A PZT BASED MATERIAL FOR BIMORPH TYPE TRANSDUCERS AND A NEW OPTICAL METHOD TO EVALUATE THEIR PERFORMANCE

C. MICLEA, C. TANASOIU, C.F. MICLEA, I. SPANULESCU*, C.N. PLAVITU*, M. CIOANGHER, L. TRUPINA, C.T. MICLEA*

National Institute for Materials Physics, Bucharest-Magurele, ROMANIA

*HYPERION UNIVERSITY, Str. Calarasi 169, Bucharest, ROMANIA

1. INTRODUCTION

Many devices based on piezoelectric materials have been developed during the recent years. They received considerable attention since their application area become wider and wider, especially for MEMS. There are several piezoelectric displacement systems which use the direct expansion of piezoelectric materials. Among them the most usual are the multilayer actuators, flextensional moonie and cymbal actuators and unimorph or multimorph actuator. These devices can perform either actuator or sensor functions by utilizing the direct or converse piezoelectric effect and along this line, bimorph and unimorph configurations represent the classical examples of such devices. Such configurations have been widely used for acoustic sensing, relay, micropositioners and many others. Such structures can produce large displacements under low electric voltages as actuation elements or even high force as sensor elements. In order to accomplish this it is necessary to have a proper piezoelectric material of high performance.

2. OBJECTIVES

The main objectives of this investigation can be summarized as folows:

- To design a PZT type material with high piezoelectric characteristics, such as: high electromechanical factors k_p and k_{31}, high strain constants d_{33} and d_{31} and a reasonable dielectric constant ε_r. Such a material was a PZT based composition doped with nickel and niobium, according to the literature data.
- To use such a material for construction of a unimorph type transducer used in high displacement devices.
- To apply a new noncontact method to characterize the unimorph transducer, namely the Moiré deflectometry.

3. EXPERIMENTAL AND RESULTS

The material. The chemical formula of our material was as follows: $Pb_{0.97}Ba_{0.08}Nb_{0.03}Ni_{0.06}Zr_{0.46}Ti_{0.40}O_3$ and we denoted it as PBNNZT material. The material was prepared by the usual mixed oxide route. The powder was double calcinated for 3 h at 850 °C and 885 °C followed by milling for 48 hours in a planetary ball mill. Rectangular shaped samples of 50x20x10 mm^3 as well as disc shaped samples of 12 mm diameter and 1 mm thickness were then pressed from this powder at pressures of about 50 MP and sintered in dense alumina crucibles at temperatures between 1050 and 1300 °C for 6 hours. Piezoelectric properties were determined by resonance spectroscopy using an Agilent 4294 Impedance analyzer.

Material characterization. Figure 1 illustrates the powder morphostructures of PBNNZT material before and after annealing at 700 °C. X-ray diagrams of the powder evidenced the peaks of the perovskite structure indicating that the material is single phased. At the sintering temperature of 1200 °C the pressed compacts are fully densified up to about 98 % of TD as can be seen in figure 2. The dielectric and main piezoelectric properties were evaluated and the results are shown in table 1.

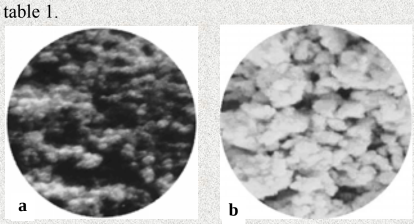

Figure 1
SEM images of the milled powder of PBNNZT: (a) freshly milled; (b) after annealing at 700 °C for 24 hours

Param	ε_r	k_p	k_{31}	d_{33} [pm/V]	d_{31} [pm/V]
Value	2000	0.64	0.42	680	-235

Table 1
Values of the main piezoelectric parameters of PBNNZT material, sinterized at 1200 °C for 6 hours.

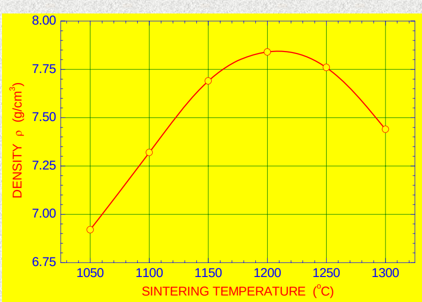

Figure 2
Density versus sintering temperature for PBNNZT samples

The transducer. Transducers in bimorph or unimorph type configurations are the most suitable ones and in this experiment we used the simplest unimorph configuration made from a thin piezoceramic plate bonded on a thin glass plate as shown in figure 3a and 3b and with one end fixed and the other one free. When subjected to a certain voltage ΔV the free end moves one side or another against the equilibrium position (V=0). The tip displacement to external excitation will depend on the material parameters, especially on d_{33}, k_{31} and ε_r as results from the figure of merit: $S = d_{31}/\varepsilon_0\varepsilon_r(1-k_{31}^2/4)$ A large S means a high sensitivity of the unimorph, and taking the values of the piezoelectric parameters from table 1 the figure of merit for our material was estimated to S= -13.88•10^{-3}

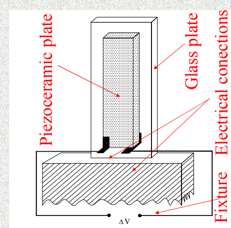

Fig. 3a
Schematic of the unimorph structure with one end fixed and the other end free

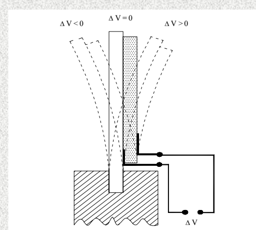

Fig. 3b The displacement of the free end of the unimorph under the influence of voltage ΔV applied to the piezoceramic electroded plate surfaces

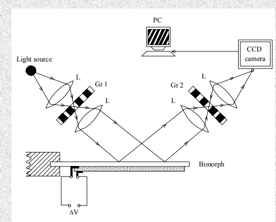

Figure 4
The experimental set up for Moiré deflectometry measurements

Transducer characterization. In order to characterize the behavior and performance of such transducer it is necessary to accurately determine its deformation under the influence of the electric field. Non contact methods are preferred they being more accurate than the contact ones. We have used for our experiments a new reliable optical method namely Moiré deflectometry which is quite accessible and provids good precision and easiness to use. The experimental set up for the measurements is shown schematically in figure 4. The working principle is rather simple. The telecentric projection of grating G_1 is reflected onto the unimorph glass surface and its image is focused onto the grating G_2. The Moiré fringes formed by the superposition of the two gratings are supplied to the CCD camera and displayed on the PC screen. Any deformation of the unimorph surface produces distorsion and a corresponding rotation of the fringes on the screen that can be easily measured. The deformation of the bimorph was monitorized by applying controlled voltages ΔV on the piezoelectric plate followed by analyzing the Moiré fringes. Figure 5 shows the images of Moiré fringes for different voltages. One can notice the rotation of the fringes with respect to the fixed points marked with arrows.

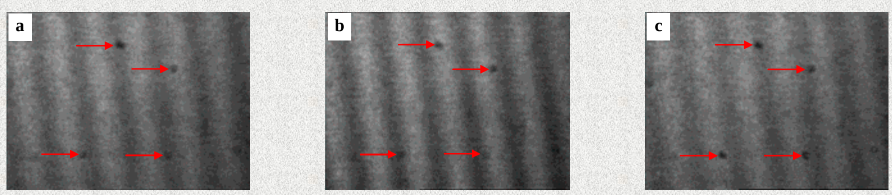

Figure 5. Moiré fringes obtained for different voltages applied to the plate: a) 0 V; b) 100 V, c) 200 V

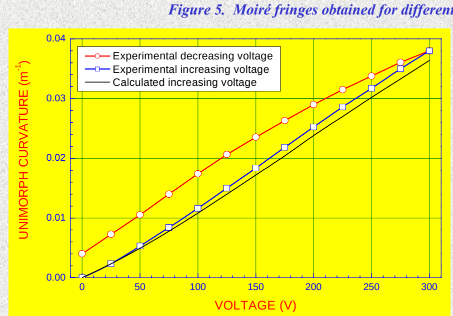

Figure 6
The dependence of the unimorph curvature on the voltage applied to the piezoceramic plate of the unimorph transducer

The experimental results regarding the characterization of the unimorph transducer are shown in figure 6. In this figure there shown the mesurements for increasing and decreasing displacement versus applied voltage as well as the results of a theoretical model of unimorph bending proposed in the literature. The calculated curve is a good aproximation of the real behavior, at least for increasing voltage. Discrepancy appeared in the case of decreasing voltage due to the nonlinearities of the piezoceramic materials.

4. SUMMARY

A soft PZT based material doped with Nb and Ni and having high electromechanical factor and high strain constants was designed in order to be used for a unimorph type transducer. The material was made by the usual mixed oxide route and was sintered at 1200 °C where the densification reached nearly 98 %. The main piezoelectric parameters were: k_p=0.64 and k_{31}=0.42 while the strain constants were d_{33}=680 pm/V and d_{31}=-235 pm/V respectively. Thin sheets were cut from the sintered ceramic body and a unimorph type transducer was made from it. The characterization of the transducer was accomplished by a new optical method namely by Moiré deflectometry. The experimental results, recording the bending as a function of the applied voltages showed that the method was sensitive enough and suitable for such measurements. A good fit between the experimental results and the calculated curve for transducer bending was found.