A HIGH PERFORMANCE PZT TYPE MATERIAL USED AS SENSOR FOR AN AUDIO HIGH FREQUENCY PIEZOELECTRIC SIREN

C. MICLEA, A. IUGA, I SPANULESCU*, C.F. MICLEA, C. PLAVITU*,
L. AMARANDE, M. CIOANGHER, L. TRUPINA, C.T. MICLEA*, M. SUSU*
NATIONAL INSTITUTE FOR MATERIALS PHYSICS, Bucharest-Magurele, ROMANIA
*HYPERION UNIVERSITY, Faculty of Physics, Str. Calarasi 169, Bucharest, ROMANIA

INTRODUCTION

The increasing demand for high performance and sophisticated piezoelectric devices and transducers requires high quality piezoceramic materials and inovation in transducer design continues to be the driving force for the development of new piezoelectric materials. Piezoelectric ceramics based on PZT type perovskite are currently the material of choice, since they offer high piezoelectric activity and electromechanic coupling as well as a large range of high strains, dielectric constants and low dielectric loss. Traditional applications of piezoelectric ceramics include buzzers, speakers, sonars, ultrasonic transducers for nondestructive testing, transducers for medical diagnostics, actuators for precise positioning systems, ultrasonic motors, vibration control and so forth. The large area of application of piezoelectric materials is based on the fundamental property of such materials to develop an electric charge when subjected to a mechanical stress and viceversa.

OBJECTIVES

- To develop a soft type piezoceramic material with stable properties against temperature;
- The material should be based on doped lead titanate lead zirconate solid solutions;
- To chose the proper type and amount of dopants so as to produce a material with high coupling factor, dielectric constant, mechanical quality factor and displacement constant and low dielectric losses within a large temperature interval, at least up to about 200 ^oC;
- To use such a material for the fabrication of a high performance ultrasonic sensor;
- To design a high quality ultrasonic siren due to be efficiently used for performing acoustic emision in air.

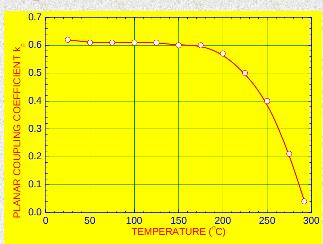
EXPERIMENTAL

The method used for the preparation of the material was the solid state reaction of oxide constituents. The raw materials were oxides and carbonates of p.a. purities. The chemical formula was $Pb_{0.85}Sr_{0.15}Bi_{0.01}Nb_{0.05}Ni_{0.06}Zr_{0.48}Ti_{0.41}O_3$. The reasons to chose this composition consisted in the known enhancing effect of these additives on the piezoelectric properties of the basic PZT material. Sr increases the dielectric permittivity and charge constant d_{33}. Bi is effective in suppressing the grain growth and Nb and Ni increase the electromechanical coupling coefficient and decrease the dissipation factor tanδ. Some supplementary additives like CeO_2, SiO_2 and PbO were also used in a total amount of 3%. The oxides were mixed for 6 h in a planetary ball mill in methanol media, and calcined at 850 ^oC for 3 h. The calcined product was wet milled for 24 h in a planetary ball mill, at a ball/powder weight ratio of 2:1, in order to produce a fine submicronic powder with an increased reactivity. The pressed samples were sintered at 1270 ^oC for 6 h.

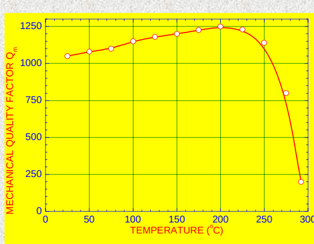
RESULTS

THE MATERIAL

We have measured the temperature dependence of the main parameters between room temperature and the Curie point. The results are shown in figures 1 *a)-f)*. The most remarkable thing about these results is that nearly all piezoelectric parameters, except charge and voltage constants, show a rather constant and steady variation with temperature over a large temperature interval up to nearly 250 ^oC after which their values drop much more rapidly to zero (**k_p**, **Q_m**, **d_{33}** and **g_{33}**) or increase to very high values (**ε_r** and **tanδ**) by approaching the Curie temperature, due to the sudden depoling effect of ceramic. Such a behavior is benefic for transducers in that they can be safety and efficiently used up to 250 ^oC, without any major risk to alter their functionality, but the most secure and recommended upper limit of working temperature must be taken at 200 ^oC.



a)



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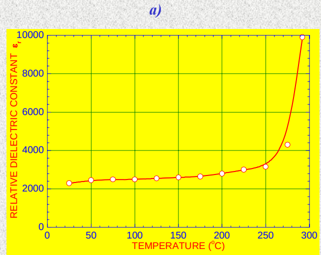

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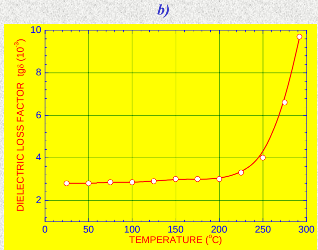

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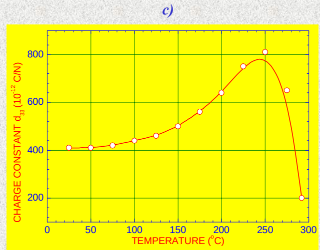

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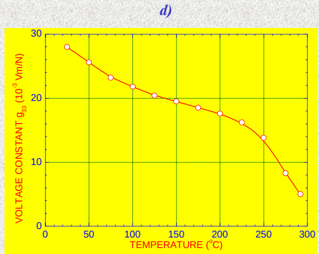

f)

Figure 1
The temperature dependence of the main piezoelectric parameters of the piezoceramic material:
a) k_p; b) Q_m; c) ε_r; d) tanδ; e) d_{33} f) g_{33}

THE SIREN

Two PZT disks of 20 mm diameter and 0.45 mm thickness, were glued on the two sides of a brass disk (21 mm diameter, 0.1 mm thickness). The poling directions of the discks were parallel. When an alternative emf at resonant frequency is applied to them, a stationary movement is generated. In order to increase the acoustic emission of the resonator in free space (air) an impedance matching between the high impedance ceramic and the low impedance air is necessary. This was achieved by using a rigid thin conical cardboard horn fixed in a ventral point of the bimorph (fig. 2). This horn assures an easy fixing of the device and contributes to the forward directing of the acoustical waves. The behavior of the siren is given in fig 3. The typical PZT resonance - antiresonance appear evident from the spectra (fig. 3). The equivalent circuit used to estimate the dissipation is shown in fig.4. The best resonance is obtained at 7.74 kHz. This result can be checked from the acoustic spectrum of the siren shown in fig. 5 where the maximum value occurs at 7.74 kHz. The spectrum appearance is not symmetric indicating a higher output at high frequencies induced by the proximity of other higher modes. From the acoustical spectra shown in fig. 5 the bandwidth and the relative bandwidth at 6 dB is 0.078, which gives a mechanical quality factor *Qm* of 13. This means that the excited system set free will still execute essentially 13 oscillations until it will regain its state of rest. The acoustical output of the siren gave a level of 130 dB at 10 cm on the axial line in front of the siren, with a driving emf of 10 Vef at full resonance.

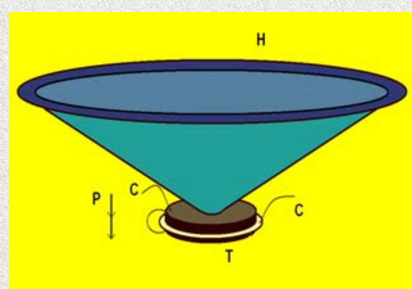

Figure 2
The siren assemble: C-the electric connectors, T- the triplet (bimorph + metallic plate), P- the paralel polarization vectors and H the acoustic horn.

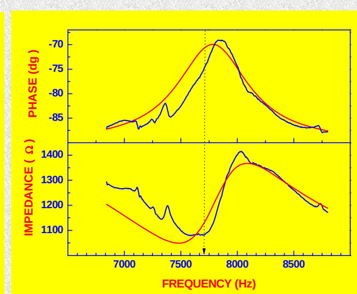

Figure 3
The impedance – phase spectra for the siren. The red graphs represent the equivalent cirquit's spectra. The arrow indicates the full resonance .

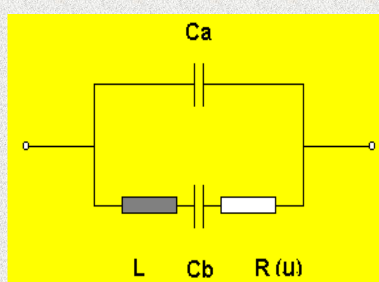

Figure 4
The electrical equivalent circuit for the siren. The values of the circuit elements are: Ca=16.98 nF, Cb=549.6 pF, L=772 mH and R=4.1 kΩ

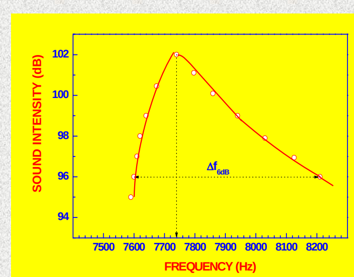

Figure 5
The acoustic spectrum of the siren at 10 cm in front of it on the axial line. The downwards arrow marks the resonance, while the horizontal one measures the bandwidth at 6 dB

SUMMARY

Associating two PZT disks into a bimorph with an intermediate metallic plate produces an acoustical resonator which can be dimensionally arranged through theoretical considerations to oscillate in the high frequency audio range. A rigid cardboard conical horn will improve the impedance match between the resonator and the surrounding air, allowing a high intensity sound to be emitted in an angle of ~π/2 rad. The siren can be used as a high intensity sound in alarm systems.