

MOLECULAR ORIENTATION ANGLE OF BIAXIALLY STRETCHED POLY(ETHYLENE TEREPHTHALATE) FILMS

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1. INTRODUCTION

Poly(ethylene terephthalate) (PET) is an important polymer for film applications, such as magnetic recording tapes, food packaging films, capacitor layers, and photographic films. Generally, PET films are fabricated by flat film stretching process. The stretching process in the most case is accompanied by molecular orientation of the polymer. It is well known that there are three kinds of molecular orientation in semicrystalline polymers; the orientation of crystalline phase, the orientation of amorphous phase, and the average (overall) orientation of the two phase. Since the orientation changes the internal morphological structure of the films, it is desirable to control the orientation of each phase in improving their mechanical properties.

In industrial practice, a tenter is widely used to stretch PET films along the transverse direction (TD). One of the most serious problems in the tenter process is the so-called "bowing" phenomenon, which causes the nonuniformity of molecular orientation in the TD [1,2]. In fact, the nonuniformity can be explained by the orientation angle as well as the distribution of orientation. However, less attention has been devoted to the orientation angle in biaxially stretched polymer films, although it is of great importance to determine the angle in controlling

their properties. In this paper, we measured the three kinds of orientation angle in biaxially stretched PET films with various techniques and suggested the equation of molecular orientation angles between amorphous orientation angle and crystalline one.

2. CONCLUSIONS

We investigated the molecular orientation of commercial PET films fabricated by a sequential and biaxial stretching process. The angles of the three different orientations could be determined by means of refractive index measurement, XRD and IFM. It was observed that the orientation angles change with position in the TD, due to the "bowing" phenomenon. It was also found that all the angles of amorphous phase at any position of TD are greater than those of crystalline one.

The amorphous angles obtained from XRD were in a good agreement with those from IFM (Figure 1). From the comparison with the measured angles, it was shown that eq. 1 is useful to determine one of the three orientation angles if the two angles are known.

$$\theta_a = \cos^{-1} \left(\frac{\cos^2 \theta_o - \chi_c \cos^2 \theta_c}{1 - \chi_c} \right)^{0.3} \quad (1)$$

In figure 2, the dynamic viscoelastic test indicated that the direction of the maximum storage modulus is closer to the angle of amorphous phase rather than that of crystalline one.

3. REFERENCES

1. S. Kase and T. Nishimura. *J. Rheol.*, **34**, 251 (1990).
2. T. Yamada and C. Nonomura. *J. Appl. Polym. Sci.*, **48**, 1399 (1993).

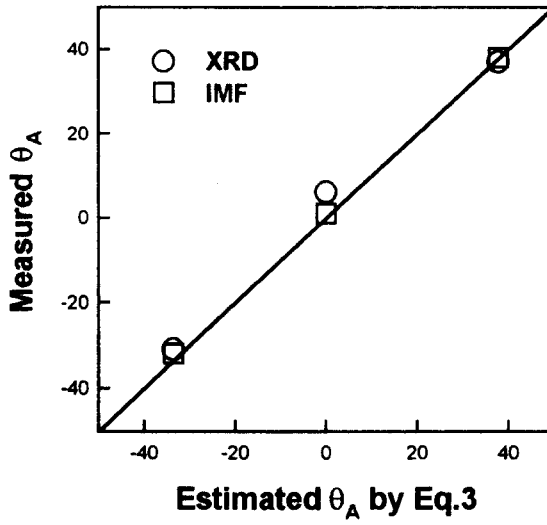


Fig. 1. Comparison of the estimated amorphous orientation angles by eq. 1 and the measured ones from XRD and IFM. For θ_o and θ_c , the values measured from Reflectometer and XRD were used.

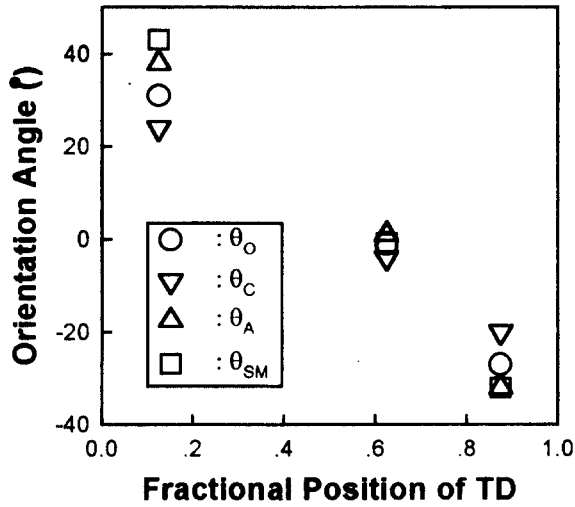


Fig. 2. Comparison of the anisotropy of storage modulus with the three different orientation angles. The amorphous angles, θ_A , were obtained from IFM, and θ_{SM} was defined by the angle between the TD and the direction of the maximum modulus