PYROELECTRIC DEVICES OF ZnO-BASED SYNTHESIZED WURTZITE NANOPOWDERS

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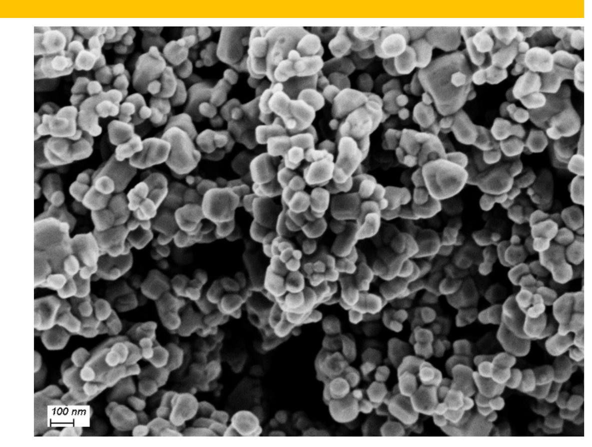
INTRODUCTION

Pyroelectric devices are widely used as temperature sensing. They produce electrical energy that can be used as energy source for small electronic devices or stored in commercial capacitors and supercapacitors.
This work aims to promote the use of an innovative, sustainable and low-cost technology for energy recovery through the development of pyroelectric devices based on Zinc Oxide (ZnO) ceramic components capable of recovering and accumulating energy from the environment.
Pyroelectric devices were obtained by integrating high-density thin cylindrical ceramic components starting from different synthesized ZnO nanopowders.

SYNTHESIS OF ZnO NANOPOWDER

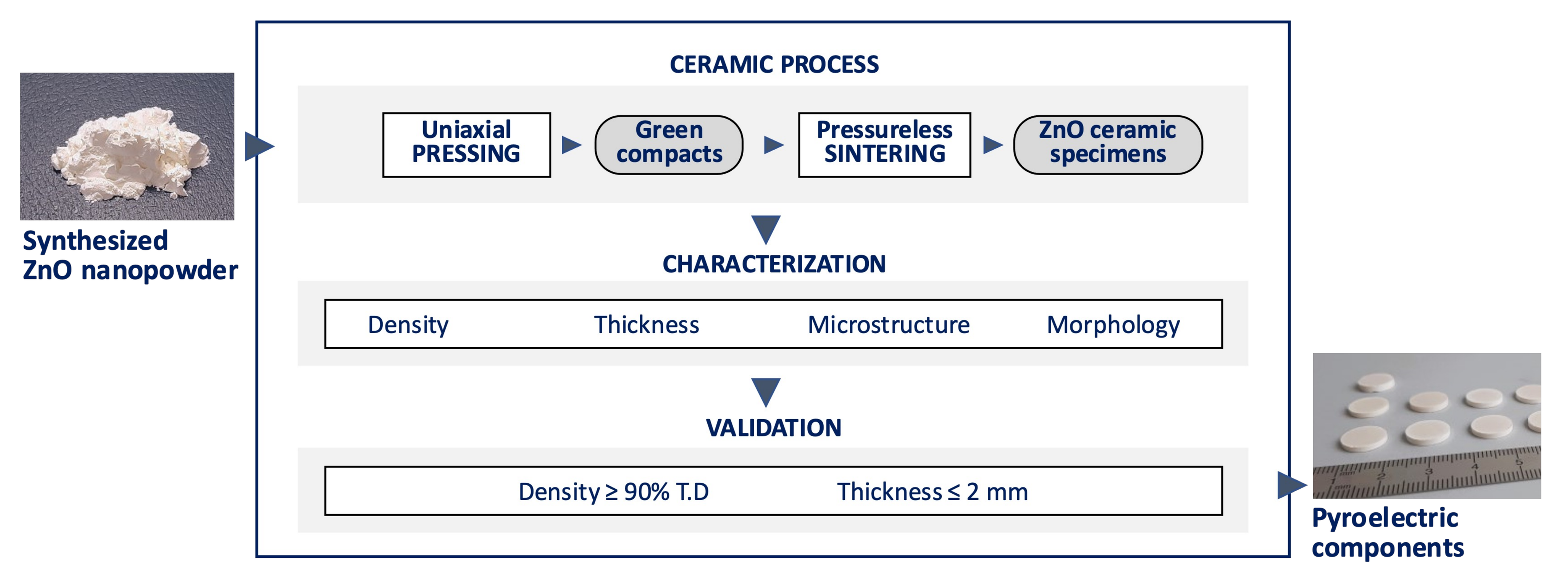
Nanostructured wurtzite powders of ZnO and ZnO with Mg doping of less than 10% were synthesized by low-temperature aqueous chemical growth method and characterized by XRD and SEM.
A measured quantity of magnesium acetate in water was mixed with an aqueous zinc acetate solution to obtain a concentration of 0.1 mol % of Mg.
The required amount of aqueous NaOH suspension was added drop by drop to the mixture to form a white precipitate (pH=8).



Nanocrystalline wurtzite Mg doped ZnO; particle size: 50 nm (FE-SEM LEO 1530).

FABRICATION OF CERAMIC COMPONENTS

ZnO ceramic specimens were produced to be used as component in the pyroelectric device.
Synthesized nanopowders (ZnO and Mg-doped ZnO) were used as starting material.
The sintering was performed by a simple and easy to scale up pressureless process. The pyroelectric components, with diameter of 10-11 mm, were obtained with high density (≥ 90% T.D.) and a thickness ranging from 1.2 to 2 mm to maximize the pyroelectric performances.

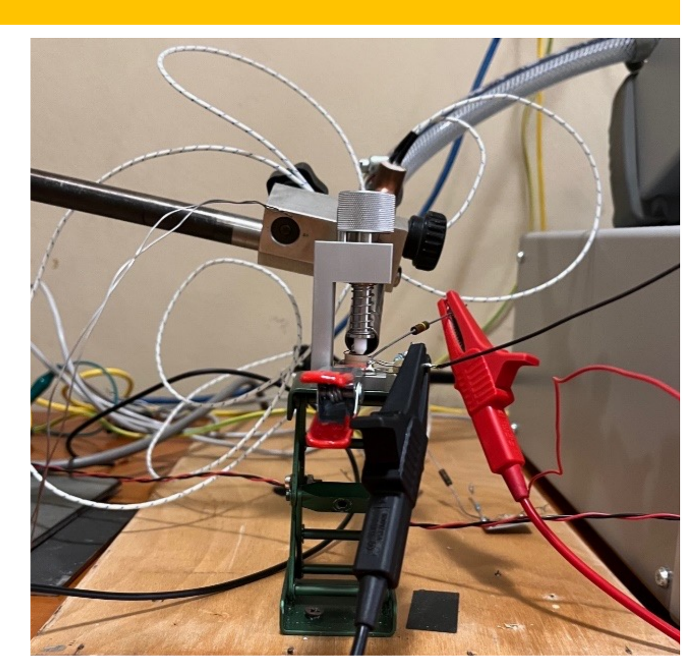


Fabrication of ceramic components for pyroelectric devices

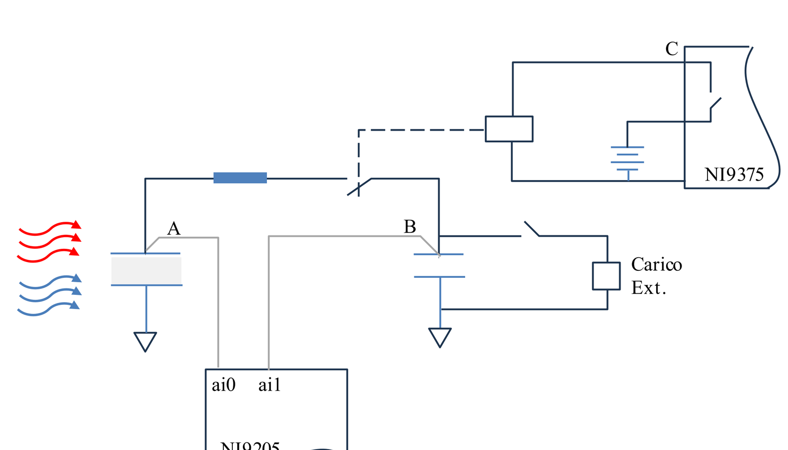
EXPERIMENTAL SET UP FOR PYROELECTRIC MEASUREMENTS

The pyroelectric properties of the ZnO based devices were measured by uniform ramps (r=5/10 °C/min) and cycles between Tamb and 200 °C (r=5/10 °C/s).
The obtained results were a pyroelectric coefficient of 4.3 ± 1.85 μC m^{-2} K^{-1} at T=100 °C and max current of 0.24 nA cm^{-2}.
Characterization of the Mg-doped ZnO specimens gives similar results.
The pyroelectric devices were realized by optimizing the charging circuit by also exploiting the reverse polarity part of the cycle and inserting a diode bridge rectifier with low voltage drop to passively achieve energy accumulation.

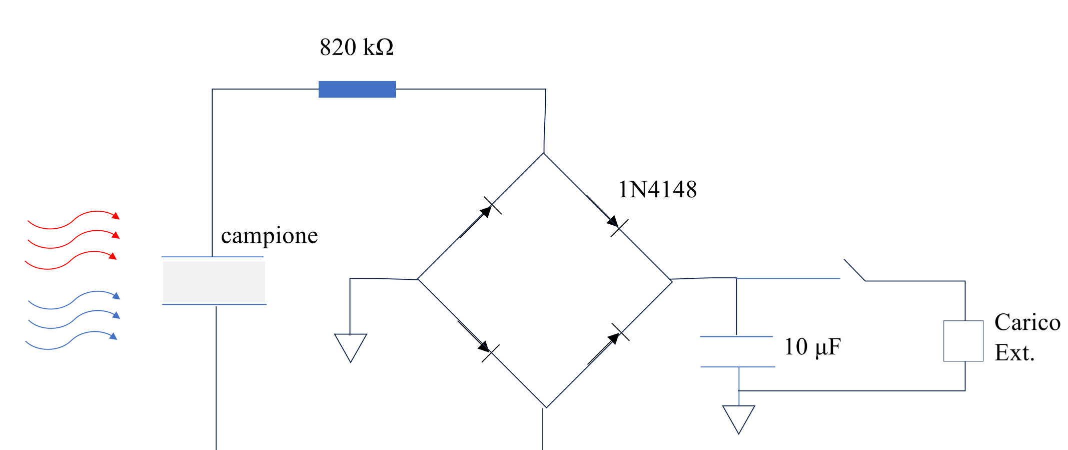
Circuits were developed for the accumulation in capacitors of energy produced by the pyroelectric effect. The use of energy in resistors and external circuits was demonstrated obtaining max voltage equal to 5 V on 10 μF capacitor (125 μJ accumulated energy) and max power of 42 nW continuous and 1.25 μW intermittent.



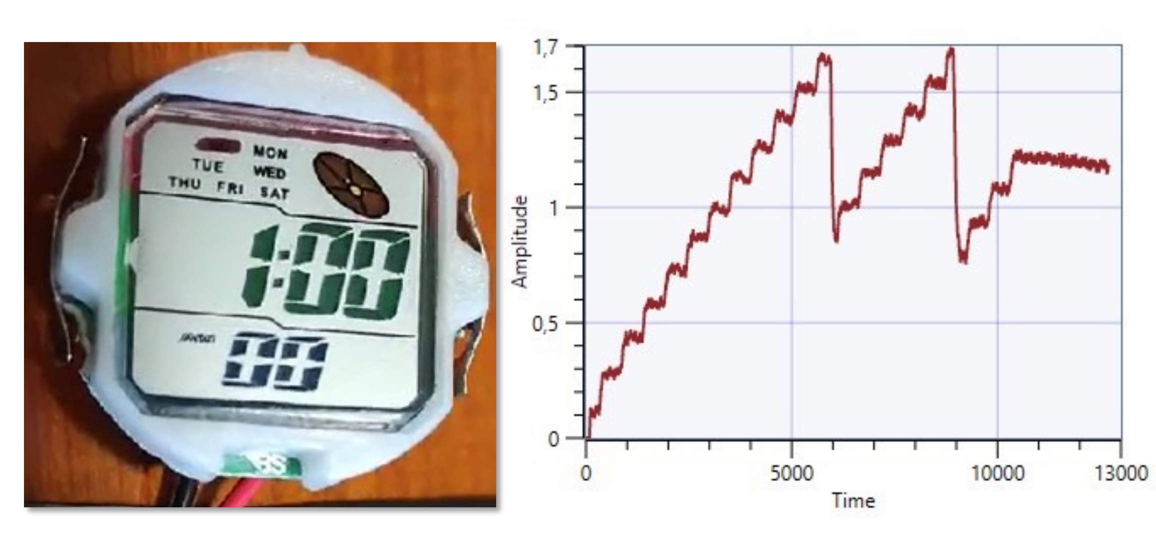
Pyroelectric device

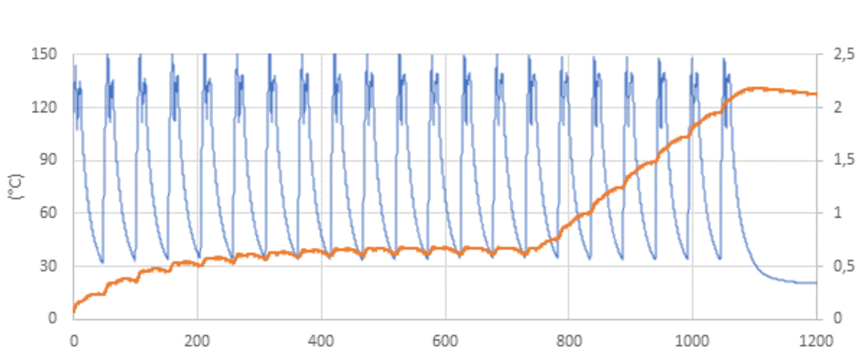


(a)



(c)





(b)

a) Circuit of capacitor charge
b) Test of capacitor charge
c) Charging circuit with active rectifier
Capacitor voltage with and without external load R=10 MΩ.
Average power at steady state: 42 nW.

Digital wristwatch (V_{nom} 1,5 V) connected in parallel to the capacitor (10 μF).
Operation between 1.6 and 0.7 V and duration of 7 seconds.
Repeatable cycle after 300 seconds of charging (5 thermal cycles).

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