Development of materials and devices for energy harvesting applications

Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

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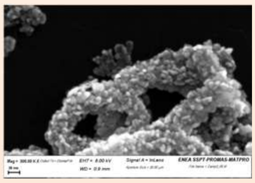
Industrial processes lead to a dispersion in the environment of high amounts of thermal energy in the form of hot flows generally in the gaseous and liquid form. The possibility of exploit these energy forms represents a challenge for the research that could be overcome through the development of materials thermo and pyroelectric as bulk and thin films for the production of generators. In particular thermoelectric materials in bulk form are already used both in the aerospace field as radioisotope thermoelectric generators (TEG) and in military applications and are on the market as Peltier cells. A large-scale application such as TEG requires the construction of components based on efficient materials with low cost production processes.
The activities are focused on the study bulk and thin film materials with good functional characteristics and low environmental impact through the development and implementation of conventional and unconventional fabrication techniques with features of low cost, environmental-energetic sustainability and strong industrial scalability.

Low temperature "green" synthesis of ZnO wurtzite nanoparticles: tailoring the process for effective production yield

METHODS

1. Wet chemical synthesis
2. Zn source: Zinc acetate dihydrate or Zinc chloride
3. Precipitating agents: NaOH or KOH
4. Solvents: Ethyl alcohol and deionized water
5. Chemicals recycling
6. Process's temperature (room temperature-60°C)
7. Post-synthesis thermal treatment (100°C for 2 hours)
8. Characterization: XRD (SmartLab Rigaku powder diffractometer), SEM (Zeiss-LEO 1530) .



Nanocrystalline wurtzite ZnO with nanoparticles of approx. 10 nm in size

RESULTS

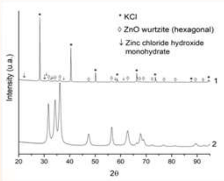
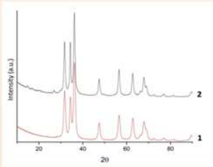


Figure 1. XRD patterns of ZnO nanopowders produced using: 1) Zinc Chloride and KOH, 2) Zinc Acet. Dihydrate and NaOH.

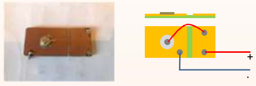


XRD patterns of 1) sample #2 (red line) and 2) sample with chemical recycling (black line).

DISCUSSION

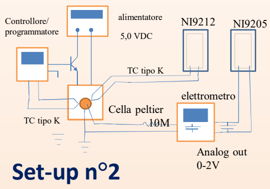
- The synthesis route used for sample #1 production needs to be improved.
- The synthesis used for sample #2 production was optimized by altering some parameters to increase the ZnO nanopowder production yield.
- Using Zinc acetate dihydrate and NaOH (Zinc acet. dehydr./NaOH =2) in ethanol a high efficiency of ZnO nanopowder was obtained (sample #2).

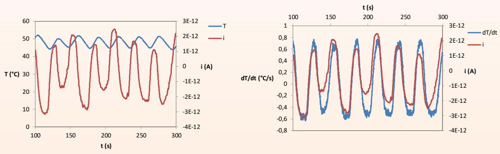
Pyroelectric measurements of wurtzite ZnS ceramics for thermal energy harvesting



A photo of the "pyro-cell" (left), and its schematic representation with connectors (right).

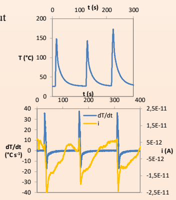
Set-up n°1





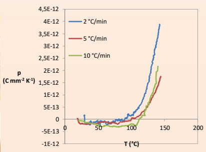
Pyroelectric current measurements on an ZnS ceramic sample, using testing set-up n°1

Set-up n°2



Testing set-up n°2.

Pyroelectric test system



Pyroelectric coefficient measurements

The pyroelectric behaviour of the wurtzite-ZnS ceramic samples was further confirmed by the measured current values both using Peltier cell and using air heather and cooling (for the thermal cycles for temperatures up to 150 ° C), which were in the order of tens of pA for a sample area of 34.19 mm^2.

Pyroelectric Test System was used to measure the pyroelectric coefficient and monitor its change at different frequencies.

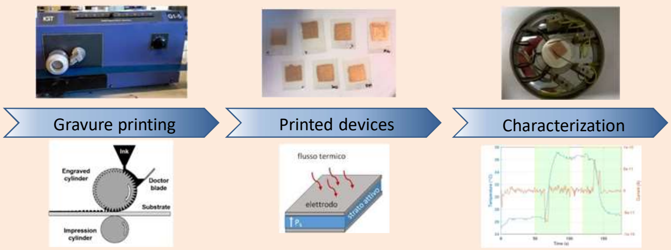
$$p = i / (A\ dT/dt)$$

Temperature range: 20 °C - 150° C, heating rate range: 2-10 °C/min.

Manufacturing processes of ceramic components for pyroelectric demonstrators

Study on printing processes for the production of pyroelectric films and devices

The aim of the research is to explore the potential of using printing techniques as rapid, versatile and low-cost production process for the direct deposition of films and pyroelectric devices

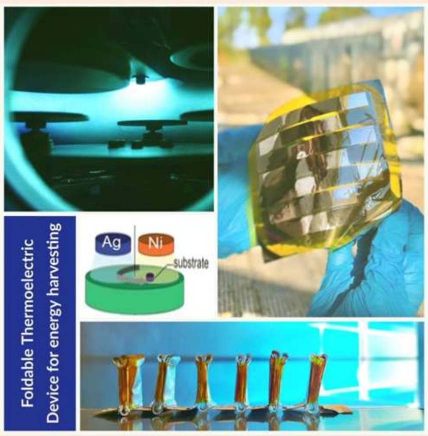


Preliminary results showed a pyroelectric current generation process for PVDF-based printed devices

Screen printing process for thermolectric films and devices

Screen printer | Screen | Thermoelectric generator screen printed on PET

The thin film TEG device consists of 8 pairs in series. Each pair is made up of PEDOT:PSS organic material (dark, in the figure) and Silver, both deposited by screen printing on a flexible substrate (PEN). The whole process is carried out in air and at room temperature. Continuous printing is possible by roll-to-roll technology.



Proof of concept demonstrator

- PVD deposition of metallic-based thermoelectric legs onto a Kapton film sheet
- Deposition of a protective film of PDMS
- Realization of a module by cutting and folding 2 couple of thermoelectric legs
- Each module is electrically connected to enhanced the final performance

Acknowledgments

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