Study on ZnO and BaTiO3 for Low Frequency Applications

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Abstract:
In this paper, we have discussed about piezo electric materials and its properties which are suitable for design and fabrication of low frequency applications. In this we have multiple of piezoelectric materials for the design of low frequency cantilever beam among them some of are here like, ceramic, lead zirconate titanate, composite material, barium titanate, quartz, pvdf, lithium niobate, lithium tantalate, zinc oxide, piezoelectric ceramics, among this here we compared two piezo electric materials they are P(VDF-TrFE) and copolymer such as ZnO and BaTiO3. This process has been done through polarization and annealing. Initially the process the process starts by simulation which includes calculation of polarization frequency of a compared elements, further the characterization of an BaTiO3 and ZnO will be done by oscilloscope and the fabrication of this materials will done through electrospinning.

Keywords: Piezoelectrical co-polymer P(VDF-TrFE), Cantilever beam, Piezoelectric material, BaTiO3, ZnO, Electrospinning.

INTRODUCTION

Piezoelectric materials are the materials that may produce electric energy upon application of mechanical stress. A generally known piezoelectric substance is quartz. The method involves the creation of an electric charge as a result of the electron's mobility in response to stress.

There are six different types of piezoelectric materials, including single crystalline minerals like quartz, piezoceramics like lead zirconate titanate (PZTs), piezoelectric semiconductors like ZnO, polymers like polyvinylidene fluoride (PVDF), piezoelectric composites, and glass ceramics. Moreover, PZT fibres can be combined with resin to create PZT or macro fibre composites. The mechanical and piezoelectric properties vary among these distinct piezoelectric materials. Due to the great efficiency of power generation, PZT material has been used in numerous commercial goods.

Zinc oxide crystallises hexagonal wurtzite and cubic zinc blende in two major forms. Wurtzite's structure is most stable and prevalent in ambient conditions. On substrates with a cubic lattice structure, adding ZnO can stabilise the zincblende form. These materials can be used in manufacturing rubber, ceramic industry. BaTiO3 (BT) was the first polycrystalline ceramic material ever identified that demonstrated ferroelectricity. As we discussed above, ZnO and BaTiO3 can be used in low frequency applications such as energy harvesting, cantilever beams, acoustic applications and so on.

LITERATURE SURVEY

Furukawa *et al* [1] claim that while PVDF's ferroelectric domain switching period at 200 MV-m1 is only 4 s, 10 Hz is more than enough it is now time for ZnO to swap domains /P(VDF-TrFE) thin films. The output sinusoidal signal is created by an Agilent 33210A arbitrary waveform generator and is after which promoted to the necessary power by an Ultravolt 5HVA24 high voltage module. With an Agilent MSO8104A mixed-signal sample, it is possible to monitor the film response and applied electric field (E = Va/d, where Va is the applied voltage and d is the film thickness).

Li *et al* [2] Poly vinylidene fluoride-co-trifluoro ethylene/carbon-based nanomaterial composite sheets have been proposed for use in pressure sensing applications. A composite piezoelectric film made of PVDF and TrFE was given a better crystallinity and piezoelectric action by utilising polarisation and annealing. They reported that the content of the -phase rose from 73.6% to 86.4% and that the piezoelectric efficiency increased, going from 19.8 1.0 to 26.4 1.3 pC/N. yet, there is place for improvement in the research approach taken to produce the videos. The fabrication method affects both the phase crystallisation and the piezoelectricity of the composite.

Utilising *Date et al* [3], we are aware that higher remnant or permanent polarisation suggests more ZnO NP alignment and piezoelectricity. The results show that higher ZnO weight percentages result in more residual polarisation. These findings demonstrate that regardless of whether 75 MV-m-1 of applied electric field is increased., piezoelectric ZnO nanoparticles contained in P(VDF-TrFE) piezo-polymer matrices do in fact boost bulk film piezoelectricity. Yet, it appears that the remaining polarisation has reached saturation.

Marzencki *et al* [4] The construction and fabrication of a thin film AlN cantilever micro-generator was successful. It can generate 0.038 lW of power at a resonance frequency of 204 Hz from an acceleration of 0.5 g (g = 9.81 m/s2). Sadly, due to the characteristics of the AlN material, the output power is constrained to low power levels.

Fang *et al* [5] created a compound cantilever design with nickel metal to enhance output frequency and power scalability. The purpose of the cantilevers is made at low frequencies. It has been found that the resonance frequency is not achieved when the stimulation frequency falls within a very limited bandwidth of approximately 2-3 Hz, the output voltage decreases. In most cases, the generated frequency should be determined before developing or producing those devices. In order to create a gadget that will operate flawlessly across a range of frequencies, this is done. It is possible to create cantilevers with a lower resonance frequency by taking the right structural characteristics into account. The specified vibration frequency level establishes the middle level of resonance frequency.

Liu *et al* [6] Prior cantilever construction only achieved 3.06 V, which is lower than the cantilevers' ultimate overall value (5.256 V). Performance of the array under 229 Hz of stimulation. There is a 120-phase gap between C1 and C2. After rectification, only 2.51 V of dc voltage with a maximum output of 3.15 W is produced across the capacitor because this transfer function prevents the cantilevers from electrically accumulating. It is quite gratifying to see that the arrayed device increased the generator's power output and operation bandwidth.

In order to generate 60 lW of output power at a 572 Hz resonance frequency, Elfrink *et al* [7] created a 2 g (g = 9.81 m/s2) MEMS-based AlN piezoelectric cantilever micro-generator. We developed a variety of devices using different cantilever beams and mass geometries. For the top and bottom coverings, glass wafers were employed. In the top image, design and package architecture of the generator are displayed in a resting condition, and in the bottom image, the resonance-induced mass movement of the generator is depicted. The chambers that held the devices with top and bottom glass substrates were capable of dispersing up to 400 lm of mass.

Using PEDOT/PSS electrodes (poly(3,4-ethylenedioxy-thiophene)/poly(4-styrene sulfonate)), Lee *et al* [8] created a PVDF film. Indium tin oxide (ITO) and platinum, two inorganic electrode materials, were compared to sheets coated with PEDOT/PSS (Pt).It was observed that even when films with Pt electrodes were subjected to vibrations of the same amplitude throughout a range of frequencies at a frequency of 33 kHz, fatigue crack deterioration of the electrode surface started to appear. The ITO electrodes were affected by operating at a 213 Hz frequency. Yet, the electrodes were not in danger during the 10 hours while the PEDOT/PSS film was operating at 1 GHz.

Mohammadi *et al* [9] developed a piezo - electric substance based on fibres. As a result, flexible composites were developed, 40% of which were made of aligned piezoelectric fibres and 60% of which were made of epoxy. The composite was cut into a number of 34 mm x 11 mm rectangular plates of varying thicknesses, with the fibres oriented in the direction of the plate thickness, to create a number of samples. The reaction was measured by dropping a 33.5 g, 20 mm diameter stainless steel ball onto the voltage output of the test samples from a height of 10 cm.

Cho *et al* [10] enhanced Richards' work by analytically maximising the coupling coefficient in a piezoelectric power harvesting device and then testing the optimization technique in a real-world environment. A rectangular thin-film PZT membrane was first mathematically modelled with electrodes of varied sizes on both sides and two layers: a passive elastic material and a piezo - electric material. The coupling coefficient increases with electrode size, reaching its maximum when the electrode covers 42% of the membrane's surface, per their model. For each thickness of the substrate layer, there is a suggested thickness for the piezoelectric layer, which is rigid and has a preferred thickness.

A piezoelectric bimorph's effectiveness was also studied by Jiang *et al* [11]. By simulating a cantilever bimorph with a proof mass attached to one end, they were able to compare performance to various physical and geometrical features. The results revealed that by raising the proof mass attached to the cantilever's end and decreasing the thickness of the bimorph's elastic layer, the resonance frequency of the system was dramatically reduced. It has been established that lower resonance frequencies lead to higher maximum power. Anderson and Sexton (2006) accomplished the same result by modifying the geometrical and physical properties of a related bimorph. The researchers found that adjustments in the mass, length, and width of the proof had an impact.

Gurav *et al* [12] study's primarily concentrated on raising the output of micro-scale piezoelectric cantilever harvesters. An uncertainty-based design optimization strategy that takes into account the fine form tolerances and the wide range of material properties that are involved in micro-scale machining operations was used to establish the ideal design criteria for a cantilever power harvester at the microscale. Each of the geometrical parameters that needed to be optimised had limits set on it to prevent designs from being unbuildable. An analytical comparison of the optimised geometry and a cantilever's baseline geometry showed that the enhanced geometry outperformed the baseline design by 30% in terms of power.

CONCLUSION

Based on this study, the piezoelectric materials such as P(VDF-TrFE), ZnO and $BaTiO_3$ are used to design and fabricate the low frequency cantilever beam. Further, cantilever beams with various dimensions are to be designed and simulated using COMSOL Multiphysics 5.3a software and design suitable for the fabrication with lowest frequency obtained is to be suggested for fabrication. Low frequency application such as energy harvesting, cantilever beams, acoustic applications and so on can be implemented using ZnO and $BaTiO_3$.

REFERENCES

1. T. Furukawa and G. E. Johnson, “Measurements of ferroelectric switching characteristics in polyvinylidene fluoride,” Appl. Phys. Lett., vol. 38, no. 12, pp. 1027–1029,mj 1981
2. Li, J.-W.; Huang, C.-Y.; Chen, K.-Y.; Chen, J.-X.; Hsu, X.-Y.; Chen, Y.-F.; Kuo, C.-F.J.; Cheng, C.-C.; Suen, M.-C.; Chiu, C.-W. Enhanced Piezoelectric Properties of Poly (Vinylidenefluoride-Co-Trifluoroethylene)/Carbon-Based Nanomaterial Composite Films for Pressure Sensing Applications. Polymers 2020, 12, 2999.
3. M. Date,T. Furukawa, and E. Fukada, “Hysteresis phenomena in polyvinylidene fluoride under high electric field,” J. Appl. Phys., vol. 51, no. 2, pp. 1135–1141, 1980.
4. Marzencki M, Basrour S, Charlot B, Grasso A, Colin M, Valbin L. Design and fabrication of piezoelectric micro power generators for autonomous microsystems, DTIP’05, Montreux, Switzerland; June 01–03, 2005.
5. Fang HB, Liu JQ, Xu ZY, Dong L, Wang L, Chen D, et al. Fabrication and performance of MEMS-based piezoelectric power generator for vibration energy harvesting. Microelectron J 2006;37:1280–4.
6. Liu JQ, Fang HB, Xu ZY, Mao XH, Shen XC, Chen D, et al. A MEMS-based piezoelectric power generator array for vibration energy harvesting. Microelectron J 2008;39:802–6
7. Elfrink R, Kamel TM, Goedbloed M, Matova S, Hohlfeld D, van Andel Y, et al. Vibration energy harvesting with aluminum nitride-based piezoelectric devices. J Micromech Microeng 2009;19.
8. Lee, Joo J, Han S and Koh S K 2004 Multifunctional transducer using poly(vinylidene fluoride) active layer and highly conducting poly(3,4-ethylenedioxythiophene) electrode: actuator and generator
9. Mohammadi F, Khan A and Cass R B 2003 Power generation from piezoelectric lead zirconate titanate fiber composites Proc. Materials Research Symp.
10. Cho J, Anderson M, Richards R, Bahr D and Richards C 2005a Optimization of electromechanical coupling for a thin-film PZT membrane: I. modeling J. Micromech. Microeng. 15 1797–803
11. Jiang S, Li X, Guo S, Hu Y, Yang J and Jiang Q 2005 Performance of a piezoelectric bimorph for scavenging vibration energy Smart Mater. Struct. 14 769–74
12. Gurav S P, Kasyap A, Sheplak M, Cattafesta L, Haftka R T, Goosen J F L and Van Keulen F 2004 Uncertainty-based design optimization of a micro piezoelectric composite energy reclamation device Proc. 10th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conf. pp 3559–7