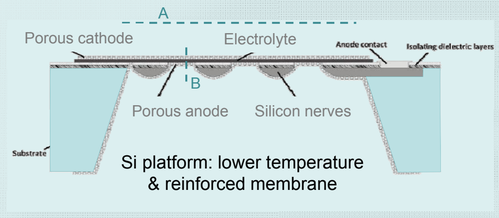
Ion exchange membrane

microfluidic

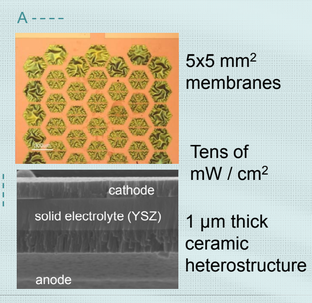


micro SOFC (high temperature: 400-700ºC)

Silicon



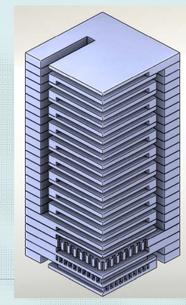
Si platform: lower temperature & reinforced membrane

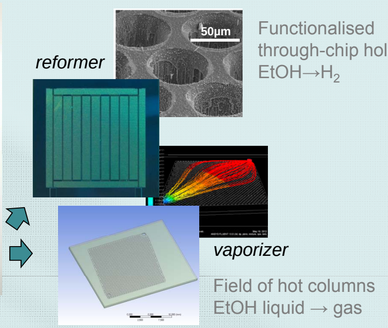


5x5 mm² membranes

Tens of mW / cm²

1 µm thick ceramic heterostructure





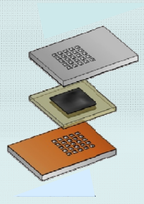
Functionalised through-chip holes EtOH→H_2

Field of hot columns EtOH liquid → gas

Passive micro direct methanol fuel cells (alkaline)

Silicon

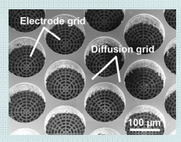
Hybrid



Si anode

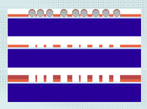
Alkaline MEA

Si cathode



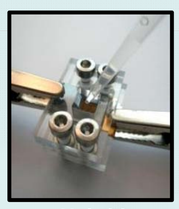
Integrating electrodes into Si current collectors

nanoporous metal and catalyser electrodes



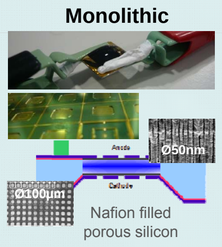
Passive micro direct methanol fuel cells (acidic)

Silicon | **Polymer**

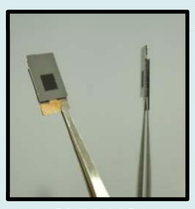


Hybrid

Monolithic



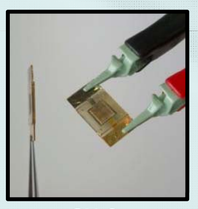
Nafion filled porous silicon



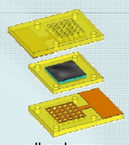
Si-PDMS

screw-less Si-PDMS bonding

Structured PDMS filled with Nafion



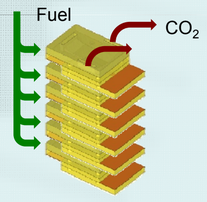
SU-8



all-polymer components

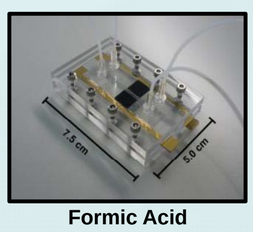
passive fuel delivery

Surface texturing

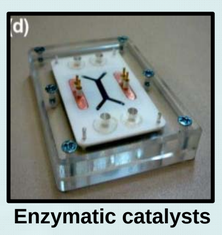


Membraneless microfluidic fuel cells

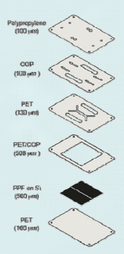
Glass / PDMS | **Silicon / Flexible plastic foils** | **Paper**



Formic Acid



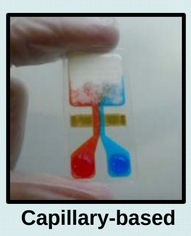
Enzymatic catalysts



PPF electrodes

Pressure sensitive adhesives

Glucose/O_2



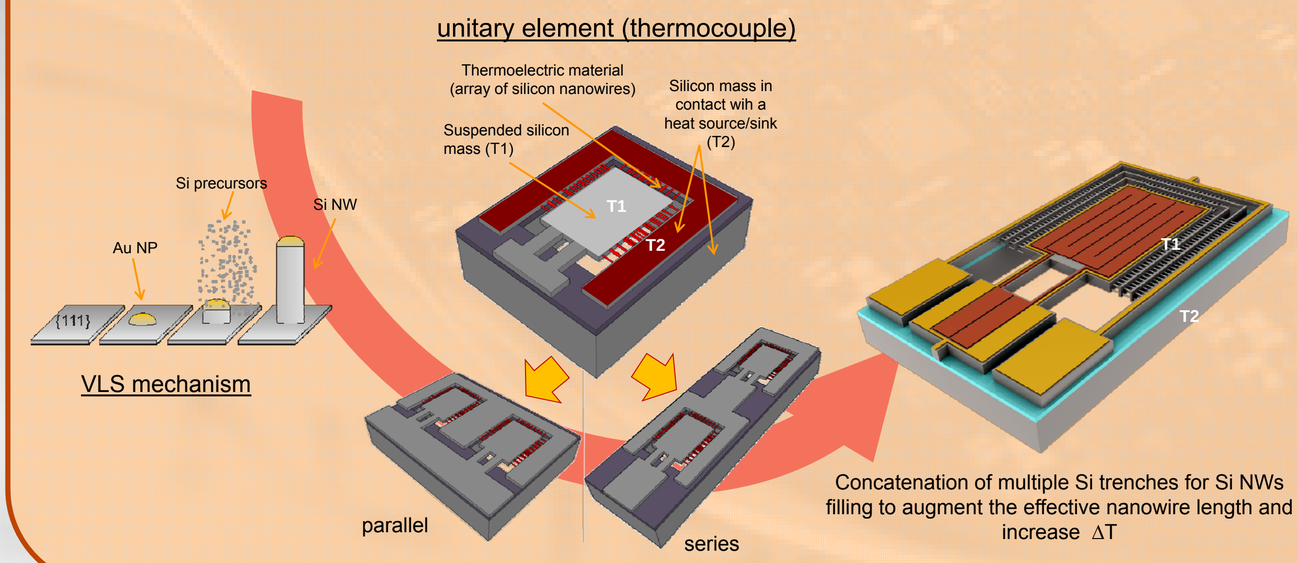
Capillary-based

MeOH / KOH

HARVESTING

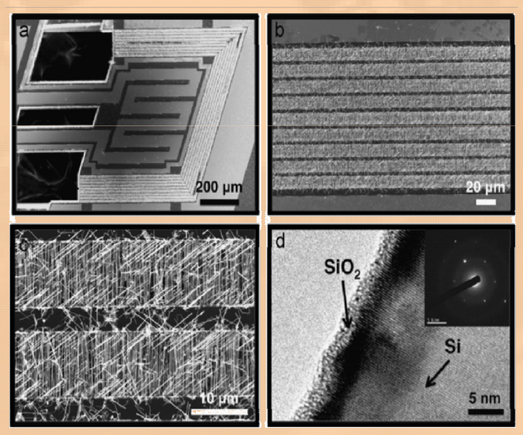
ALL-SILICON MICRO-NANO THERMOELECTRICITY:

top-down and bottom-up process integration

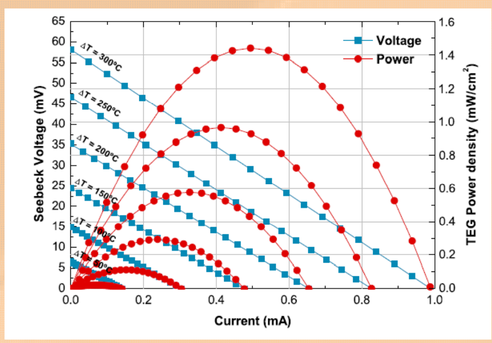


Concatenation of multiple Si trenches for Si NWs filling to augment the effective nanowire length and increase ΔT

- **All-silicon:** Si is an abundant material and technologically enabling
- **All-silicon:** bulk-Si is not a good thermoelectric material, but Si NWs are
- **Top-down:** appropriate starting wafer ((110) SOI wafer) and device architecture
- **Top-down:** DRIE micromachining for vertical trench definition (along (111) planes)
- **Bottom-up:** Si NWs quasi-epitaxial growth of nanowires from silicon surfaces selectively sown with gold nanoparticles (VLS mechanism)



A few tens of NW/µm² of 80nm Ø
Several millions per device



mW/cm² power densities achievable if ΔT of 200ºC can be conveyed across the Si NWs

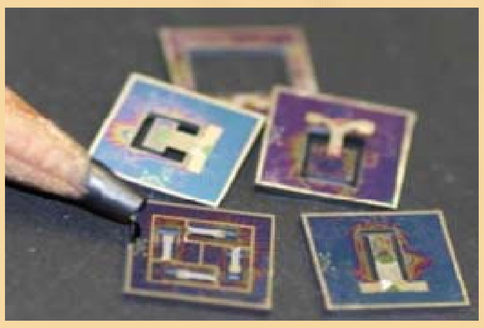
VIBRATIONAL HARVESTING: ELECTROMAGNETIC AND PIEZOELECTRIC

Electromagnetic harvester device for scavenging ambient mechanical energy with slow, variable, and randomness nature

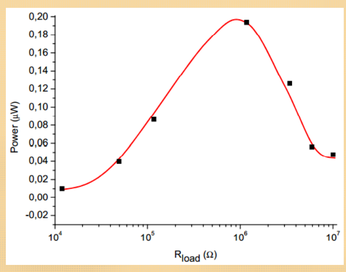
smalle Technologies

www.smalletec.com

MEMS piezoelectric harvesters based on AlN



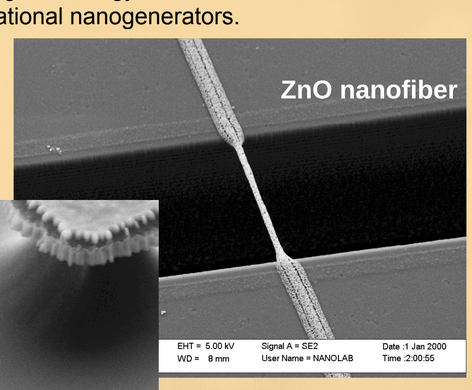
A scavenged power of around 0.2 mW ≅ 0.13 mW/cm³ of power density

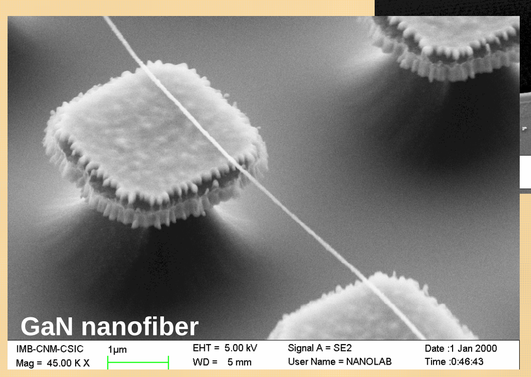


Towards NANOgenerators

INTEGRATION to silicon processing technology of ELECTROSPUN fibers and consequently, development of vibrational nanogenerators.

Collaboration with U. Puerto Rico





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