Meso-structural Changes of PP/PVDF Blend Melts under External Electric Fields

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1. Introduction

It has been well known that meso-structural changes of immiscible binary liquid whose components have different dielectric constants each other can be taken place by applying electric fields. It has been reported that, in an immiscible liquid blend, droplets dispersed in matrix are aligned along the direction of electric field and bridge between two electrodes. This phenomenon can be applied to thermoplastic blend systems to develop new materials whose mesoscopic structures are controlled by the electric field. Recently, we found that, even in thermoplastic blend systems, a similar structural change to those in immiscible liquid blends can be occurred. In this study, we selected a substance that has a high dielectric constant and a high electrical conductivity at molten state, and we estimate the velocity of structural change by electric current measurement under electric fields. Then we estimated a relative velocity between two interacting droplets with induced dipole moment. Finally we report that one of candidates of application where structural changes obtained by applying electric fields are used.

2. Experiment

The sample used here is a blend that consists of polypropylene (PP) having a low dielectric constant and a small amount of poly(vinylidene fluoride)(PVDF) having a high dielectric constant. The blend was prepared in a twin screw kneader at 200 °C, 72 rpm for 5min. The blend samples were heated to 200 °C and kept at 200 °C for 5min, and then an electric field (1.5kV/mm AC, 50Hz) was applied to the molten samples. During the electric field was applied, electric currents in the samples were measured.

3. Results and Discussion

Figure 1 shows the electric current in PP/PVDF under an electric field (1.5kV/mm AC, 50Hz) at 200 °C . In case that the electric field was applied to a pure PVDF system, the electric current became flat after a peak was observed. In the case of a pure PP system, however, no electric current was observed. From the three blend cases in Fig.1, it can be considered that dispersed droplets (PVDF) bridged between two electrodes at a time when the current gives a maximum. That is, the times when columns were formed between two electrodes are 65, 257 and 589 sec for 80/20, 85/15 and 90/10 ratio of PP/PVDF blends, respectively. We calculated a characteristic relative velocity between two droplets in PP-matrix by using induced dipole moment in order to compare experimental results with calculated ones. Figure 2 shows the time evolution of characteristic distance between two droplets R(t) that are obtained by considering the interaction between two droplets having induced dipole moments. Because it can be considered that two droplets attached each other at the time when the distance between two droplets becomes two times of radius 2a , we estimated the time t<sub>a</sub> that a column connects two electrodes is formed. The connecting times t<sub>a</sub>'s for ratios 80/20, 85/15 and 90/10 of PP/PVDF blend are turned out to be 57,600, 119,000 and 302,000 sec respectively. By comparing the estimated times t<sub>a</sub> with experimental results, it is found that the velocities of structural change obtained from experiments are much faster than that calculated using the induced dipole moment. Consequently, this implies that the structural change in PP/PVDF blend system is not only due to the induced dipole-dipole interaction but also due to following factors (1) in-homogeneity of dispersed droplets, (2) electric conductivity of PVDF, (3) impurities with electric charge in PVDF, (4) elongation of droplets along the direction of the electric field, (5) many-body effect by other droplets, (6) shear thinning of PP-matrix around droplets.

Finally we show that one of examples of application using PP/PVDF system. After applying an electric filed for 3min at 200 °C , and then cooling down to room temperature, we could obtain fibers made of PVDF by removing the PP-matrix using Xylene. The averaged radius is around 10-40 μm. If we will be able to control a thinner cylindrical structure than that in the present study, such a material will be one of the candidates of filter with nanoscale cylindrical holes in PP-matrix.