Flexible piezoelectric micro-power generator based on P(VDF-TrFE)

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ABSTRACT – In this paper, we have successfully demonstrated the fabrication of poly(vinylidene fluoride) trifluoroethyleneP(VDF-TrFE) thick films on flexible substrate using rod mayer method. The flexible piezoelectric transducer was able to generate a maximum output power of 0.552µWat an external load of 1MΩ with a maximum peak voltage of 743mV when pinching between two fingers with a force of 5N.

1. INTRODUCTION

Piezoelectric materials have been widely used for various energy harvester applications such as biomedical engineering, smart sensor detection, and flexible electronic applications [1]. Poly(vinylidene fluoride) (PVDF) and PVDF-trifluoroethylene (PVDF-TrFE) are piezoelectric polymers with lower piezoelectricity compared to ceramic based piezoelectric material such as PZT but can conform to complex structuralsurfaces due to their polymeric nature. PVDF and PVDF-TrFE is a highly non-reactive, flexible,inexpensive, and leading polymer with good piezoelectric property [2].

The disadvantage of the PVDF piezoelectric materials is that it requires mechanical stretching, which is not suitable for conventional microfabrication processes [3]. PVDF-TrFE in another hand consists of crystalline structure andtherefore the piezoelectric properties depend on the molecular proportion x of vinyledene fluoride in P(VDFxTrFE1−x).The presence of TrFE in the copolymer of the PVDF-TrFE film introduces significant features to the PVDF homo-polymer.One of the advantages of PVDF-TrFE is that it increases the tendency to crystallize in the polarβ-phase without the requirement of mechanical stretching totransform the nonpolar α-phase to the polar β-phase as in the case of PVDF, when $0.6 < x < 0.85$ [4].

Among the PVDF-TrFE copolymers, the copolymer at composition near 75/25 mol.% exhibits the highest ferroelectric responses [5-6]; hence, in this paper, the PVDF-TrFE copolymer with a molar ratio of 75/25 was used to fabricate as a thick-film on a flexible substrate. The voltage signalresponses to finger pinching of the piezoelectric PVDF-TrFE structures was studied.

2. METHODOLOGY

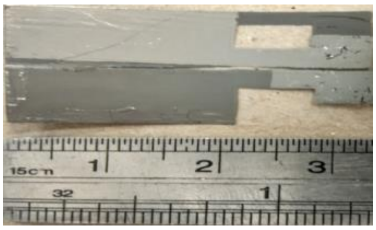
P(VDF-TrFE) thick films in this work was prepared using Poly(vinylidene fluoride-trifluoroethylene) with a molecular weight of 350,000 gmol^{-1} or [70:25mol%] manufactured by Kureha, Japan. Prior to the thick film fabrication, P(VDF-TrFE) (70:25mol%) powder were dissolved in *N,N*-dimethylformamide (DMF) obtained from Sigma Aldrich, with a concentration of 30ml.

The P(VDF-TrFE) powder was prepared according to the designated weight in percentage of 15wt%. The powder was dissolved in DMF and mechanically stirred at 100 °C for 1 hour. The solution was then immersed in an ultrasonic bath for 20min to ensure that the solution was fully dissolved. Then it was used to deposit a thick film to an approximation of 250µm thick by using mayer rod coating method (RDS #44 wire size, R.D. Specialties) on a flexible polymer (Melinex 723) substrate with thickness of 75 µm. The thick film was dried under infra-red light for 15 min with a temperature of 60˚C in order to remove the residual solvent.

Prior to the P(VDF-TrFE) deposition, first palladium-silver electrode layer were screen-printed using screen stencil onto the blank Melinex 723 substrate. The second palladium-silver electrode layer was applied after the infra-red light treatment. The thick film was subsequently annealed in an ambient environment oven at 100˚C for 1 hour to obtain a smooth and crystalline surface with reduced porosity [7]. Electrical poling was performed across the thick films using D.C. power supply at 100 V for 20 min at 100°C (near to Curie temperature of P(VDF-TrFE). This polarization is to align the domain dipole according to the polarity of the DC voltage. The fabricated sensor device of the sandwiched P(VDF-TrFE) thick film is illustrated in Figure 1 which is being used for the experimental testing in next step.

3. RESULTS AND DISCUSSION

A simple experiment setup was conducted to measure the output of the flexible micro-power generator by pinching between two fingers until both end of the flexible substrate meet each other. The force's magnitude applied by the fingers was estimated by substituting the fingers forces with incrementally loaded mass weights that placed on the flexible substrate until both substrate end touched. The output from the flexible micro-power generator is measured using digital oscilloscope (Agilent Technologies: DSO-X2012A) as shown in Figure 2. The result shows that the peak-to-peak voltage output signal varying between ±2 mV when a force of average 5N is being applied to the polymer sensor due to the bending and stretchingmovement of a finger.


(a)

(b)

Figure 1 (a) Photograph of a fabricated flexible piezoelectric micro-power generator., (b) the schematic diagram of the sandwiched thick film.

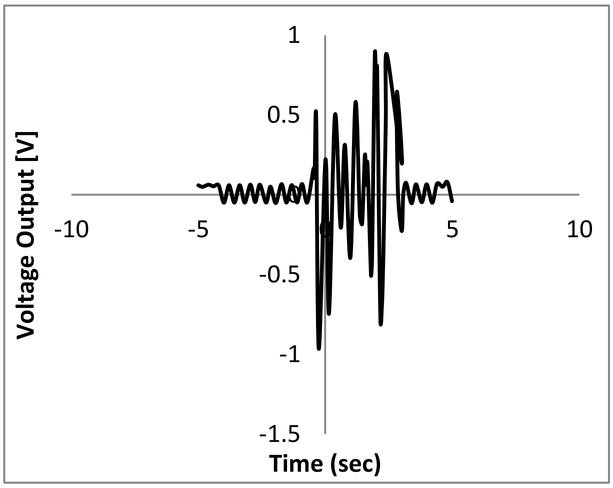


Figure 2 Output voltage from finger movement.

The output power of the flexible sensor is can be evaluated by using equation,

$$P=V^2/R_L \quad (1)$$

Where V is the output voltage across a 1MΩ external load resistorR_L. Based on the experimental output voltage, the average output voltage is 843mV and therefore the output power can be calculated as 0.711µW from a single layer P(VDF-TrFE) micro-power generator.

4. CONCLUSION

In this paper, piezoelectric P(VDF-TrFE) thick films were successfully fabricated and polarized simultaneously onto the Melinex polyester substrate as sensor generator using rod mayer method. Repeated and consistent experiment results of output voltage up to 843mV has been generated under bending and stretching movement with an estimated force of 5 N, of which the output power can be calculated as 0.711µW.

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REFERENCES

[1] X. P. Qing, H.-L. Chan, S. J. Beard, and A. Kumar, “An active diagnostic system for structural health monitoring of rocket engines,” *J. Intell.Mater. Syst. Struct.*, vol. 17, no. 7, pp. 619–628, Jul. 2006.

[2] Z. L. Wang, “Zinc oxide nanostructures: Growth, properties and applications,” *J. Phys.: Condens. Mat.*, vol. 16, no. 25, pp. R829–R858, 2004.

[3] Chunyan Li, Pei-Ming Wu, Sooh Yun Lee, Andrew Gorton, Mark J. Schulz, and Chong H. Ahn, “Flexible Dome and Bump Shape Piezoelectric Tactile Sensors Using PVDF-TrFE Copolymer,”*J. MEMS. SYS*, vol. 17, no. 2, pp.334-341, Apr. 2008.

[4] H. Ohigashi, “Piezoelectric polymers—Materials and manufacture,” *Jpn.J. Appl. Phys.*, vol. 24, pp. 23–27, 1985.

[5] H. Nalwa, *Ferroelectric Polymers*. New York: Marcel Dekker, 1995.

[6] T. Furukawa, “Ferroelectric properties of vinylidene fluoride copolymers,” *Phase Transit.*, vol. 18, no. 3/4, pp. 143–211,1989.

[7] Rahman Ismael Mahadi, W.C.Gan and W.H. Abd. Majid, “Hot Plate Annealing at a Low Temperature of a Thin Ferroelectric P(VDF-TrFE) Film with an Improved CrystallineStructure for Sensors and Actuators,” *Sensor*, vol.14, pp.19115-19127,2014.