Application Brief

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Dynamic Viscoelastic Measurements of Magnetic Film I

1. Introduction

Magnetically coated films are widely utilized for many applications including cassette tapes, VHS tapes, computer floppy disks, etc. The performance characteristics of magnetic tapes are very much dependent on the properties of the coating, which generally consists of a thermosetting binder and magnetic particles. The magnetic coating is contained on a stable thermoplastic film such as polyethylene terephthalate (PET). The characterization of magnetic tapes has been difficult using traditional thermal analytical techniques because both the coating and the substrate are very thin (e.g., 1mil or less).

Dynamic mechanical spectroscopy (DMS) provides a very sensitive means of characterizing the physical and mechanical properties of various polymeric materials such as plastics, films, fibers, elastomers, thermosets and composites. The technique provides a wealth of information on the molecular motions associated with a given material and on the particular morphology, or structure, of a polymer. Because of the high sensitivity of DMS, the transitions associated with thin coatings, such as magnetic coatings on videotapes, can be easily detected.

In this study, the viscoelastic properties of a 0.8mil videotape were studied along with that of the base substrate (PET film with a thickness of 0.3mil).

2. Experimental

In this particular study, a 0.8mil videotape (consisting of a magnetic coating on a PET substrate) was characterized using the DMS200. The viscoelastic response of the PET substrate (thickness of only 0.3mil) was also determined.

The following conditions were used to characterize the videotape and its substrate:

Heating rate: 2°C/min
Initial temperature: -100°C
Deformation mode: combination auto-tension
Sample length: 6 mm
Sample width: 4 mm
Sample thickness: 0.009 mm (PET substrate)
0.020 mm (video tape)
Frequencies: 1, 2, 5, 10 and 20 Hz
Strain amplitude: 30μm
Base force: 10 grams
Initial force: 200 grams
Tension proportional coefficient: 1.3

3. Example of Analysis

Displayed in Figure 1 are the results obtained on the PET substrate. This figure shows the tensile storage modulus (*E*') and the loss modulus (*E*'') as a function of sample temperature. The beta relaxation event for PET is observed as a series of peaks in *E*'' between -100 and 0°C. At a frequency of 1Hz, the beta relaxation has an *E*'' peak temperature of -74°C. The glass transition, or alpha relaxation, for the crystalline, oriented PET substrate is observed at 111°C. The elastic modulus exhibits a significant decrease as the amorphous phase undergoes softening at Tg.

The analysis of materials using various frequencies provides a benefit in that the activation energy, *ΔE*a, may be assessed using the Arrhenius approach. This entails plotting the log of the frequency versus the inverse of the peak temperature. A straight line will be obtained which has a slope equivalent to -*E*a/R, where R is the ideal gas constant. Shown in Figures 2 is the Arrhenius plots generated for the alpha and beta relaxation events, respectively, for the PET substrate. An activation energy of 350kJ/mole is obtained for the alpha transition while the value of *ΔE*a is 5l kJ/mole for the beta relaxation event.

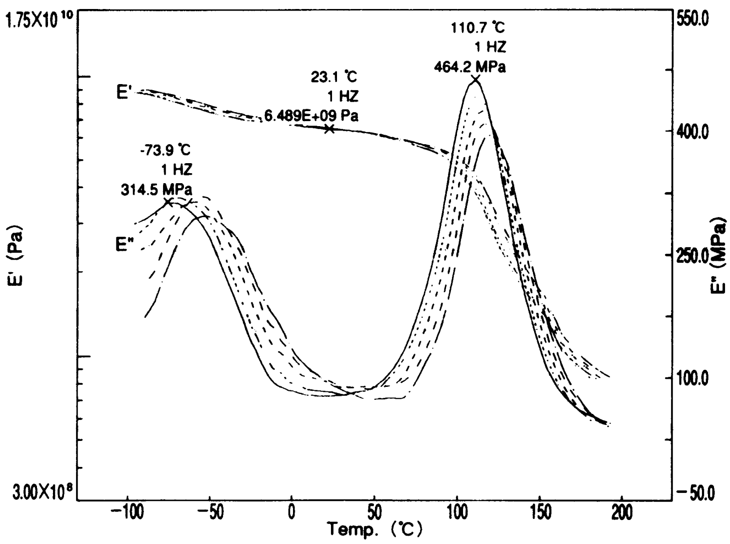

Figure 1　Dynamic viscoelasticity spectrum of PET substrate

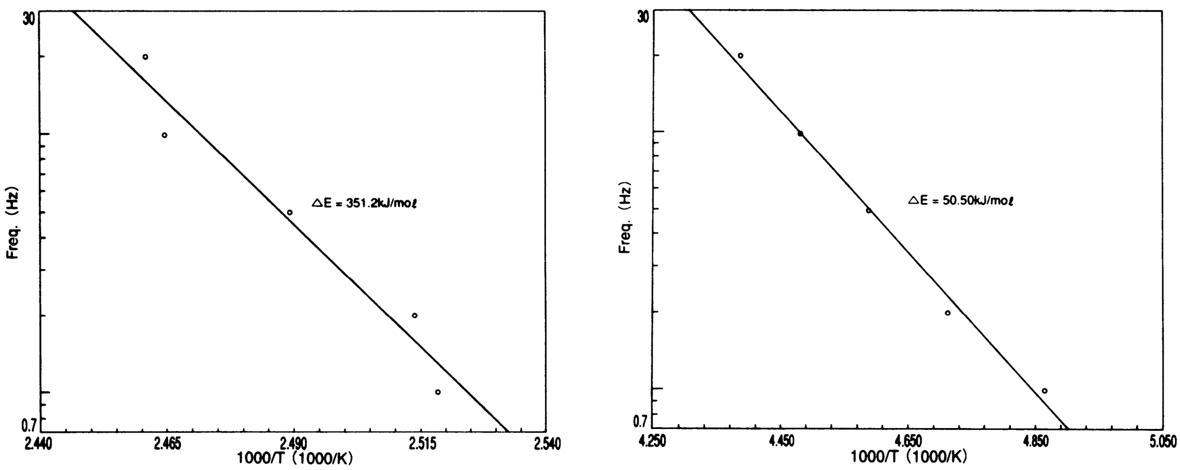

Figure 2　Arrhenius plots of the alpha and beta relaxation for PET substrate

Displayed in Figure 3 are the results obtained on the 0.8mil videotape specimen. Three well-defined transitions are observed between -100 and 200°C: the PET beta relaxation event at -67°C, the PET alpha relaxation at 108°C and a transition at 62°C which is reflective of the Tg of the magnetic coating. The shape and temperature of the coating transition is important since it may be related to the wear-resistance properties of the videotape.

Displayed in Figure 4 is a direct comparison of the tanδ behavior of the PET substrate and the videotape. This data was plotted at a reference frequency of 1Hz. As may be seen, the presence of the coating results in an additional transition at 60°C. The magnitude of the beta transition is decreased for the videotape since the effects of the PET polymer are "diluted" with the addition of the magnetic coating.

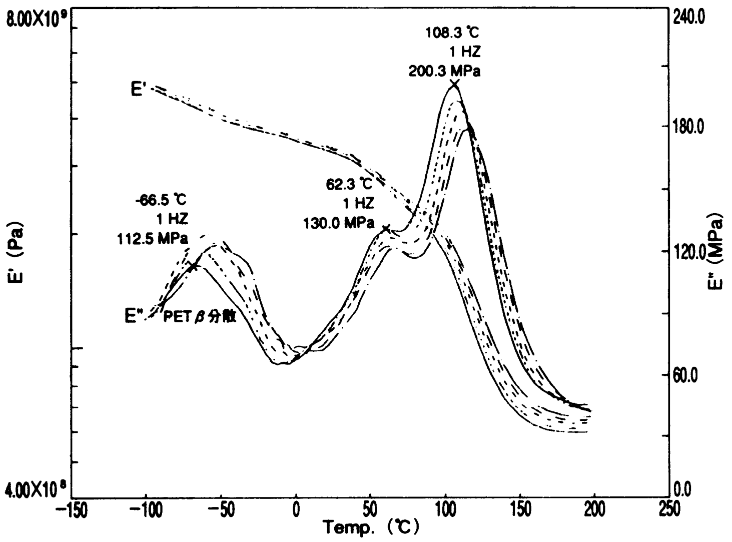

Figure 3　Dynamic viscoelasticity spectrum of videotape

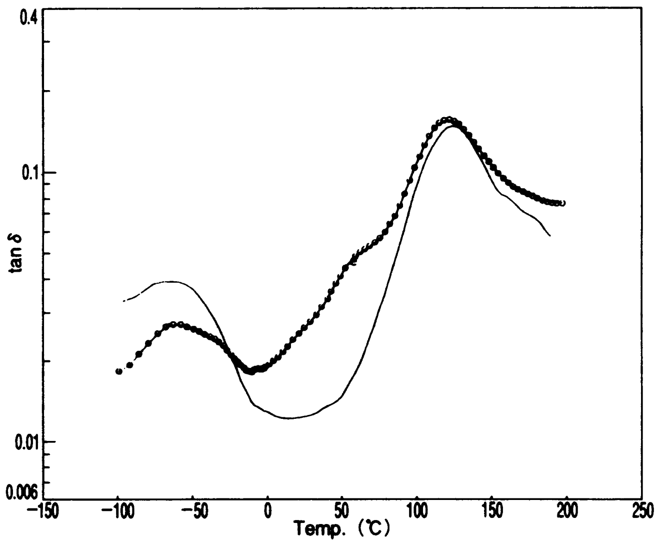

Figure 4　Comparison of the tanδ for PET substrate and Videotape.

——————— PET substrate

-ooooooooooo- Videotape

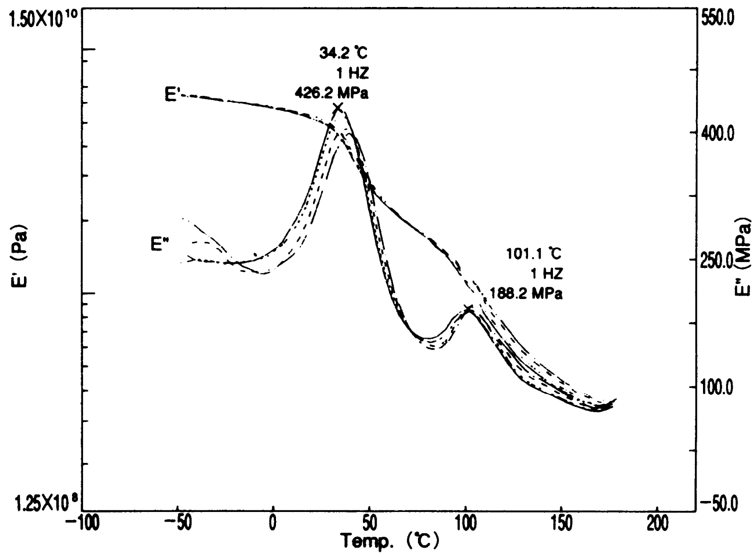

Figure 5 Dynamic viscoelasticity spectrum of Floppy disk

As a comparison to the videotape, a specimen taken from a computer floppy disk was characterized using the DMS200. The results obtained from the floppy disk specimen are displayed in Figure 5. Again, three transitions are observed for this material: a PET beta relaxation event, the PET Tg at 101°C, and the transition due to the magnetic coating at 34°C. The transition observed with this particular coating occurs at a significantly lower temperature than that observed with the videotape (due to differences in the chemistries) and is also more intense. The intensity is directly related to the greater relative thickness of the floppy disk coating.

4. Conclusion

The viscoelastic properties of a videotape and its PET substrate were characterized using the DMS200. The instrument utilizes an auto-tension mode which permits the acquisition of data across a large temperature range, even if the sample undergoes shrinkage. Excellent results were obtained on the PET substrate which had a thickness of only 0.3mil. The beta and alpha relaxation events for the PET substrate were observed at temperatures of -74°C and 111°C, respectively. The addition of the magnetic coating resulted in an additional transition at 62°C.