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A new PZT (Lead Zirconate Titanate) Piezoelectric Transducer Performances Analysis

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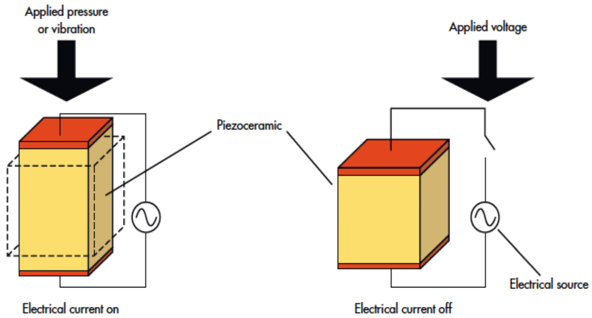
Abstract: *Presently there is number of Current measuring devices/ instrument are widely use for measurement of low and high current measurement. In the past decades there was surprisingly low attention of Electrical sensor, this sensor are very useful for replacing some kind of equipment in our existing power system. These measuring requirements are fulfill by using conventional sources out of which Piezoelectric Transducer is having major contribution in future. Considering the rate at which conventional sources are being consumed more power, cost, size and their life into control of power system, it is necessary to adopt alternate current measure ring technology for sustainable development. Out of various current measuring systems, Piezoelectric Transducer is most cost effective in addition to its various advantages. Considering the increasing share of Piezoelectric Transducer interfaced into the system it is necessary to study the power quality and current quality and stability issues. In case of conventional type CT use of copper is cost effective way is essential. This paper presents the operating principle, the performance MATLAB/SIMULATION, and the design of a piezoelectric transducer for measuring high currents. This transducer is based on the piezoelectric technique, the transducer designed can measure currents of around 1500 A current on software and 1000 A on prototype model.*

Keywords: *Piezoelectric polymer (PZT), Ferroelectret polymer, MATLAB Software,*

1. Introduction

A classical definition of piezoelectricity is the change of electrical polarization in a material in response to mechanical stress [1]. Pyroelectricity, instead, is described as production of electrical response due to the thermal excitation [2].



Piezoelectric Effect

The differences in material properties are considered in the model (Piezoelectric polymer PVDF, PZT & Ferroelectret polymer EMFi), and especially, the effects of dynamic and static forces and temperature to the electrical output signals provided by the sensors constructed from the materials are discussed [3].

1.1 Piezoelectric Polymer PVDF

PVDF $(CH2–CF2)_n$ is a piezoelectric material having a solid structure with approximately 50–65% crystal inity. The morphology consists of crystallites dispersed within amorphous regions. During the manufacturing process the PVDF sheet is stretched to cause a chain packaging of the molecules into piezoelectric b crystalline phase. These dipole moments are randomly oriented and result a zero net polarization. In the polarization stage the polymer is exposed to a high electric field. The dipoles are oriented in the direction of the field and a net polarization is formed. Finally, the film is metalized to provide electrodes. The change in film thickness due to an external force compressing the film generates a charge and thus, a voltage to appear at the electrodes. The piezoelectric coefficient dij is related to the electric field produced by a mechanical stress; the first suffix i = 1, 2, 3 refers to the electrical axis and the second j = 1, 2,……, 6 to the mechanical axis. The dij is a third-rank tensor conventionally expressed in terms of 3 X 6 matrix, however, crystal symmetry reduces the number of independent piezoelectric coefficients. The symmetry class of the poled polymer is orthorhombic 2 mm, for which the matrix can be written as,

$$d_{ij} = \begin{bmatrix} 0 & 0 & 0 & 0 & d_{15} & 0 \\ 0 & 0 & 0 & d_{24} & 0 & 0 \\ d_{31} & d_{32} & d_{33} & 0 & 0 & 0 \end{bmatrix} \quad (1)$$

The electrical flux density D and output voltage V_0 of a PVDF sensor are defined in Eqs. (2) and (3) as

$$D = d_{3n}X_n \quad (2)$$

And

$$Vo = g_{3n}X_n t \quad (3)$$

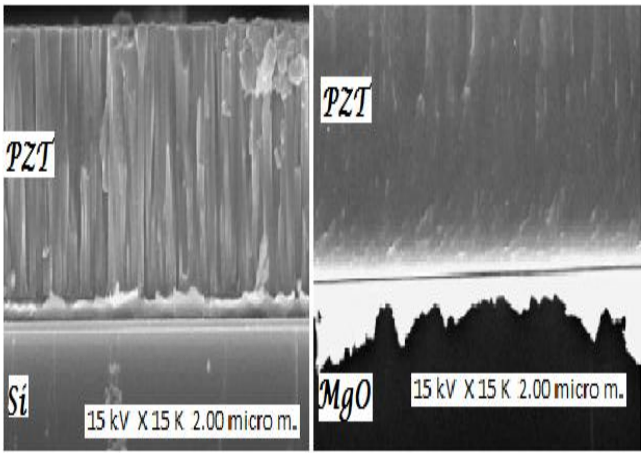
1.2 Ferroelectret Polymer EMFi

EMFi is a thin polypropylene (PP) material having a special cellular structure. The internal structure of EMFi is made by stretching the PP preform during manufacturing process in longitudinal and transversal directions. He film is charged with a corona discharge method using electric field strength exceeding the breakdown voltage of the air voids. The film is then coated with electrically conductive electrode layers. The EMFi material consists of three layers: smooth and homogenous surface layers and a dominant, thicker midsection. The midsection is full of flat gas voids separated by leaf-like PP-layers; the voids are formed by small physical nucleation agents during the biaxial orientation of the PP film preform. The voids can be compared to large electrical dipoles that are easily compressed in thickness direction by externally applied pressure. The lateral dimensions of the voids are about 10–100 lm and vertical dimensions of a few microns.

1.3 Piezoelectric polymer PZT [4]

Transverse piezoelectric properties of Pb(Zr, Ti)O3 (PZT) films were estimated using a simple measuring method we developed. The *c*-axis oriented PZT films were epitaxial grown on Pt/MgO substrates, while the polycrystalline PZT films with the preferential orientation of (1 1 1) were deposited on Pt/Ti/Si substrates using rf sputtering technique. The piezoelectric characteristics of the

PZT films with different crystalline structures were evaluated by the tip deflection of the unimorph cantilevers of the strip specimen just cleaved out from the substrates.



The PZT films on MgO substrates showed excellent linear piezoelectric deflection to the applied voltage with the stable piezoelectric coefficient *e*31 of −4.7 to −4.9 C/m2 which is caused by the ideal lattice motion of the single domain structure.

Table 1. *Typical properties of 28 µm thick PVDF and 70 µm thick EMFi materials*

Properties	Symbol	PVDF (28 µm)	EMFi (70 µm)
Piezoelectric coefficient(CN^{-1})	d_{33} & d_{31}	-33 X 10^{-12} & 23 X 10^{-12}	170 X10^{-12} & 2 X10^{-12}
Young's modulus ($N\ m^{-2}$)	Y	(2 to 4) X 10^{9}	< 1X 10^{6}
Pyroelectric coeffi. ($Cm^{-2}K$)	P	30 X 10^{-6}	(0.25 to0.45) X 10^{-6}
Capacitance ($pF\ cm^{-2}$)	C	380	14
Permittivity (Fm^{-1})	ε	(106 to 113) X 10^{-12}	10 X10^{12}
Relative permittivity	$\varepsilon/\varepsilon_0$	12 - 13	1.2
Mass density (kgm^{-3})	ρ	1.78 X 10^{3}	330
Surface resistivity of electrodes (ohms/square)	R_s	0.1	< 2
Dynamic range (Pa)	p	(1 to 5) X 10^{9}	< 1 X 10^{6}
Temperature range (^{0}C)	T	-40 to 100	-40 to 50
Glass transition temp. (K)	T_c	223	278

Ideal Characteristics of transducer material.

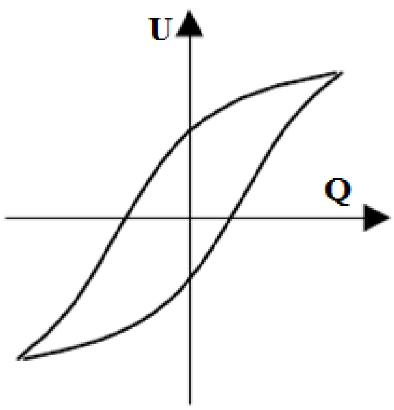


Figure 1. *Theoretical Result Electric field (Q) V/S magnetic field (U)*

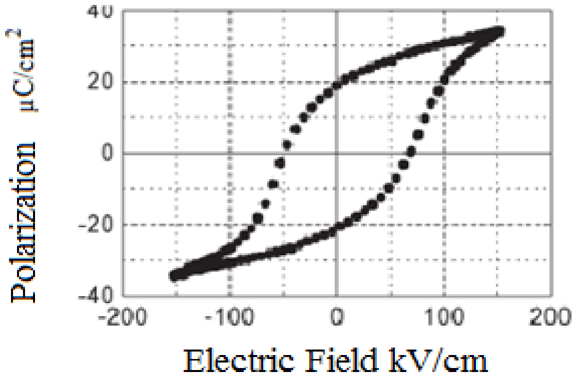


Figure 2. *Hysteresis loop of PZT thin film*

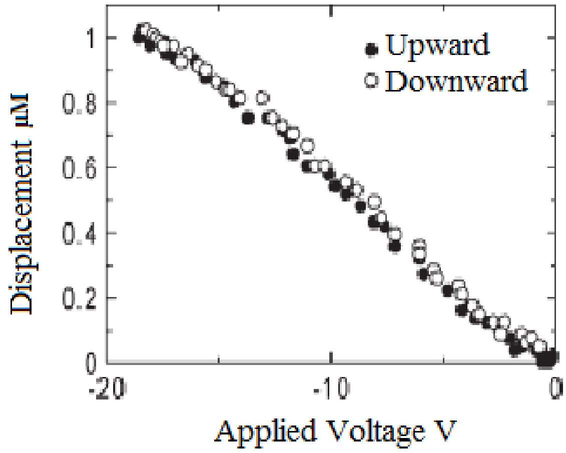


Figure 3. *Tip displacement as a function of Applied Voltage*

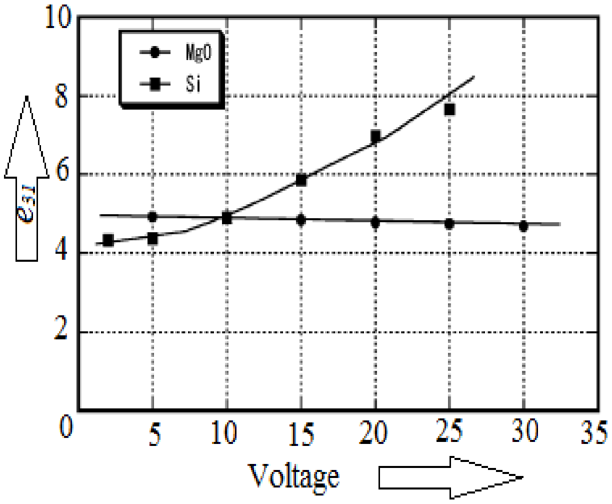


Figure 4. *Piezoelectric coefficient $e_{31}$of the PZT films deposited on Pt/MgO and Pt/Ti/Si substrates as a function of applied voltage*

2. SOFTWARE ILLUSTRATION FOR MATERIAL

In the process of testing piezoelectric current sensor, the first step is selection of appropriate piezoelectric material suitable for better performance of the system, which has to be simulated and verified in MATLAB environment. An algorithm is developed to decide exact material requirement for piezoelectric current sensor by verifying performance characteristics of the piezoelectric material. The case I illustrates the performance results of three different piezoelectric material characteristics.

2.1 Algorithm

Step-1: start the program

Step-2: Assign the value of parameters

I_m(Magnitude of input primary current),

f (supply frequency),
l (length of conductor),
a (distance between conductor),

g_{33} & d_{33}(Voltage constants and charge constants),

t_r and r (thickness and radius of material),

μ_o(permeability of free space) and

t (time period)

Step-3: Calculate the values of,

$\omega = 2 \times \pi \times f;$

$I = I_m \times \text{Sin}(\omega t);$

$F_{mag} = u_0 \times I^2 \times l/(2\pi a);$

$V = g_{33} \times F_{mag} \times t_1/(2\pi r);$

$Q = d_{33} \times F_{mag};$

Step-4: Plot (t, I,'r');
Plot (t, Fmag,'k');
Plot (t, V,'Color', cmap (i, :));
Plot (t, q,'Color', cmap (i, :));

Step-5: stop.

3. MATLAB PROGRAME

```
Im=1000;
disp(['current value of Im is',num2str(Im,7)]);
c=input(' do you want to change(y/n) :','s');
if(c=='y')
Im=input('enter the value of Im: ');
end
f=50;
disp(['current value of f is ',num2str(f)]);
c=input(' do you want to change(y/n) :','s');
if(c=='y')
f=input('enter the value of f: ');
end
```

```
l=80e-3;
disp(['current value of l is ',num2str(l,6)]);
c=input(' do you want to change(y/n) :','s');
if(c=='y')
l=input('enter the value of l: ');
end
a=13e-3;
disp(['current value of a is ',num2str(a,6)]);
c=input(' do you want to change(y/n) :','s');
if(c=='y')
a=input('enter the value of a: ');
end
w = 2*pi*f;
t = 0:0.0001:2/f;
u0=4*pi*10^-7;
end
I = Im*sin(w*t);
Fmag = u0*I^2*l./(2*pi*a);
t1=6e-3;
end
```

4. MATLAB RESULT

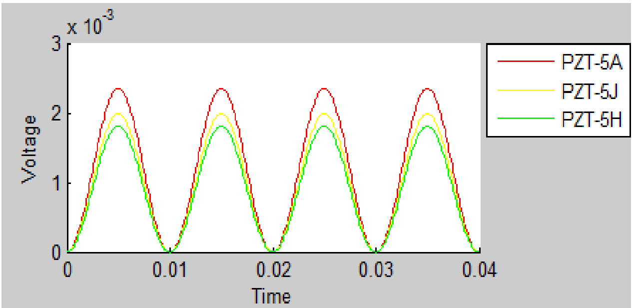


Figure 5. *The voltage response of different piezoelectric material*

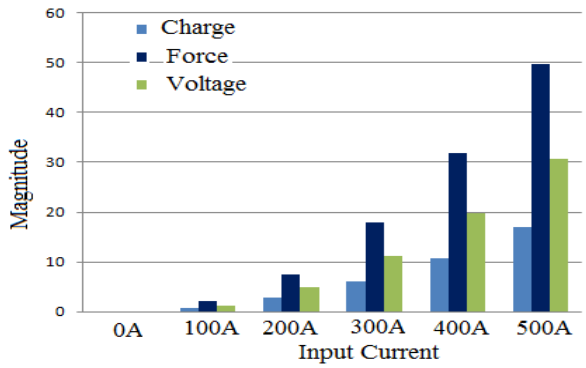


Figure 6. *Comparative responses for variable input current for PZT-5J material*

Above chart shows that the there is variation in force, charge and voltage of material as input primary current increases the output parameters of material get increases. Hence performance of PZT-5J piezoelectric material is analyzed. The hardware description parameters generated from algorithm are used to implement hardware structure of two wire piezoelectric current sensor and appropriate material selection has done for the same.

5. Conclusion

The software illustration model describes the interaction between an electrical signal and mechanical motion. The model presented in this study predicts the sensor operation of a sensor constructed from piezoelectric PVDF or ferroelectret EMFi materials.

References

[1] Avinash Suryakant Katkar, M.F.A.R.Satarkar. “ Novel Approach for Measurement of High Current by Piezoelectric Technology.” 978-1-4673-0934-9/12/$31.00 ©2012 IEEE.

[2] J.S. Harrison, Z. Ounaies, Polymers, Piezoelectric, Encyclopedia of Smart Materials, John Wiley & Sons, 2002.

[3] T. Furukawa, Piezoelectricity and pyroelectricity in polymers, IEEE Trans. Electrical Insulation 24 (1989) 375–394.

[4] Satu Kärki, Jukka Lekkala “A lumped-parameter transducer model for piezoelectric and ferroelectret polymers” 0263-2241/ - see front matter. 2011 Elsevier Ltd. All rights reserved.

[5] Isaku Kanno, Hidetoshi Kotera, Kiyotaka Wasa “Measurement of transverse piezoelectric properties of PZT thin films” Kanno et al. / Sensors and Actuators A 107 (2003) 68–74. Elsevier Ltd. All rights reserved.

[6] X. Qiu, Patterned piezo-, pyro-, and ferroelectricity of poled polymer electrets, J. Appl. Phys. 108 (2010) 011101–011119.

[7] E.H. Yang, Y. Hishinuma, J.-G. Cheng, S. Trolier-McKinstry, E. Bloemhof, and B. M. Levine, “Thin-film piezoelectric unimorph actuator-based deformable mirror with a transferred silicon membrane,” J. Microelectromech. Syst., vol. 15, no. 5, pp. 1214–1225, Oct. 2006.

[8] J. H. Lee, K. H. Yoon, K. S. Hwang, J. Park, S. Ahn, and T. S. Kim, “Label free novel electrical detection using micromachined PZT monolithic thin film cantilever for the detection of C-reactive protein,” Biosens. Bioelectron., vol. 20, no. 2, pp. 269–275, Sep. 2004.

[9] N. Ledermann, P. Muralt, J. Baborowski, M. Forster, and J. P. Pellaux, “Piezoelectric Pb (Zrx, Ti1−x)O3 thin film cantilever and bridge acoustic sensors for miniaturized photoacoustic gas detectors,” J. Micromech. Microeng., vol. 14, no. 12, pp. 1650–1658, Dec. 2004.

[10] Y. B. Jeon, R. Sood, J.-H. Jeong and S.G. Kim, “MEMS power generator with transverse mode thin film PZT,” Sens. Actuators A, Phys., vol. 122, no. 1, pp. 16–22, Jul. 2005.