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## Dynamic Viscoelastic Measurements of Polypropylene

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### 1. Introduction

Polypropylene (PP) is a general-purpose resin is used by many industries for the production of everyday products like automobile parts and household electrical goods.

Three common types of PP used as industrial materials are homopolymer (made of propylene only), block copolymer (with ethylene), and random copolymer (with ethylene). These three types of PP have their own properties and their use depends on the required characteristics of the final products.

Figure 1 shows the molecular structures of the three types of PP. In addition to block PP, the block-copolymer also combines homo PP, ethylene propylene rubber (EPR), and PE copolymer. The block copolymer has a sea-island structure which contains a continuous phase of the matrix PP with a disperse phase of EPR and PE copolymer domains.

In this brief, PP homopolymer and block-copolymer are measured as examples of dynamic viscoelasticity measurement of PP.

### 2. Experiment

The samples were a commercially-available PP homopolymer and a block-copolymer composed of the homopolymer and approximately 6% ethylene.

DMS210 Dynamic Mechanical Spectrometer (Tension Module) connected to a SDM5600H Rheol. Station was used for the measurements. Measurement conditions included 5 measurement frequencies of 0.5, 1, 2, 5, and 10Hz. The measurement temperature range was -120°C to 150°C and the heating rate was 2°C/min.

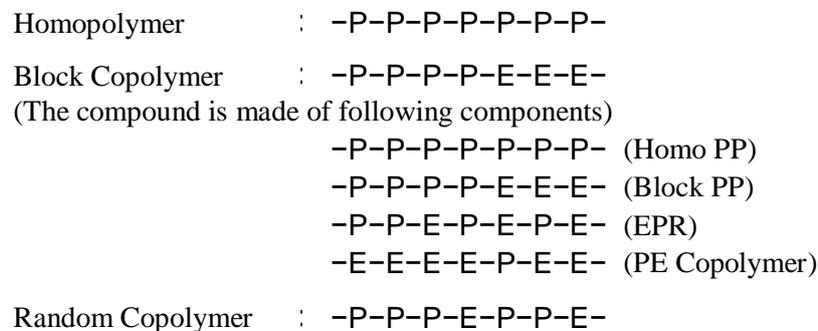


Figure 1 PP Molecular Composition Diagram

P: Propylene

E: Ethylene

### 3. Measurement results

Figures 2 and 3 show the dynamic viscoelastic spectrums of the homopolymer and the copolymer, respectively. The results are simultaneous measurements of temperature and frequency dispersions and show the  $E'$ ,  $E''$  and  $\tan \delta$  curves for 5 frequencies from 0.5Hz to 10Hz. The homopolymer measurement results (Figure 2) show three dispersions,  $\alpha$ ,  $\beta$  and  $\gamma$ , from the high temperature side. The  $\alpha$ -dispersion is attributed to crystal relaxation,  $\beta$ -dispersion is attributed to the main dispersion (glass transition) and  $\gamma$ -dispersion is attributed to the local mode relaxation<sup>1)</sup>. In addition to  $\alpha$ -,  $\beta$ - and  $\gamma$ -dispersions, the block-copolymer measurement results (Figure 3) show a peak between  $-50^{\circ}\text{C}$  and  $-30^{\circ}\text{C}$  on the  $E''$  and  $\tan \delta$  curves. This is likely the main dispersion (glass transition) of EPR in the block PP.

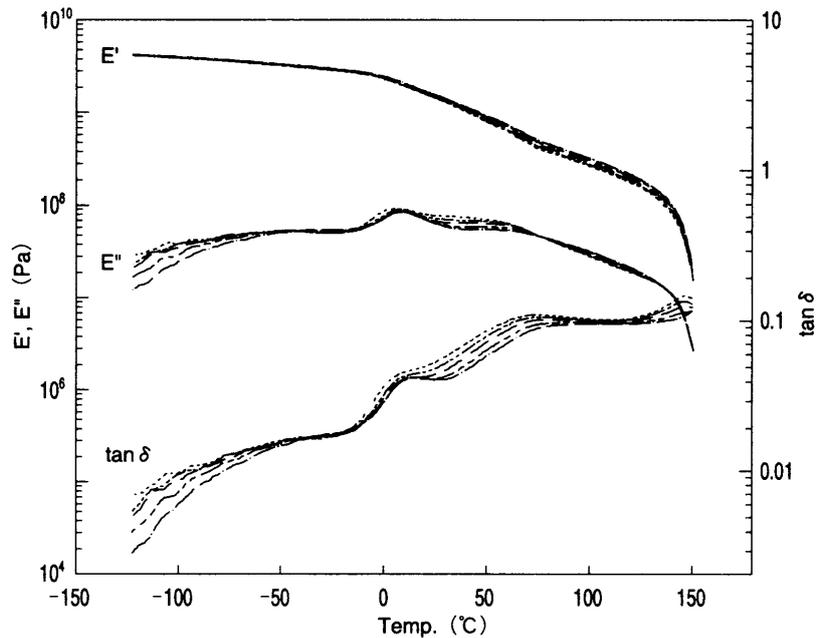


Figure 2 Dynamic viscoelasticity spectrum of homopolymer

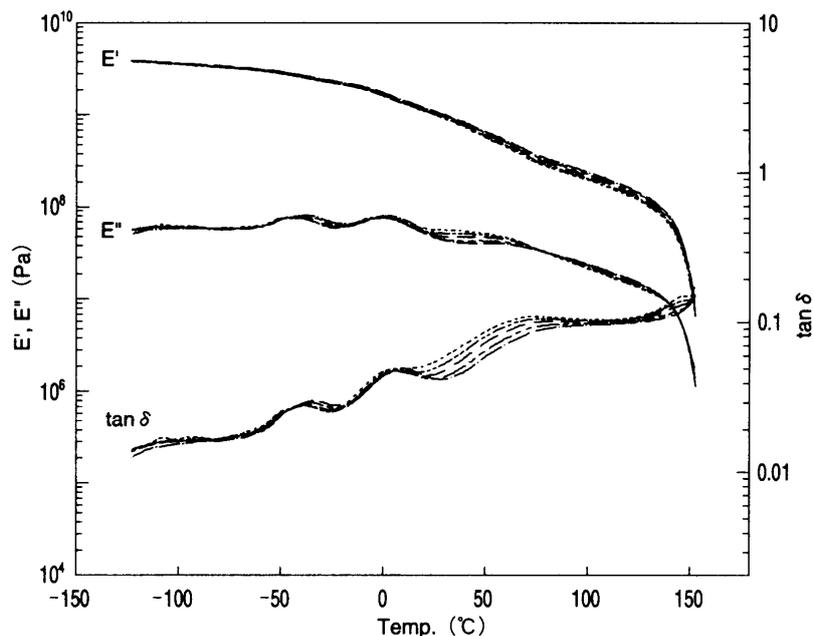


Figure 3 Dynamic viscoelasticity spectrum of copolymer

Figures 4 and 5 show the analysis data of the apparent activation energy<sup>2)</sup> obtained from the dispersion peaks of the  $\tan\delta$  curves in the Figure 2 and 3.

Roughly the same values were obtained for  $\alpha$ -dispersion (crystal relaxation) and  $\beta$ -dispersion (glass transition) for the PP component for both the homopolymer and block-copolymer. Furthermore, the apparent activation energy of the dispersion peak between  $-50^{\circ}\text{C}$  and  $-30^{\circ}\text{C}$  in the block-copolymer measurement results was  $292.5\text{kJ/mol}$ . This value also supports the idea that the dispersion peak is the glass transition of the EPR in the block PP.

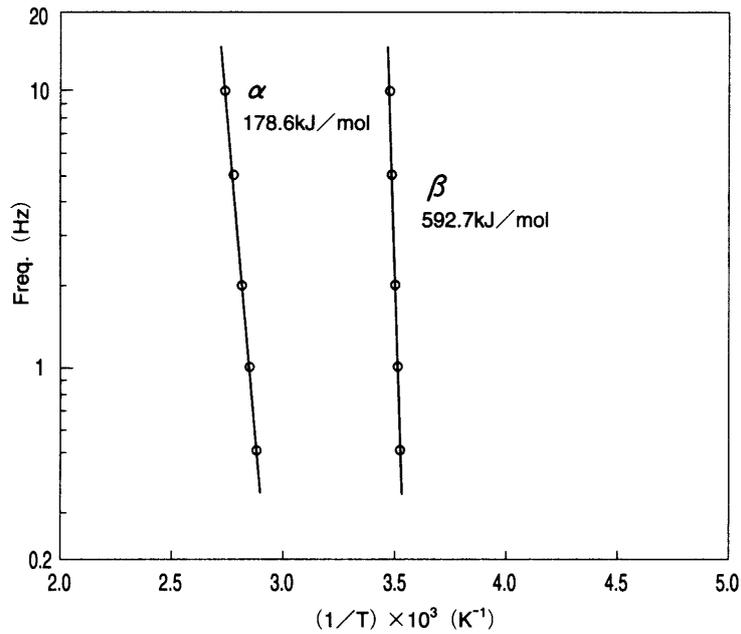


Figure 4 Apparent Activation Energy for  $\alpha$ - and  $\beta$ -dispersion of homopolymer

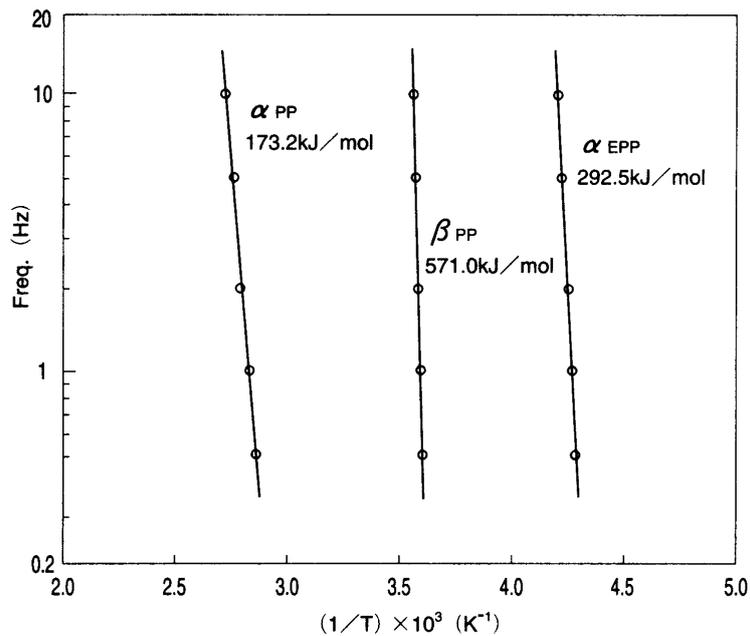


Figure 5 Apparent Activation Energy for  $\alpha$ - and  $\beta$ -dispersion of copolymer

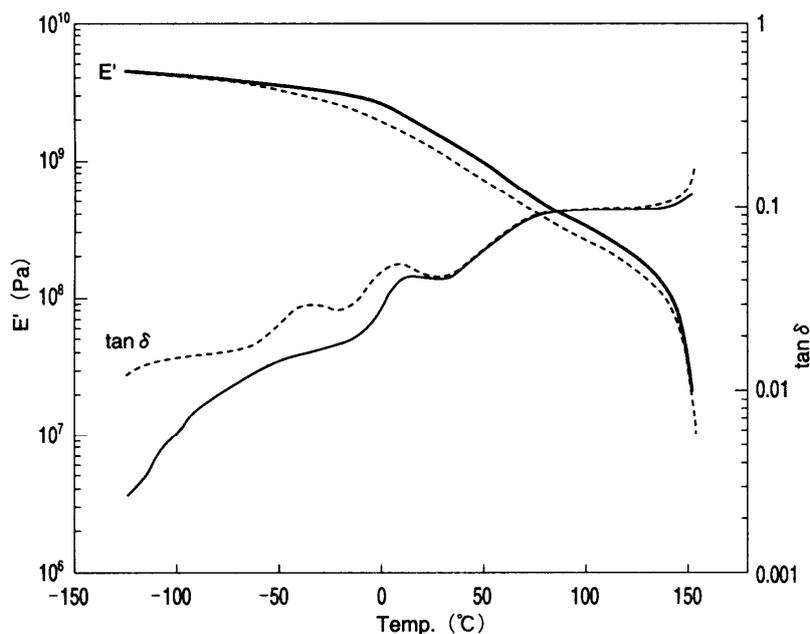


Figure 6 Comparison of  $E'$  and  $\tan\delta$  Curves for homopolymer and copolymer  
 Frequency: 1Hz  
 ————— : homopolymer  
 - - - - - : copolymer

Figure 6 shows the  $E'$  and  $\tan\delta$  curves for 10Hz of the homopolymer and block-copolymer measurement results. When the  $E'$  curves are compared, homopolymer and block-copolymer show roughly the same elastic modulus transition below  $-80^{\circ}\text{C}$ . However, after the EPR dispersion, elastic modulus of the block-copolymer is lower than that of the homopolymer. This is likely due to the effects of the EPR and PE copolymer domain in the block PP. Furthermore, a comparison of the  $\tan\delta$  curves shows that the block copolymer  $\tan\delta$  value increased in the temperature range below PP dispersion. In other words, this shows that the vibrational absorption of the block copolymer is higher than that of the homopolymer in temperature regions below room temperature. This is also an effect of the domain of EPR and the PE copolymer in the block PP. It is known that domain proportion increases and miniaturization of the dispersion phase improve vibration absorption.

#### 4. Conclusion

This application brief introduced the measurements of homopolymers and block-copolymers as applications of dynamic viscoelastic measurements of PP. In the block-copolymer results, the main dispersion (glass transition) of EPR (ethylene propylene rubber) was observed in addition to the inherent relaxation of PP. Furthermore, a difference was seen in the vibration absorption of homopolymers and block-copolymers, especially at low temperatures.

#### References

- 1) Yasaku. Wada, "Solid Properties of Polymers", Baihukan (1971)
- 2) N. Okubo, Application Brief DMS No.7, Hitachi High-Tech Science Corporation (1990)