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Dynamic Mechanical Behavior of a Novel Polymeric Composite Damping Material

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Abstract: The dynamic mechanical behavior of a novel polymeric composite damping material has been investigated in this article. The composite consists of chlorinated polyethylene (CPE), N,N-dicyclohexyl-2-benzothiazolylsufenamide (DZ), 4,4′-thio-bis(3-methyl-6-*tert*-buthylphenol) (BPSR) and vapor-grown carbon fiber (VGCF). It is found that either the position or the intensity of damping peak can be controlled by changing the composition of CPE/DZ/BPSR composite. Within a certain composition region, damping peak maximum depends on CPE/DZ ratio, whereas damping peak position is controlled by BPSR content. Moreover, the improvement of storage modulus can be achieved by incorporation of VGCF. These results may imply that a damping material possessing both good damping properties and high strength can be designed and obtained.

Keywords: Dynamic mechanical behavior, polymeric composite, damping material.

Damping of vibration has become an important requirement in the design of automotive and aerospace structure. Many efforts have been made to control the vibration and noise. One of the most common methods is the application of a viscoelastic material[1,2], such as a rubber with a broad and high damping peak in its glass transition region. However, the improvement in the damping efficiency of such a material is limited to some extent[3]. For example, the glass transitions of most rubbers are lower than the application temperature and the enhancement of damping usually causes corresponding reduction in stiffness and strength.

Recently, polymeric composites have increased interest in the development of damping materials due to their relatively high strength and excellent damping characteristics[4-6]. A polymeric composite containing piezoelectric ceramic powders and electrical conductive particles has been developed[7,8]. The damping mechanism of such a composite is assumed to be due to the energy transferring effect through the cooperation among the components. Such an energy transferring effect has been referred to the piezo-damping effect[8].

Although the piezo-damping effect indeed existed in such conductive piezoelectric polymer composites, due to the mismatch between the piezoelectric ceramic filler and the polymeric matrix, the values of loss factor in the room temperature region may be not

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high enough for the practical application. In the present work, a novel polymeric composite containing two kinds of organic piezoelectric additives and short carbon fibers have been developed to improve the damping efficiency and strength.

Experimental

Chlorinated polyethylene (CPE) (from Showa Denko Co.) was used as a polymeric matrix. N,N′-Dicyclohexyl-2-benzothiazolylsufenamide (DZ) (from Oouchi Shinko Kagaku Kougyou Co.), 4,4′-thio-bis(3-methyl-6-*tert*-buthylphenol) (BPSR) (from Seiko Kagaku Co.) were used as organic additives. Vapor-grown carbon fiber (VGCF) (from Showa Denko) was used as filler. The polymer and additives were mixed on a two-roll mill at 160 ℃ for 25 min. Then the mixture was pre-molten at 160 ℃ for 10 min and compressed under a pressure of 18 MPa for 10 min, followed by quenching into water to obtain a film with the thickness of 0.5 mm. Dynamic mechanical measurements were carried out on a dynamic mechanical analyzer (DVA-200S). The experiment was performed in tension mode at 0.1% strain amplitude at a frequency of 10 Hz and varied temperatures from -50 to 150 ℃ with a heating rate of 5 ℃/min.

Results and Discussion

The dynamic mechanical spectra for CPE/DZ samples at a frequency of 10 Hz are shown in **Figure 1**. The loss factors (tan δ) for all the samples present a single relaxation peak, which corresponds to the glass transition temperature of the mixture. The damping peak position shifts to a higher temperature with increasing DZ content, indicating that the strong interaction existed between the DZ and CPE chains. With the increase of DZ content, damping peak intensity increased dramatically, while the storage modulus (E′) increased below the glass transition temperature but decreased above the glass transition temperature. The value of damping peak intensity for the mixture with 70 wt.% DZ was three times higher than that for pure CPE.

Figure 1 Temperature dependence of loss factor and storage modulus for CPE/DZ blends

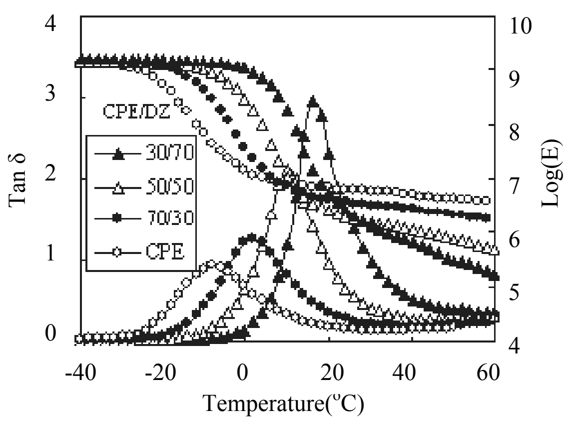


Figure 2 Temperature dependence of loss factor and storage modulus for CPE/DZ/VGCF

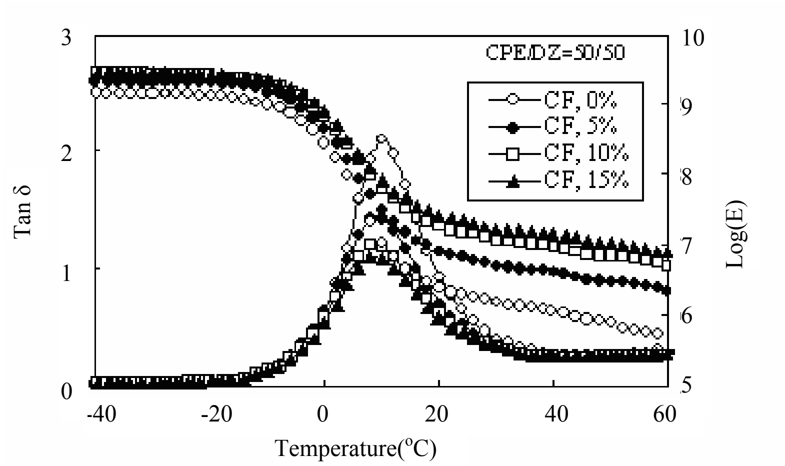
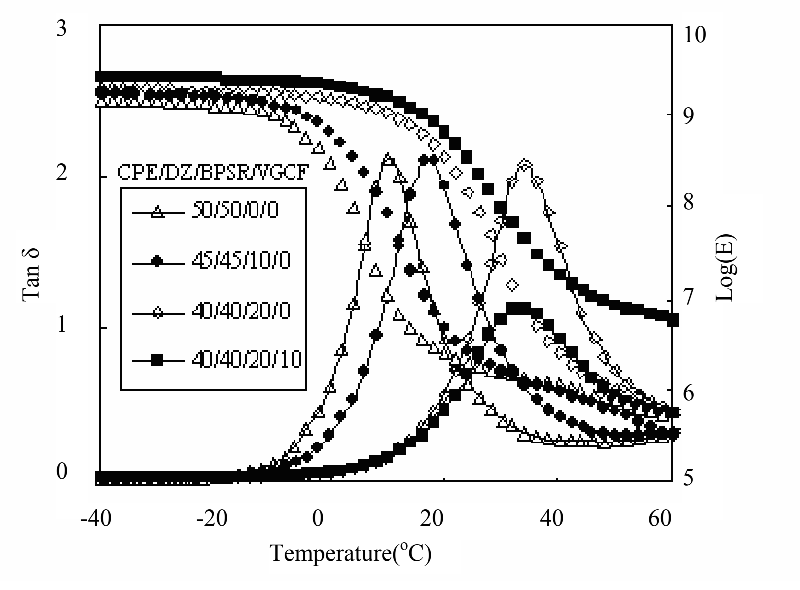


Figure 2 shows the temperature dependence of storage modulus and loss factor for VGCF filled CPE/DZ (50/50) system at various VGCF volume fractions. When VGCF is added, the relaxation peak has no obvious shift but its intensity decreased with VGCF content. Both the decrease in the concentration of CPE in the composites and the increase of E' value due to the addition of VGCF induced decrease in loss peak intensity. However, the incorporation of VGCF in CPE/DZ mixture resulted in a significant enhancement of storage modulus, especially in the temperature region around the glass transition. These can be attributed to the excellent strength but low damping capacity of VGCF.

Figure 3 Temperature dependence of loss factor and storage modulus for the composites



Although the addition of VGCF can enhance the storage modulus of the material, it can not adjust the loss peak position to a required temperature region. Further studies showed that the control of loss peak position can be achieved by the incorporation of BPSR in CPE/DZ mixture as shown in **Figure 3**. For a given CPE/DZ ratio, the values of damping peak maximum for all the CPE/DZ/BPSR samples are just the same. However, the damping peak position shifts to a higher temperature at a higher BPSR content. Such an interesting phenomenon may imply that the damping properties, such as the position and the intensity of damping peak of the material can be designed to meet various practical requirements by changing the CPE/DZ/BPSR composition. Because the CPE/DZ/BPSR samples exhibited relatively low values of storage modulus in the temperature region above the glass transition, a further study is carried out to improve the strength by adding VGCF in CPE/DZ/BPSR mixture. As seen in **Figure 3**, an interesting point should be noted that the CPE/DZ/BPSR/VGCF sample exhibited both higher damping peak intensity and more strength compared to pure CPE.

Conclusions

For the CPE/DZ system, the damping peak shifts to a higher temperature and its intensity increased with increasing DZ content, indicating that the strong interaction existed between the DZ and CPE chains. The addition of VGCF in CPE/DZ resulted in enhancement in storage modulus and decrease in damping peak intensity. For the CPE/DZ/BPSR system, either the damping peak position or its intensity can be designed by changing the composition. Moreover, the improvement of storage modulus can be achieved by the incorporation of VGCF. These may imply that a damping material possessed both good damping properties and high strength.

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