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PIEZOELECTRIC AND PYROELECTRIC EFFECTS OF A CRYSTALLINE POLYMER

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SUMMARY

Polyvinylidene flouride (PVDF) is a crystalline polymer of both piezoelectric and pyroelectric nature. Piezoelectricity produces electrical signals when mechanically deformed, and pyroelectricity is the electrical polarization induced by thermal absorption in crystals. To demonstrate the piezoelectric effect PVDF is subjected to impact loads which produce electrical charges proportional to mechanical stresses. A heat source was used to demonstrate the pyroelectric nature of PVDF. The rise in temperature due to absorbed energy by the polymer produces electrical output. The qualitative test results obtained are graphically reproduced.

INTRODUCTION

Piezoelectricity is a material characteristic of certain crystalline polymers that produce electrical signals when mechanically deformed and experience dimensional changes when subjected to an electrical field. Pyroelectricity is the electrical polarization induced by thermal absorption in crystals.

This experiment deals with the demonstration of the above phenomena using Kynar Piezo Film, a specially treated polyvinylidene fluoride (PVDF) film manufactured by the Pennwalt Corporation. The special treatment consists of aligning the polar axes of individual crystallites and coating both sides of the film with aluminum or chromium for electrical contact.

To demonstrate the piezoelectric effect, the PVDF film is subjected to impact loads which produce electrical charges proportional to the mechanical stresses. A heat source is used to demonstrate the pyroelectric nature of PVDF. The absorption of thermal energy by the polymer produces an electrical output; this effect reverses when cooling.

Some of the most common applications of piezoelectric films are found in acoustics, ultrasonics, optics, transducers, and medical instrumentation.

IMPACT TESTS

Test Specimens

The specimens used in the tests were 1.0 inch square pieces of treated PVDF film. Copper electrodes 1/8 in. x 3 in. were attached to either side with an electrically conductive adhesive. The specimens were then placed in between two pieces of nonconducting, transparent protective plastic film.

Apparatus

PVDF specimen, 3/8 in. steel ball, power supply, chart recorder, and weights.

Test Procedure

The steel ball was securely attached to the center of the square film. The electrodes attached to the specimen were connected to the chart recorder. The chart recorder was set at a speed of 25 divisions per second and a sensitivity of 50 millivolts per division.

Various weights were dropped from a certain height onto the ball attached to the film. The impacts transmitted through the ball created point loads on the specimen which in turn produced electrical signals on the chart recorder. Signals were recorded five times for each weight.

The obtained electrical output is a representation of the impact load experienced by the film. The impact can be measured qualitatively from the amplitude of the signals.

Interpretation of a Sample Output

As shown in figure 1, the impact will cause both positive and negative amplitudes. For this reason, only the first crest (arbitrarily considered positive) was used to indicate the output from the film.

See table 1 for experimental data from impact tests. Only a portion of the data is given.

THERMAL TESTS

Test Specimens

The specimens used in these tests were identical to those used in the impact tests.

Apparatus

PVDF specimen, thermometer, heat source, ice, power supply, chart recorder, and a stopwatch.

Test Procedure

The electrodes extending from the specimen were connected to the chart recorder. The chart recorder was set to a speed of 25 divisions per second and a sensitivity of 20 millivolts per division.

The film was subjected to a cycle of thermal stresses as follows: The specimen was heated for 30 seconds while recording its temperature every 10 seconds. Then ice was placed on the film for the next 30 seconds while the film's temperature was recorded every 10 seconds. Heat was again applied for 30 seconds while taking temperature readings. After 30 seconds, the heat source was removed and the specimen was allowed to cool for 30 seconds while taking the temperature readings every 10 seconds. This procedure was repeated three times.

Interpretation of a Sample Output

As shown in figure 2, thermal stress on the specimen can result in a constantly fluctuating electrical signal. In such cases, the mean amplitude should be considered for a qualitative evaluation.

See figure 3 for a graphical representation of the electrical output of the PVDF film. See table 2 for quantitative test data.

RESULTS AND DISCUSSION

Impact Tests

The electrical output from the impact tests is a reflection of the structural changes experienced by the polymer. According to figure 4, the electrical output is proportional to the impact of weights above 250 g. Due to insufficient stress, the linear relationship is not observed at lower weight ranges.

Thermal Tests

The electrical output from the thermal tests shows changes in heat flow to the polymer. According to figure 3 and table 3, the electrical output is extreme when changing from ice to the heat source or vice versa rather than continuous application of either although the temperature change was greater during continuous application of thermal stress in one direction.

TABLE 1 - IMPACT TESTS

Weight (g)	Trial	Output (mv)
90	1	200
	2	200
	3	200
245	1	250
	2	250
	3	250
251	1	250
	2	225
	3	250
268	1	250
	2	250
	3	250
354	1	550
	2	450
	3	650
359	1	550
	2	400
	3	400

All weights were dropped from 5.0 inches above the film.

TABLE 2 - THERMAL TESTS

	Time (min:sec)	Temperature (°C)	Electrical Output (mv) Mean	Maximum
	0:00	21.3	40	200
Heat Source	0:10	24.3	30	100
	0:20	28.3	0	90
	0:30	31.6	-300	-500
Ice	0:40	31.0	-10	-80
	0:50	27.5	-5	-45
	1:00	24.2	40	200
Heat Source	1:10	24.6	10	160
	1:20	29.0	0	80
	1:30	33.3	35	200
None	1:40	32.5	20	100
	1:50	31.5	10	60

IMPACT TESTS

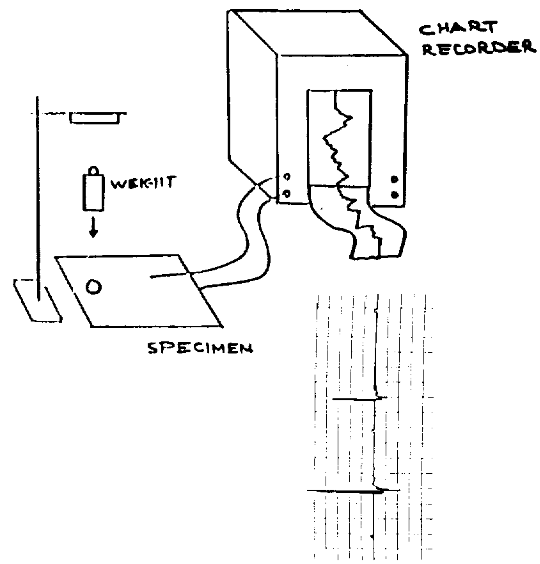

FIGURE 1

THERMAL TESTS

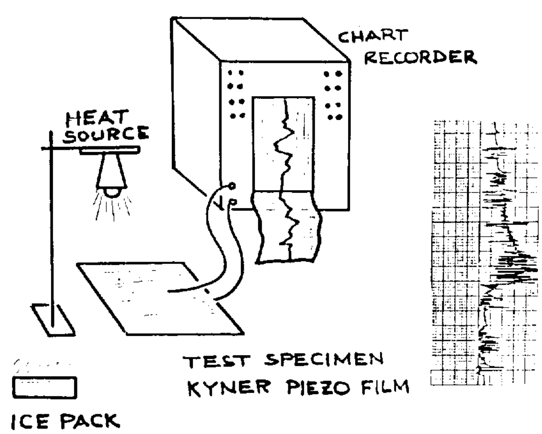

FIGURE 2

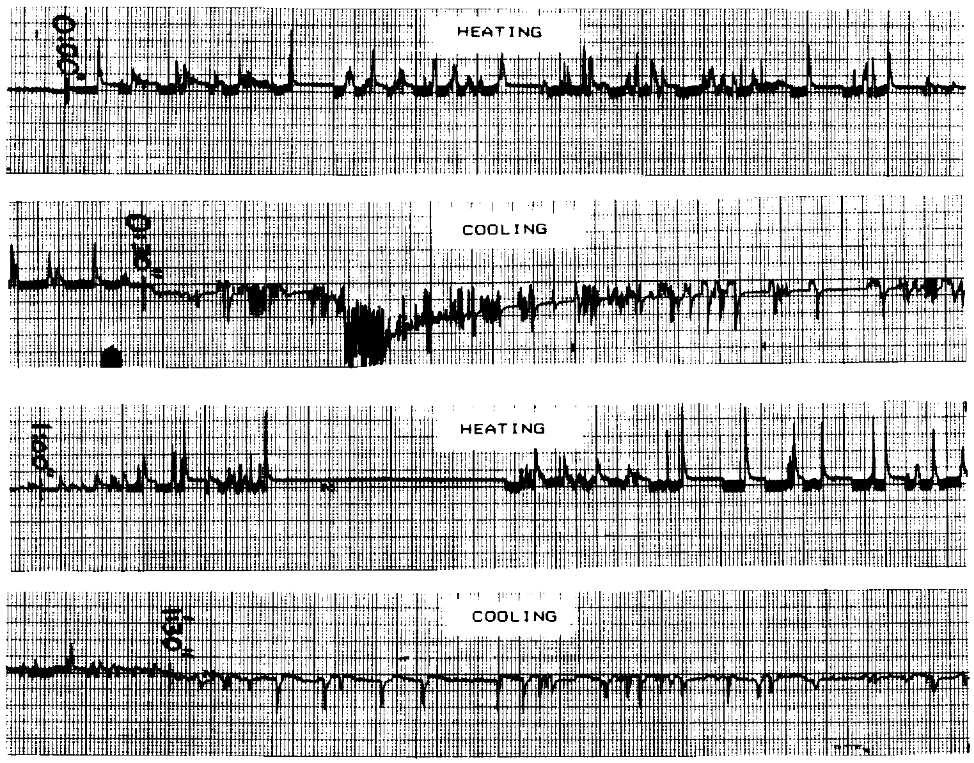

FIGURE 3

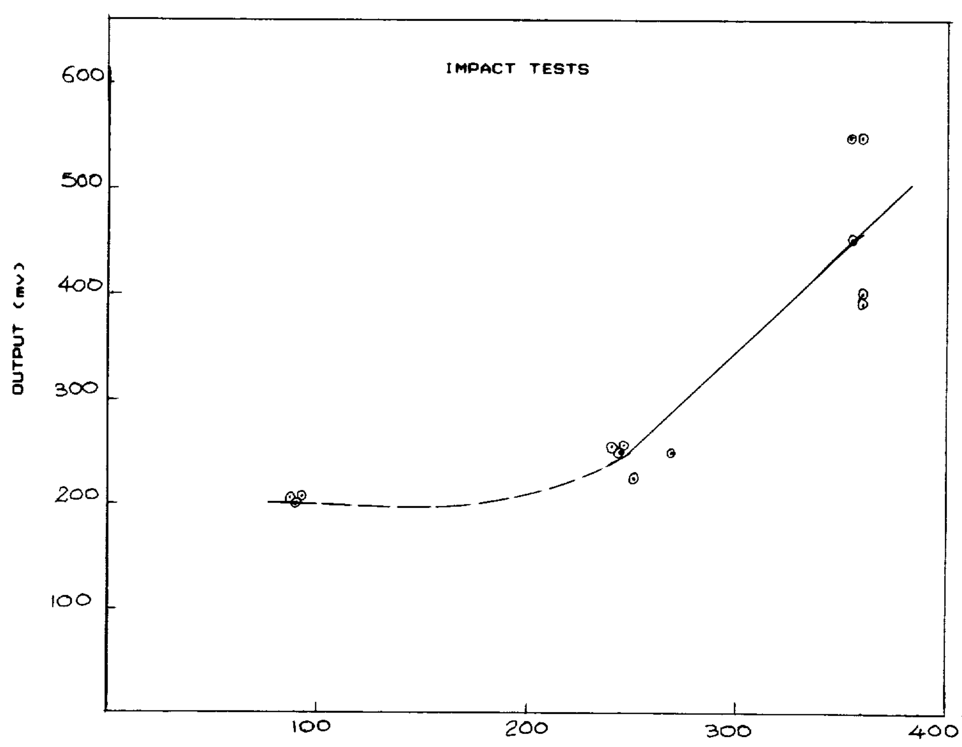

FIGURE 4