

In-situ Compatibilization of Immiscible Polymer Blends by Power Ultrasonic Wave

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초음파 가진에 의한 비상용계 고분자 블렌드의 상용화

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Introduction

Ultrasonic irradiation differs from traditional energy sources (such as heat, light, or ionizing radiation) in duration, pressure and energy per molecule. Ultrasound is a unique means of interacting energy and matter. The chemical effects of ultrasound do not come from a direct interaction with molecular species. Instead, sonochemistry derives principally from acoustic cavitation: the formation, growth and implosive collapse of bubbles in a liquid. [1] High intensity ultrasonic waves are generally employed in the areas of cleaning, plastic welding machining, etc. In addition to these conventional applications, numerous studies have suggested a new possibility as a useful way to induce mechano-chemical degradation in polymeric materials. [2-6] It was observed that if polymer solution is subjected to irradiation of high intensity ultrasonic waves, main-chain scission of polymer chains occurs and consequently the molecular weight is decreased. An important consideration here was to investigate whether the ultrasound-aided degradation is possible during melt processing. In addition, it was expected that this process could be used to compatibilize immiscible polymer blends in the absence other chemical agents or compatibilizers.

In this study, we investigated phase morphology and rheological properties of immiscible polymer blends after the materials were processed with ultrasonic-assisted mixing.

Experimental

PMMA and PS used in this were obtained from LG Chemical. Their commercial names are IH830 and GPPS, respectively. In order to impose ultrasonic wave during melt mixing, a

specially designed ultrasonic horn was assembled with a Haake mixer. For durable operation, an effective cooling accessory was necessary. The horn vibrated longitudinally at a frequency of 20kHz with an amplitude of 30 μ m. A 1.5kW power supply with a piezoelectric converter was used. Each sample was prepared on a fixed volume basis of 70% and loaded at 230°C with a rotor speed of 90 rpm. Sonication times investigated were 10, 20 and 30min. Various blend ratios were used to investigate the effect of viscosity ratio on the evolution of phase morphology.

Result and Discussion

Complex viscosity(η^*) of the neat polymers by sonication time is shown in Fig. 1. As shown in the figure, viscosities of PS decrease along with the increase of the sonication time, whereas change of viscosities for PMMA is not monotonic. In case of PMMA, 10 min. of sonication resulted in increase of the viscosities and then, further sonication lead to decrease in viscosity. After 30 min of sonication, the viscosities were close to those of pristine PMMA. In principle, the tendencies found from Fig. 1 are originated from the chain scission and generation of macroradicals of polymer chains by ultrasonic wave. After the initial chain scission, the subsequent changes are different depending on the molecular structure of the polymer under sonication. The data provided in Fig. 1 indicate that within the available range of sonication time, PS chains are continuously degraded while PMMA chains are cross-linked during the early stage and degraded at the later stage of sonication.

Fig. 2 shows complex viscosities(η^*) of PMMA/PS(7/3) blends prepared by simple mixing and sonicated mixing, respectively. In case of simple mixing, the viscosities of the blend remained unchanged for the given mixing times. However, as expected from the result of Fig. 1, the viscosities of sonicated blends were changed by sonication time. It appears from Fig. 2 that viscosities of the blend were lowest after 20 min of sonication.

Scanning Electron Microscoph (SEM) was to investigate the morphology of the PMMA/PS blends. According to the unique mode of power ultrasonic wave, the morphology of blends revealed remarkable difference in domain size of the minor component as displayed in Fig. 3 and Fig. 4. It is evident that sonicated mixing was quite effective in compatibilizing immiscible blend of PMMA/PS. Simple mixing yielded coarse morphology especially for 30 min mixing, where coalescence of the domains were promoted during the prolonged melt mixing. Sonicated mixing, however, produced stable morphology

with significantly reduced phase size, which is indicative of compatibilized blend. No doubt, such consequence is relevant to the in-situ copolymer formation between different macroradicals which are mainly generated by imposition of ultrasonic wave during melt mixing.

Conclusions

By using high intensity ultrasonic wave, it was possible to induce chain scission in the polymer melt and compatibilization of immiscible blends were successfully achieved without any compatibilizers. As a result, PMMA/PS blends prepared by sonicated mixing exhibited stable morphology with reduced phase size of the domain compared to simple melt mixing.

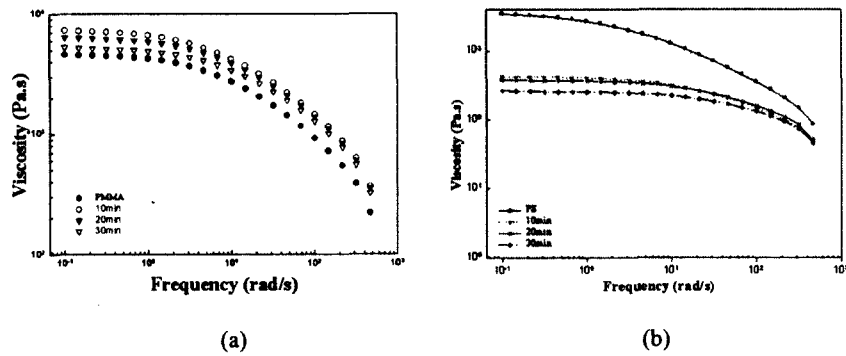


Fig. 1 Effect of sonication time on the complex viscosity(η^*)
(a) PMMA (b) PS

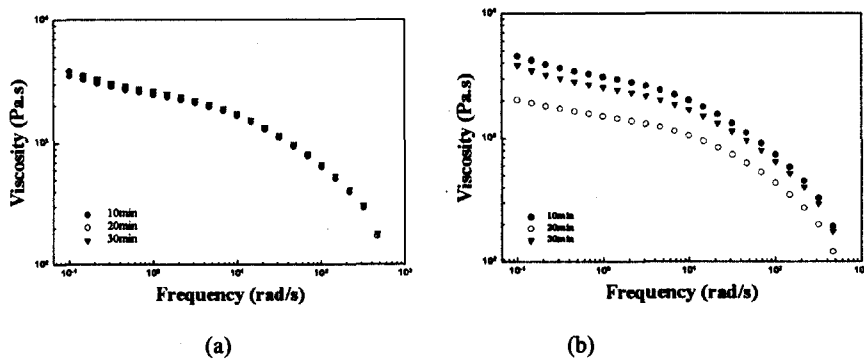


Fig. 2 Complex viscosities(η^*) of PMMA/PS blends for various mixing times.
(a) without sonication (b) with sonication

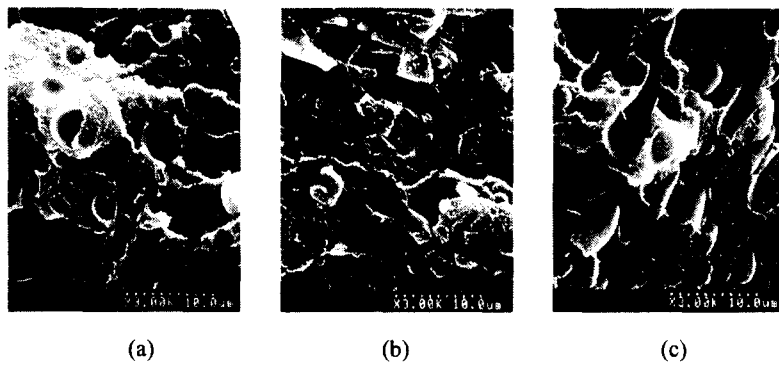


Fig. 3 SEM micrographs of PMMA/PS blends obtained by simple mixing.
Mixing time ; (a) 10 min (b) 20 min (c) 30 min

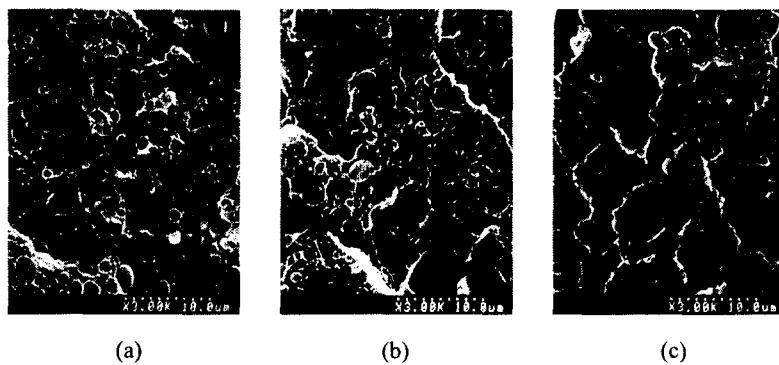


Fig. 4 SEM micrographs of PMMA/PS blends obtained by sonicated mixing.
Mixing time ; (a) 10 min (b) 20 min (c) 30 min

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