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PVDF Films for Transducer Application

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ABSTRACT

Polyvinylidene Fluoride (PVDF) finds a wide range of applications as sensors and actuators properties such as vibration sensors, accelerometer, motion detector etc., due to its outstanding piezo, pyro and Ferro-electric. The present paper signifies the performance of the PVDF sensor as a piezoelectric transducer The objective of this paper is to characterize the PVDF sensors for properties such as linearity, sensitivity, bias stability and response of the material to the shockwave required for transducer applications. A detailed testing and analysis has been carried out to check the suitability of PVDF film for transducer application. The samples were subjected to linearity tests on the shaker for ranges 1g to 18g at a constant frequency of 100Hz and was found to be linear up to 98.06% with respect to acceleration due to gravity (g), and sensitivity was found to be 23mV/g. The samples were subjected to shock of 50g for 11ms and peak to peak output voltage obtained was 20V, Once the shock is withdrawn it takes approximately a microsecond to respond normally. Thus, the PVDF sensor can be used as alternative prime element for the various transducer applications which fulfils the key requirements of wide dynamic range, light weight, desirable size and shape and good sensitivity.

Keywords : Piezoelectric, PVDF, Transducer

I. INTRODUCTION

Piezo materials have wide range of applications that have the ability to convert mechanical input into electrical energy or vice versa [1]. Every object regardless of living or non-living consists of vibration due to surrounding environment. The frequencies, velocities, acceleration and magnitude of vibrations vary with variations of object's condition. Vibration measurements are applied to various applications like portable medical detectors, structural health monitoring, non-destructive testing, active vibration control of structural vibrations etc. Piezoelectric materials are suitable for these applications and are well known to produce coupling between the mechanical and electrical domains [2]. The electromechanical coupling is the indicator of the effectiveness with which a piezoelectric material converts mechanical energy to electrical or vice versa. Polymers being flexible are preferred compared to ceramic materials. PVDF exhibits higher piezoelectricity compared to the other polymeric materials [3]. PVDF is an electro-active flouro polymer exhibiting wide variety of properties such as high dielectric strength, stability, flexibility which are adaptable in wide range of applications like aerospace, automobiles and many more [4]. These PVDF films were prepared using solvent cast method followed by thermo-mechanical stretching to obtain piezoelectric phase, and poling for dipole alignment and finally electrode to form a PVDF sensor [5]. A study is conducted to check the feasibility of using PVDF as an active sensing element for transducer applications. Present accelerometers use quartz or piezo-ceramics as a sensing element which are rigid and brittle. Detailed tests are conducted on the various parameters like the linearity, bandwidth, shock and sensitivity to produce qualified transducers with key features of wide frequency range, wide dynamic range, high sensitivity, low noise, small size, light weight and easy mounting. The response of these tests has been obtained and the results are analysed.

II. METHODOLOGIES & EXPERIMENTAL DETAILS

The PVDF films of 15cm x 15cm are produced using solvent cast method [4]. The film obtained after curing is in α phase which is a non-piezoelectric phase. This α phase film is subjected to thermo-mechanical treatment to obtain β phase i.e. the piezoelectric phase. The films are characterized for X-ray diffraction, scanning electron microscopy to confirm the β phase. The β phase film was subjected to Corona poling for polarization and alignment of dipole moment [5]. The piezoelectric properties of developed PVDF film are checked using piezometer to validate piezo property. The poled films are cut to the required size and silver metallization is carried out for 15mm x 15mm active area. PVDF sensor has been developed by fixing the edge connections to the metallized film.

A. *Tests conducted*

The PVDF sensor is mounted on the base plate of a shaker (Make Spectral Dynamics Model No DA/SD-10-240/BT600). The shaker is programmed for an operation of 1g to 18 g sweep with an interval of 60 seconds at each value of ‘g’. The shaker starts vibrating once the input is given, the output response and data is recorded in the digital oscilloscope. Parameters such as linearity and sensitivity, shock wave response and bias stability is conducted at different acceleration and at a frequency of 100Hz. The most convenient sensor to use is the one with the linear transfer function. A bias stability measurement is done to know how stable the bias of the sensor is over a specified period of time. The developed PVDF sensor is subject to stability analysis at room temperature for a period of 120 minutes and the output has been recorded. The shock is a non-periodic excitation of a mechanical system that is characterized by suddenness and severity and usually causes significant relative displacements in the system. The PVDF sensor which was mounted on the shaker is subjected to 50g acceleration for 11ms and the output response has been recorded.

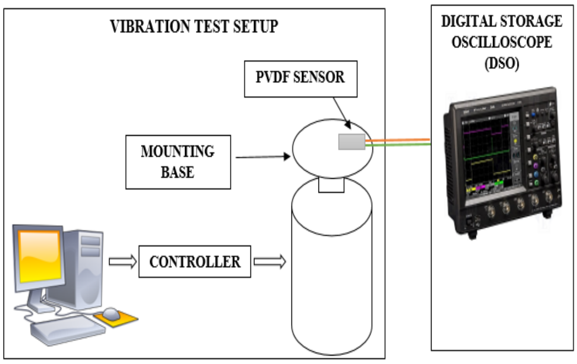
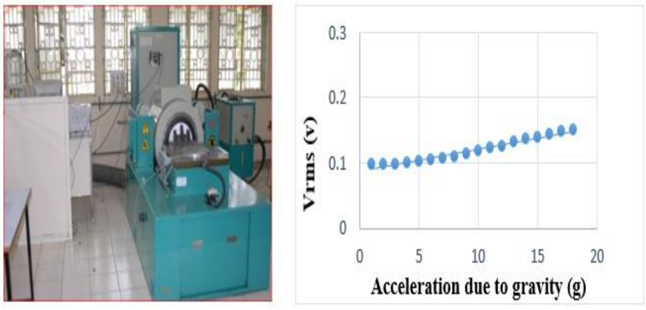


Figure 1. Shaker test rig

III. RESULTS AND DISCUSSION

A. **Characteristics of Linearity**

The sensor is subjected to acceleration sweep from 1g to 18g progressively at a reference frequency of 100 Hz. The linear relationship of the V_{rms} (root mean square value of the output voltage) of PVDF sensor as a function of ‘g’ has been plotted as shown in the Figure 2.



(a) (b)

Figure 2. (a) Vibration Testing System. (b) Linearity response of PVDF Sensor

In practical applications viz. aircraft, the response of PVDF sensor may have non-linear output which was calculated as:

$$Percentage\ of\ non-linearity = \frac{maximum\ deviation}{full\ scale\ output} * 100\%$$

$$= \frac{0.052536}{2.706516} * 100$$

$$= 1.94\%$$

Where, the maximum deviation was obtained by taking the average of the difference of the V_{rms} values from the linear equation and full scale output is the maximum voltage obtained at 18g.Hence by applying the above formula the non-linearity was obtained to be as 1.94%.

B. Characteristics of Shock response

The PVDF was subjected to shock pulse to check the behavior of the sensor for sudden shocks and the sensor was checked for its performance post shock. A single shock of 50 g was applied for a period of 11ms. The response of the PVDF sensor is shown in figure 3, where the maximum voltage obtained is 20V. The sensitivity of the sensor remains unaltered after the shock pulse test.

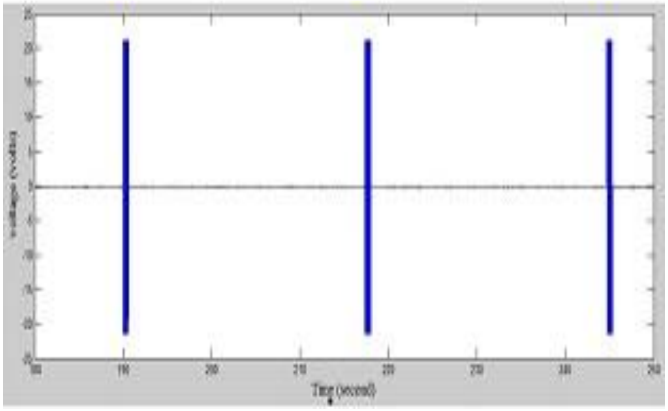


Figure 3. Shock response of PVDF Sensor.

C. Characteristics of Bias stability:

This test characterizes the bias stability of the sensor i.e. full scale output at constant temperature over a specified period of time without any external force. The sensor output was connected to a data logger. The offset variation was measured using a Digital Storage Oscilloscope (DSO) and logged over a period of two hours and plotted. The response of the sensor was found to be stable without any external force or supply when observed for 2 hours

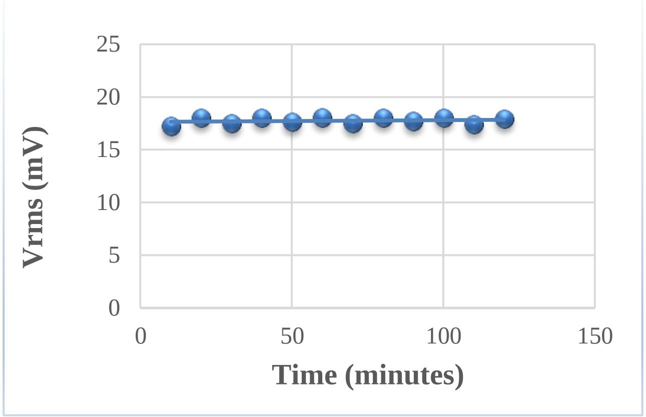


Figure 4. Bias Stability of PVDF Sensor

D. Characteristics of Sensitivity

Sensitivity of an accelerometer is the ratio of the sensor output (V_{rms}) to mechanical input. The plot for sensitivity is as shown in the graph below: The average sensitivity of the sensor was obtained to be 23mV/g.

$$Percentage\ of\ sensitivity = \left[\frac{Vrms/g}{18}\right] * 100$$

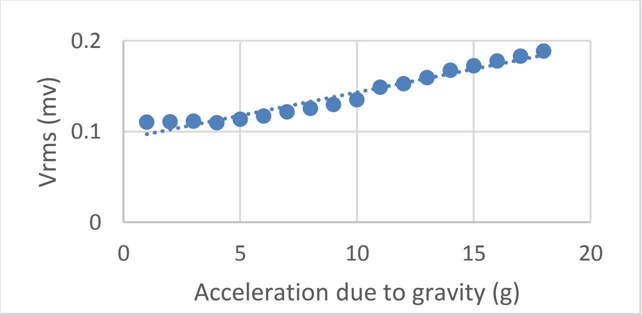


Figure 4. Sensitivity of PVDF Sensor

IV. CONCLUSION

The test for linearity, sensitivity, bias stability and shock pulse test have been performed on 15mm x 15mm active area PVDF sensor and it was found to have the linearity of 98.06% in the range of 1g to 18g, sensitivity of 23mV/g, shock response of about 20V and produces a stable output without any external force at constant room temperature. Thus, the PVDF sensor can be used as alternative prime element for various transducer applications, as it fulfils the key requirements of wide dynamic range, light weight, desirable size and shape and good sensitivity and overcomes the disadvantages of hard, brittle and bulkiness of current material used as active element in accelerometer

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