NANOTECHNOLOGY FOR THERMOGENERATORS

Dr. Laurent GRAVIER

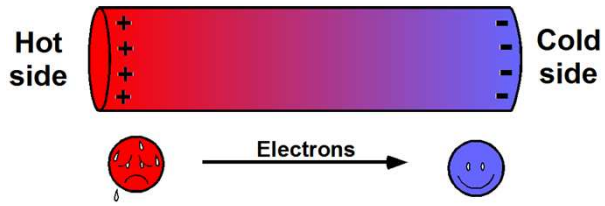
Institut de Micro & Nano Techniques

heig-vd
Haute Ecole d'Ingénierie et de Gestion du Canton de Vaud

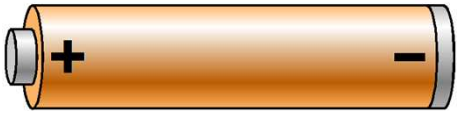
cetT
Centre d'Etudes et de Transferts Technologiques de la HEIG-VD

Thermoelectric module: principle

Any conducting materials experiencing a temperature difference…



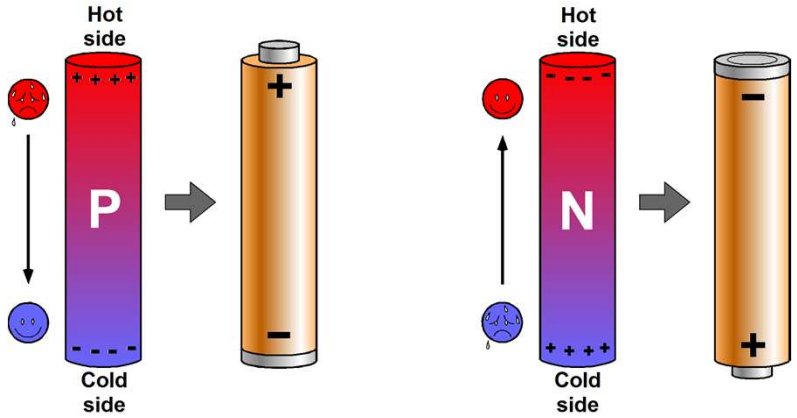
… is like a battery!



Thermoelectric module: principle

2 different material classes

Positive-type **Negative-type**



Fe, Cu, Au,…, p-type SCs

Ni, Co, … , n-type SCs

Thermoelectric module: principle

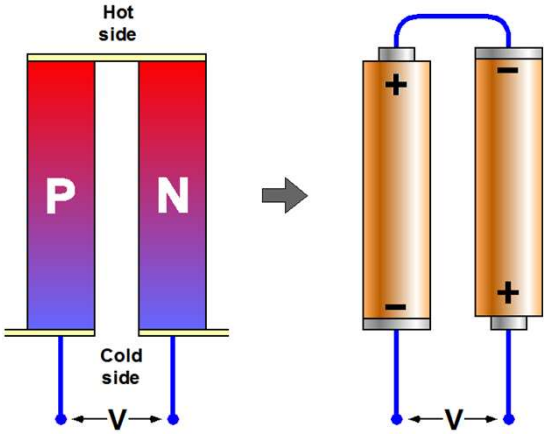
Combining P- and N- type materials:

➔ **Thermocouple**

emf proportional to temperature difference:

➔**T-sensor applications**

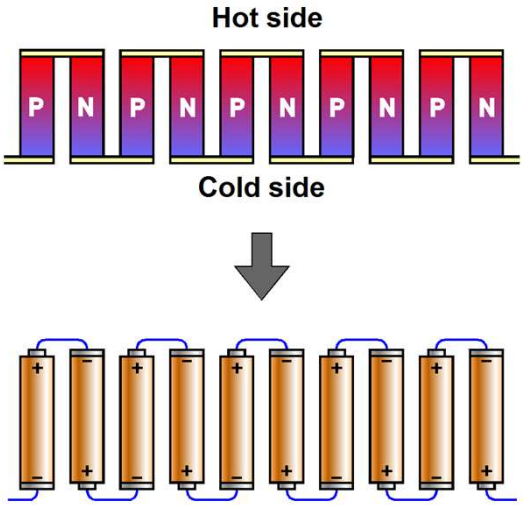
(50-400 µV/℃)



Thermoelectric module: principle

To reach higher output voltage

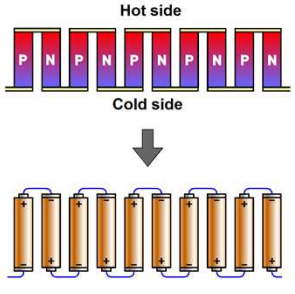
➔ **Thermocouples electrically connected in series**



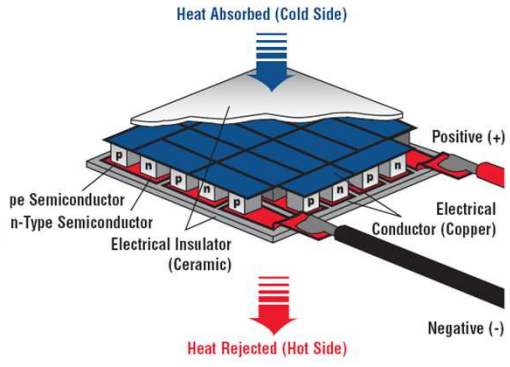
Emf: 5-40 mV/℃

Power: ~ 1 W/cm^2

Thermoelectric module: principle



… this is the way conventionnal thermoelectric modules are fabricated

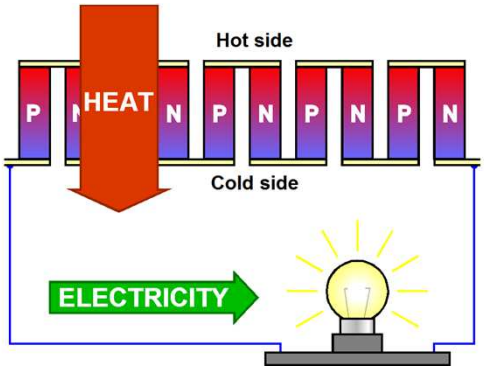


Source: Melcor

Application field: energy conversion

Conversion heat ➔ Electricity

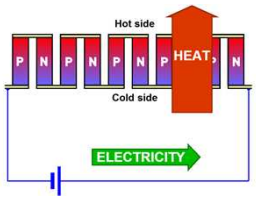
Thermoelectric Generator (TEG)



Reversibility:

Conversion
Electricity ➔ Heat

Peltier Cooler



Application field: waste heat harvesting

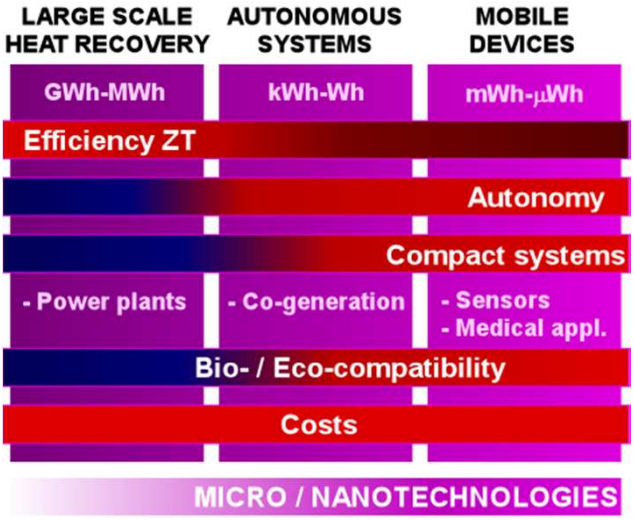
1 – Energy efficiency (TWh)
- Power plants
- Metalurgy, cementry
- Cars exhaust gas

2 – Cogeneration (kWh)
- Domestic heater/Boiler

3 – Autonomous devices (µWh)
- Human body
- Hot fluids in pipes
- Any other temperature differences…

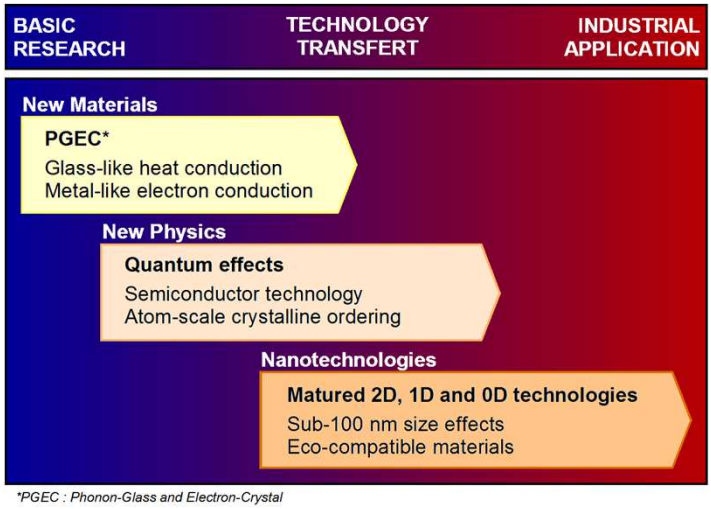
➔ **FREE energy source !!!**

Application field: waste heat harvesting



Nanotechnologies: what for?

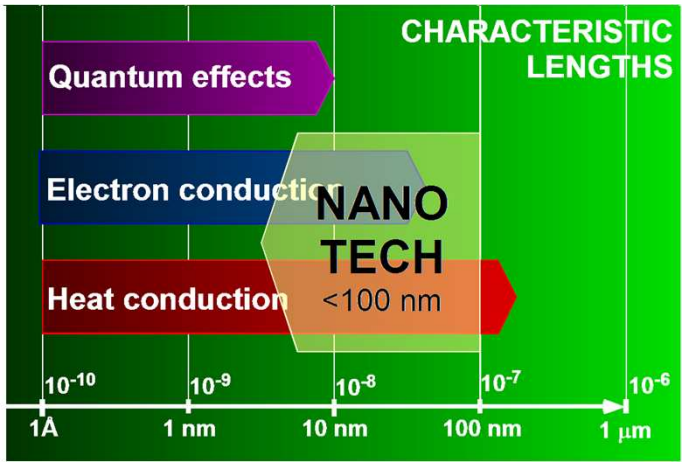
Thermoelectric materials: 3 research strategies



*PGEC : Phonon-Glass and Electron-Crystal

Nanotechnologies: what for?

Charge and heat characteristic lengths discrepancy



Nanotechnologies: what for?

Advantages

- Mastered sub-100 nm technologies
  - Thin films
  - Nanowires
  - Granulars

➔ Nanocomposites

- Size effects
  - Better efficiency than bulk
- Very small size design
  - micro- to nano-source of energy
- Eco- and Bio-compatibility

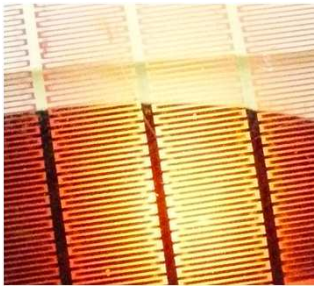
➔ Substitution technology for Bi_2Te_3

➔ Medical applications

Back to the lab:

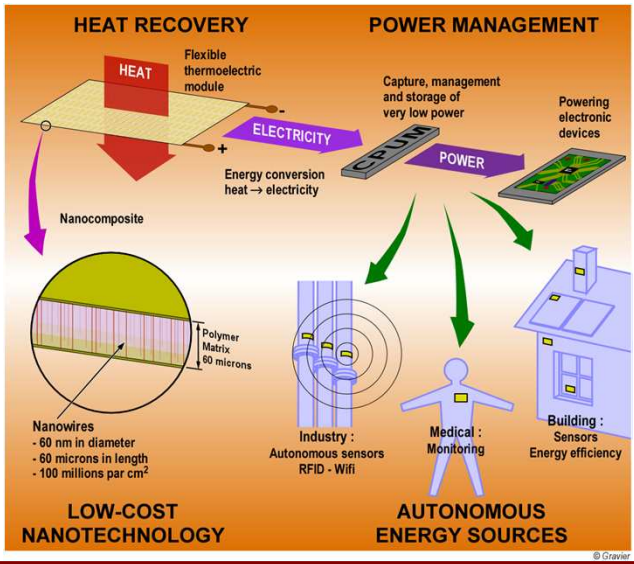
➔ **Focus to devices**

➔ **PROTOTYPE PLEASE!**



MNT research program

• MicroTEG for human body heat harvesting



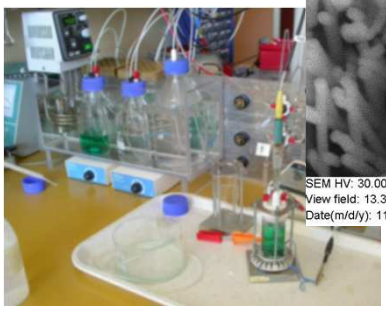
Hes·so
Haute Ecole Spécialisée de Suisse occidentale
Fachhochschule Westschweiz

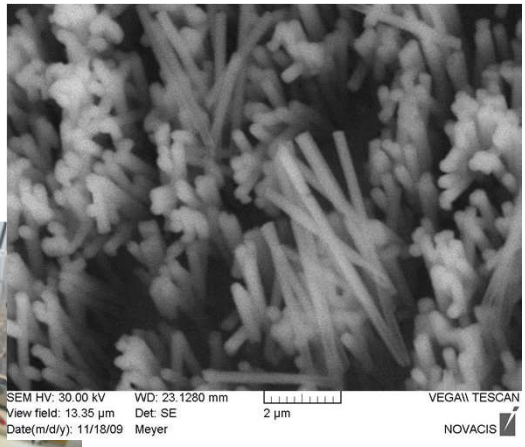
MNT research program

Low-Cost Nanotechnology

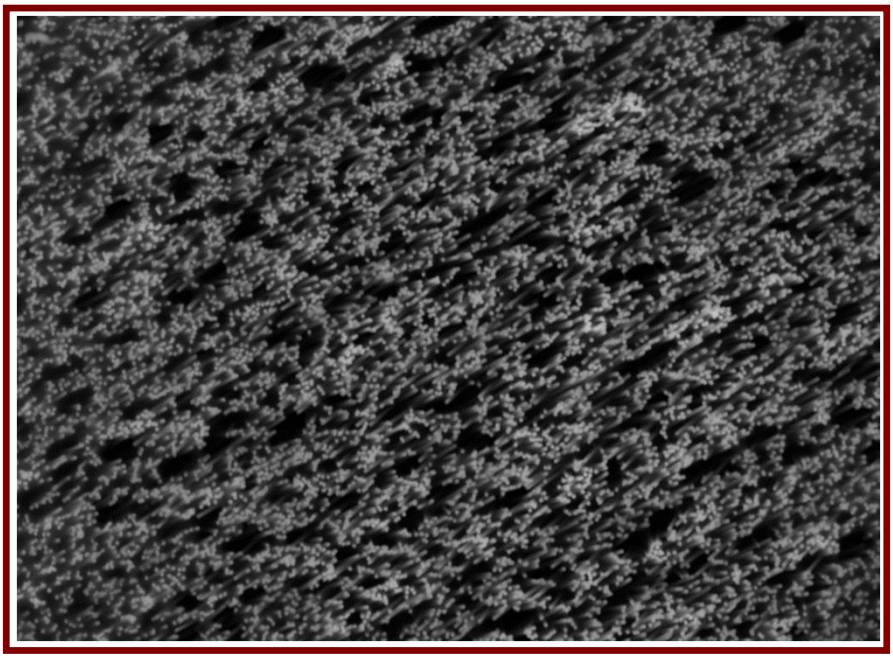
• Electrochemical growth in nanoporous template

➔ **Template synthesis**





SEM pictures: Dr. A.-G. Pawlowski (MNT)

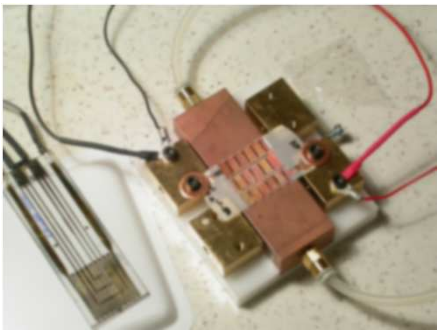


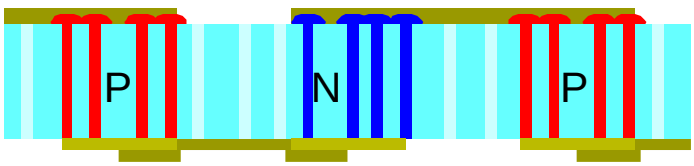
MNT research program

Flexible Micro-TEG

- Device-focused
  - 35 thermocouples/cm^2
  - 'Zero-Ohm' contacts
- Materials
  - BiTe/Cu or Ni (ref. material)*
  - NiCu/NiCr
  - Future: ZnO…

Benchmarking: ~100μW (ΔT=5K)





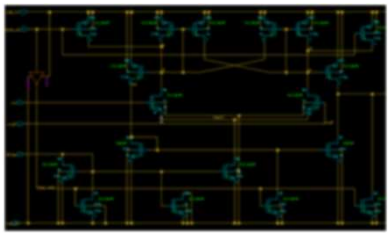
** In collaboration with Uni Metz, France*

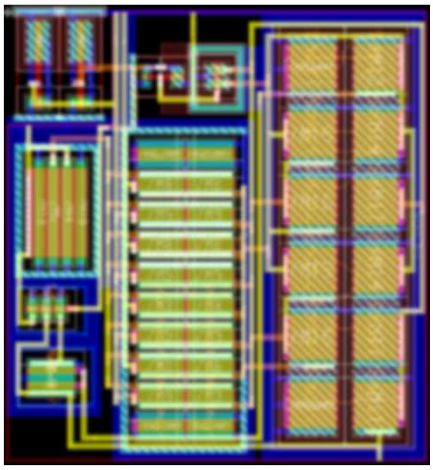
MNT research program

Clever Power Unit Management dedicated to micro-TEG

Team LEMI : Prof. F. Salchli

- Low power DC/DC converter
- Energy storage management
- Ponctual peak application





Outline

- **Thermoelectric module: principle**
- **Application field**
  - Energy conversion
  - Waste Heat Harvesting
- **Nanotechnology: what for?**
  - Thermoelectrics Research Strategies
  - Motivation for sub-100nm technology
- **MNT research program**
  - Low-cost Nanotechnology
  - Micro-TEG
  - Low-power Management Unit

Thanks for your attention…