EFFECTS OF POISSON'S RATIO AND ELECTROSTRICTION CONSTANT ON PIEZOELECTRICITY IN POLY(VINYLDENE FLUORIDE)

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INTRODUCTION

Piezoelectricity in Poly(vinylidene fluoride) (PVDF) has been drawing much attention because of its high efficiency and possible application as information transducers. However, our basic understanding of the origin of the piezoelectric effect in PVDF is relatively poor. Although most of the previous authors assumed that the effect is an inherent property of form I crystal in PVDF, recently Wada and Hayakawa emphasized the importance of Poisson's ratio and electrostriction constant of films for appearance of the Piezoelectricity. But the different contribution of the Poisson's ratio and electrostriction constant to the piezoelectricity in PVDF films are still unclear. Furthermore, on the relationship between their constants and higher order structure, such as orientation of crystalline and amorphous regions, our understanding is not entirely satisfying.

In this paper, we report experimental results of the Poisson's ratio and electrostriction constant of PVDF and discuss the role of their constants to the piezoelectric effect by using the theory developed by Wada and Hayakawa.

EXPERIMENTAL

1) Sample preparation

The materials used in this study were PVDF(#1000) produced by Kureha Chemica1 Industry Co., Ltd. Three samples with different molecular orientations were prepared by rolling, drawing and thermally shrinking. The films are rolled and drawn from 1.2 to 4.5 times of the original length at

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80°C. The oriented films were finally annealed at 120°C for 0.5 hr. In order to control the degree of molecular orientation, the uniaxially drawn samples were annealed to shrink at 160°C. Aluminum electrodes for electric measurements were evaporated onto both film surfaces. The poling condition used for this experiment was 25 MV/m at 120°C for 2hrs.

2) Measurements

We defined axes 1, 2 and 3 for the film, with 1 parallel to the draw or roll direction and 3 normal to the film plane, as shown in Figure 1. The Poisson's ratio of a stretched film is defined by the following equations.

\[
\mu_{31} = \frac{\Delta t}{\Delta t / t}, \quad \mu_{21} = \frac{\Delta w / w}{\Delta l / l}
\]  

where \( \mu \) is Poisson's ratio, \( t, l \) and \( w \) are thickness, length and width of the films, respectively. \( \mu_{31} \) and \( \mu_{21} \) were determined from the changes of thickness and width when a tensile strain within the elastic limit (0-2%) was applied along 1 axis of the sample.

The Poisson's ratio of form I crystal was determined from the changes of two lattice spacings measured by X-ray diffractometer with nickel-filtered Cu-K\( \alpha \) radiation when the external strain applied to 1 axis was. We employed the diffractions of (001) and (110,200) for this measurement and defined \( \mu_c \) by

\[
\mu_c = \frac{\Delta d(110,200)}{\Delta d(001) / d(001)}
\]

where \( d \) is the lattice spacing.

The dielectric constant \( \varepsilon \) and piezoelectric constant \( \varepsilon_{31} \) were measured by using the apparatus developed by Furukawa et al. The electrostriction constant \( \kappa_{31} = \partial \varepsilon_3 / \partial S \) was calculated by measuring an apparent piezoelectric constant under low frequency A.C bias (0.004 Hz).

Figure 1. Cartesian coordinates