DEVELOPMENT OF BENDING MODE POLYMER PIEZOELECTRIC BANDAGE FOR BONE FRACTURE HEALING

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ABSTRACT

Corona-discharge has been used as a poling technique for piezoelectric PVDF films. The bending piezoelectric stress constant b_{31} was determined by voltage measurements. The highest value of b_{31-} achieved was 600 mV/m for 3.5 wt% of iodine doped sample. Fourier Transform Infrared (FTIR) spectrophotometer was used for structural investigation.

Key words: Fourier transform infrared (FTIR) spectrophotometer, bending piezoelectric stress constant b_{31}, iodine doping

INTRODUCTION

Piezoelectric and pyroelectric polymer electrets (Sesser,1987; (Lang,1981) are found more and more in industrial applications. The piezodectric effect was discovered by the Curie brothers in 1880. This effect has been observed in wood (Bazhenov and Konstantinovo, 1951), (Bazheno,1953) wool and hair (Martin,1941) Studies show that many biological tissues including tendons, dentin, ivory, aorta, trachea, intestine, silk, elastin and ucleic acids are piezoelectric (Marino, and Becker,1975; Saha and Lakes,1979; Athenstacdt, Clausen, *et al.*,,1982)

Interest in the electric properties of polyvinylidene fluoride (PVDF) began in 1969 when Kawai (Kawai, 1969) showed that thin films that had been poled exhibited a very large piezoelectric coefficient (Kepler and Anderson, 1978; Luongo,1972) pCN^{-1}, a value which is about ten times larger than had been observed in any other polymer.

PVDF has the advantage of long term stability of its piezoelectricity at room temperature and its mechanical flexibility. Bending (or flexure) piezoelectricity in poled polymer films has been investigated by several authors (Furukawa T., *et al.*,1968; Kawai.,1970; Ibe and Jpn ,1974; Breger L. *et al.*,1976). These studies were arrived at determining the piezoelectric activity induced by bending deformation of polymer . While tensile piezoelectricity has been investigated in detail (Hayakawa and Wada, 1973), the origin of bending piezoelectricity is not yet fully understood. When a poled polymer film subjected to bending deformation , the electrical displacement should consist of two components. One is proportional to stress (as in the case of elevation) and the other proportional to the stress gradient (Hayakawa and Wada,1973; Kogan,1964; Williams, 1985). The latter effects are characterised by a bending piezoelectric strain constant b_{31} and depend on the structure of the polymer (Kawai, 1970).

In this paper, the piezoelectric behaviour is investigated in single-film polyvinylidene fluoride (PVDF) poled by corona-discharge technique (Giacometti and Oliveira, 1992). In particular the b_{31} is analysed.

2.0 MATERIALS AMD METHODS

Commercial PVDF film of 40 mm thickness were obtained from Kureha Industrial Chemical c°, Japan. Iodine doping was carried out by enclosing the samples in a sealed glass container together with 2 g of iodine for 24 hours at room temperature. The amount of iodine in the samples was determined by weighing the samples before and after iodine exposure using an electronic balance. The percentage loss in iodine was found to be 0.8%, which is insignificant and was therefore neglected in this study. Rectangular samples of size 7 mm x 40 mm were cut from the doped films.

Aluminium electrodes of thickness about 500Å were vacuum deposited on one surface of the virgin and doped PVDF samples. The samples were negatively corona charged through the non-metallized surface for 2 minutes, room temperature with the aluminum side grounded.

The samples were then suspended vertically in aluminum casing, see Figure 1(a), by clamping the upper end. Horizontal deflection of the lower end of the film was generated by eccentrically rotating a micrometer screw gauge.

Fourier transform infrared (FTIR) spectra of the virgin and iodine-doped PVDF films were recorded using a Shimadza FTRR – 8400 Fourier transform infrared spectrophotometer

3.0 RESULTS AND DISCUSSION

3.1 Fourier Transform Infrared (FTIR) Spectroscopy

The structure of virgin and iodine doped polyvinylidene fluoride was assessed by observing the structural changes of PVDF (FTIR) spectrogram. Major absorption peaks were noted at wave numbers around 3650, 3019.4 , 2977.9, 1678.9, 1653.8, 1616.2, 1378.0, 1082.0, 877.6, 837.0, 763.8, 745.4 and 489.9 $cm^{-1,}$, see (Figure 1(a). These peaks can be attributed to the CH_2 present in the main chain of PVDF molecules. The FTIR spectrum of 3.5 wt % of iodine doped PVDF showed absorption peaks at 3650, 1678.9 and 1616.2 cm^{-1} disappears with iodine doping [Figure 1 (b)]. These can be attributed the presence of iodine in the polymer structure, forming a C-I bond (Karanja and Nath, 1994).

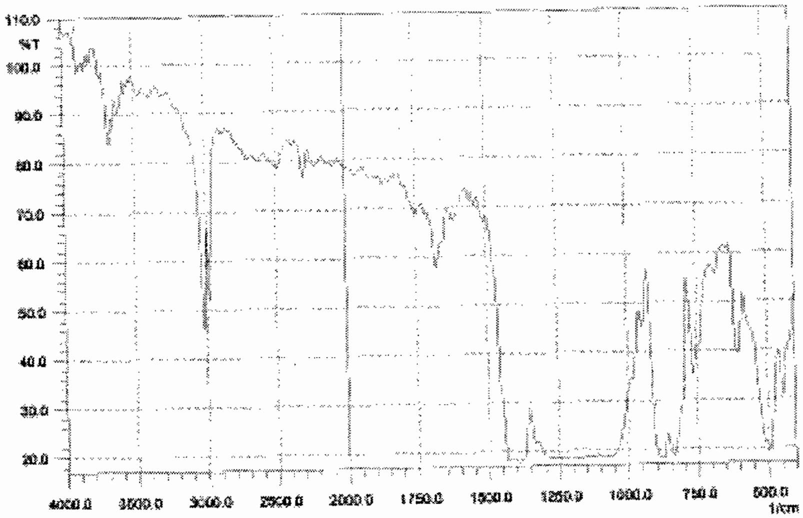

Figure 1 shows FTIR spectrum of virgin PVDF sample

Figure 1(a): FTIR spectrum of virgin PVDF sample

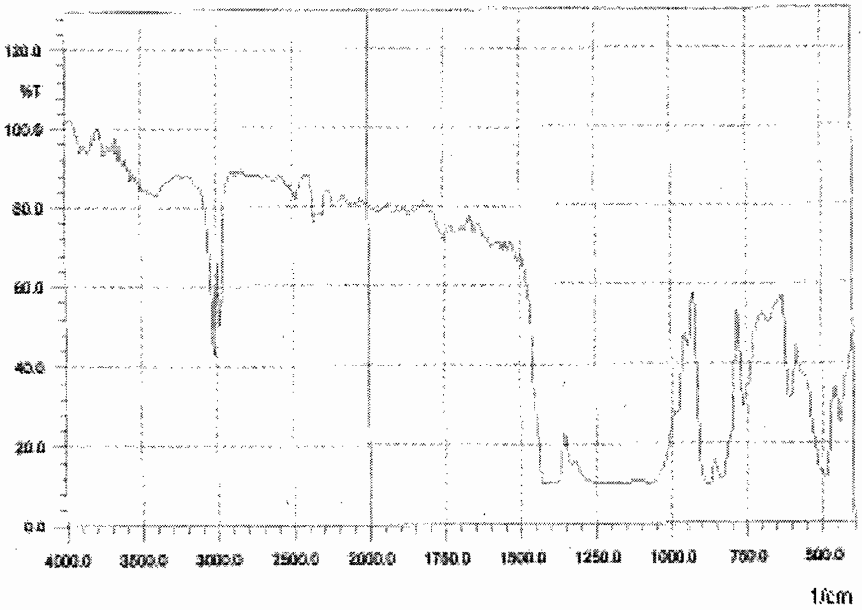

Figure 2 shows FTIR spectrum of 1.5%ww/wt iodine doped PVDF sample

Figure 1(b): FTIR spectrum of 3.5%ww/wt iodine doped PDVF

3.2 Corona Charging

The carona-charging unit is shown in Figure 2 and consists of a cylindrical Teflon support whose inside is fitted with a metallic brass cylinder. The middle of the corona unit is fitted with a sharp stainless steel needle. A screen grid is fitted between the corona and the surface of the polymer being charged.

A high voltage - 8 kV dc is supplied to the corona needle. This ensures that the sample is negatively corona charged. The surface potential was controlled with the help of a grid kept at a negative potential and held about 4 smm over the surface of the sample. This also ensured uniform charging. The samples were charged for 120 seconds at room temperature.

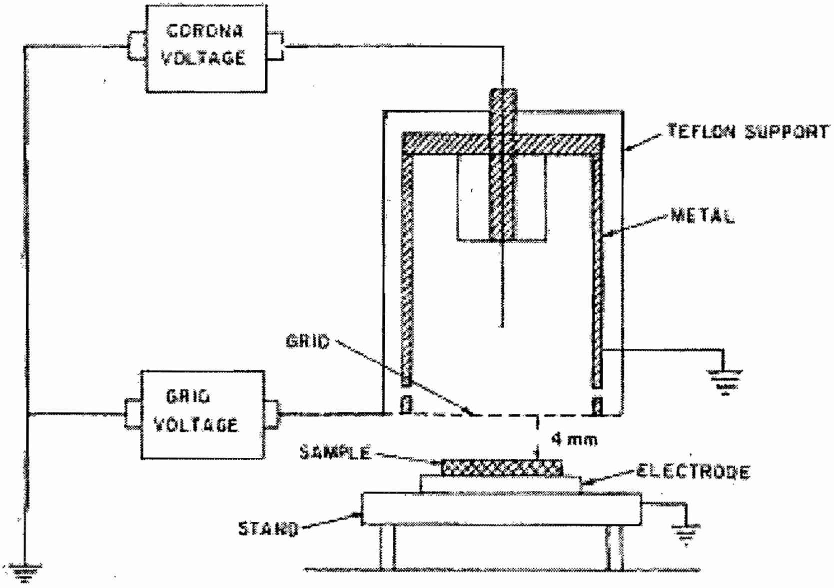

Figure 2: Schematic diagram of corona production

3.3 Piezoelectric Bending Measurements

In a cantilever beam of length l, width w and thickness t, deflection Ä Z is imposed at the end of the beam as shown in Figure 3(b). The induced electric displacement D_3 in the direction of the Z axis is given by

$D_3 = \hat{I}_3 E_3 + b_{31}\ (1/R)$ ....(1)

where E_3 and $\hat{I}_3$ are the electric field and the permittivity respectively, in the Z direction, and R is the radius of curvature. Since 1/R is equal to the thickness gradient of the strain in x-direction Ds1/Dz, the quantity b_{31} is defined as the bending piezoelectric stress constant.

In a no-uniformly polarised dielectric Gauss's law $dD_3/dz = 0$ yield D3 = constant while $\hat{I}_3 E_3$ must be replaced by the average $\hat{I}_3 E_3$. For constant $\hat{I}_3$ and under short-circuit conditions, $\hat{I}_3 E_3 = 0$ and one obtains for the electrode charge induced by bending

$Q = D_3\, lw = lwb_{31}/R$. Since for small deflection $1/R = 2\ DZ/l^2$, one has

$b_{31} = (l/2w)\ (Q/DZ)$.. (2)

The deflection D Z was generated and value of Q was observed .Then b_{31} was calculated.

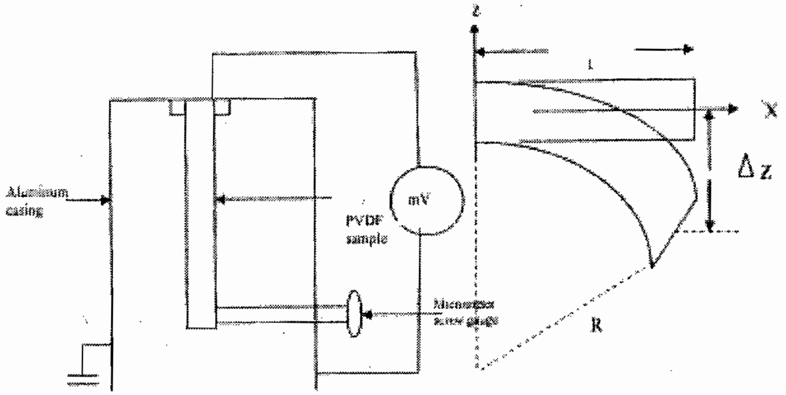

Figure 3(a): Schematic diagram of measuring device

(b): Geometry of the experiment cantilever beam of length 1 and thickness t is deflected by ÄZ

The change in voltage of unpoled PVDF films versus bending is shown in Figure 4. A b_{31} = 5 mV/m was obtained. The change in voltage for the poled PVDF against bending is shown in Figure 5. The b_{31} = 8 mV/m was obtained. The increase in b_{31} can be attributed to poling (Sesser,1987; Lang, 1981; Bazhenovand Konstantinovo, 1951; Bazheno, 1953; Martin, 1941).

The change in voltage against bending for unpoled PVDF samples at 1.0 wt% (Plot a) and 3.5 wt % (plot b) is shown in

Figure 5(b). The b_{31} varied from 13.3 mV/m (plot b) to 400 mV/m (plot b). The change in voltage for the iodine doped PVDF at 1.0 wt% (plot a) and 3.5wt % (plot b) versus bending is shown in (Figure 5(c). The b_{31} varied from 25 mV/m (plot a) to 600 mV/m (plot b). The increase in electronic conduction with iodine doping can be attributed to the increase in b_{31} (Ward, 1971).

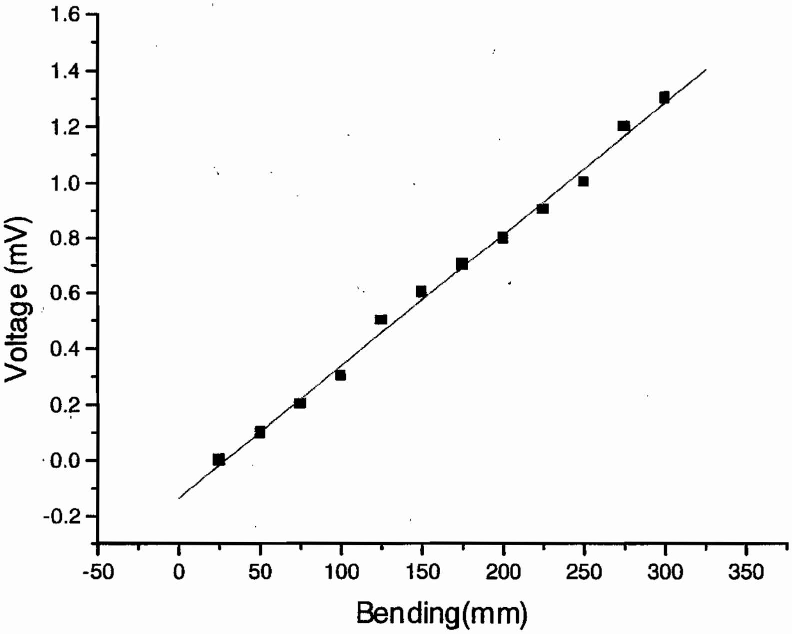

Figure 4: *Graph of change in voltage against bending for unpoled PVDF sample*

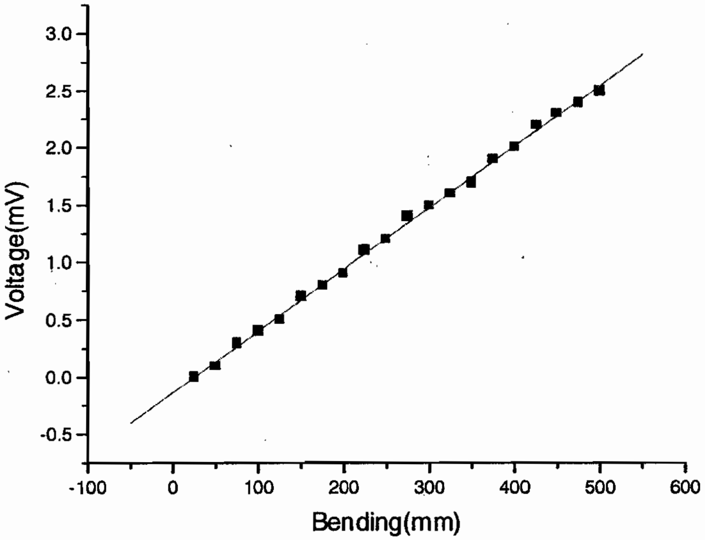

Figure 5(a): Graph of change in voltage against bending for poled PVDF sample

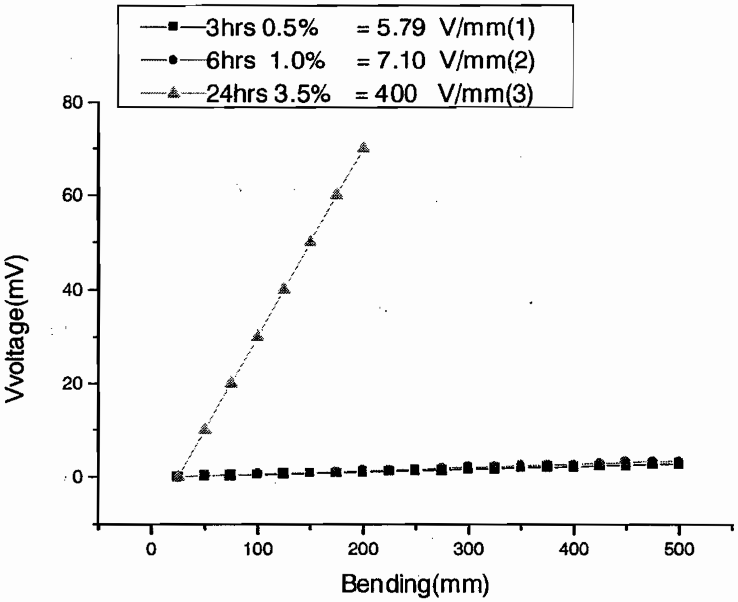

Figure 5(b) : Graph of change in voltage against bending for unpoled PVDF samples at 1.0 wt% (plot a) and 3.5 wt% (plot b)

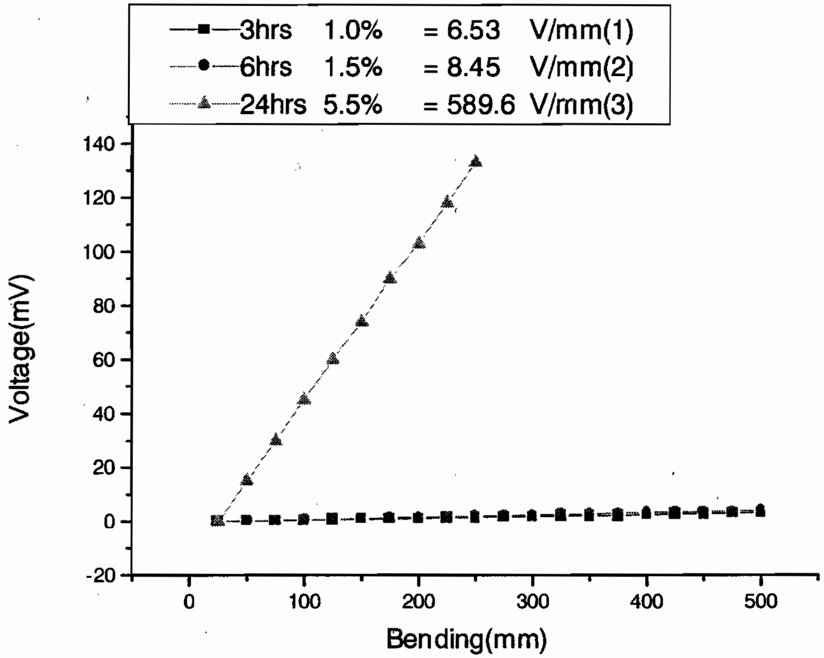

Figure 5(c): Graph of change in voltage against bending for poled PVDF sample at 1.0 wt% (plot a) and 3.5 wt% (plot b

4.0 CONCLUSIONS

The disappearance of 3650, 1678.9 and 1616.2 cm^{-1} peak in FTIR spectrum of virgin PVDF sample can be due to iodine doping. A 3 mV/m increase in b_{31} [(Figure 5(a)] can be attributed to corona poling. The increase in b_{31} [(Figure 5(b) and 5(c)] can be due to electronic conduction with iodine doping.

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