Control Factors of Foam Structure and Properties in Microcellular Injection Molding

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Abstract

We investigated the foaming control factors in microcellular injection molding method, in terms of a material design and a forming condition, and this report also describes the physical properties of the samples prepared on various processing condition.
By optimization of a material design, a processing condition and a molding design , the microcellular injection molding technology has potentialities of forming a homogeneous and microcell-structure ,which is expected several excellent physical properties. The co-polymer Polycarbonate (PC) and the long chain branching PC give better cell size uniformity and smaller cell size compared with general PC. Further, the addition of foam nucleus, injection speed and using core back process are control factors. If we choose the optimum condition carefully, the foam size can be controlled about 10 μm and the distribution of cell size is uniform. Microcellullar has good merits such as dimensional stability and reducing warpage and shrinkage, especially the random dispersion of glass fibers for glass fiber filled materials is observed by using this technology.

1. Introduction

Microcellular plastic has been getting popular, because it has advantages of dimensional stability, low warpage, light weight and good flowability by using the clean foaming agents such as CO_2 and N_2 . If the size of foam is controlled less than 10 μm uniformly, the reduction of physical properties is prevented to a minimum. This microcellular parts have potential for insulating material, precision component for IT parts, automobile parts with light weight. But the plastic products by using this process usually have a bad appearance. But if the process conditions and materials are carefully controlled, many problems are solved. For example, co-polymer PC with inorganic materials gives very fine foam plastic products and good appearance with high gross. This research presents the relationship among process conditions, material design and foam size for the microcellular injection molding.

2. Experimental

2.1 Experimental Equipment

Japan Steel Works (JSW) 180ELIII (Mucell Machine) shown in Figure 1 is used with the box type mold which has a center gate with the gate diameter 1.5mmφ and shut-off nozzle .
Super critical fluid (SCF) Nitrogen is used. Three different types of PCs which are general PC, copolymer PC and long chain branching PC are used in this research. The foam morphology of mold

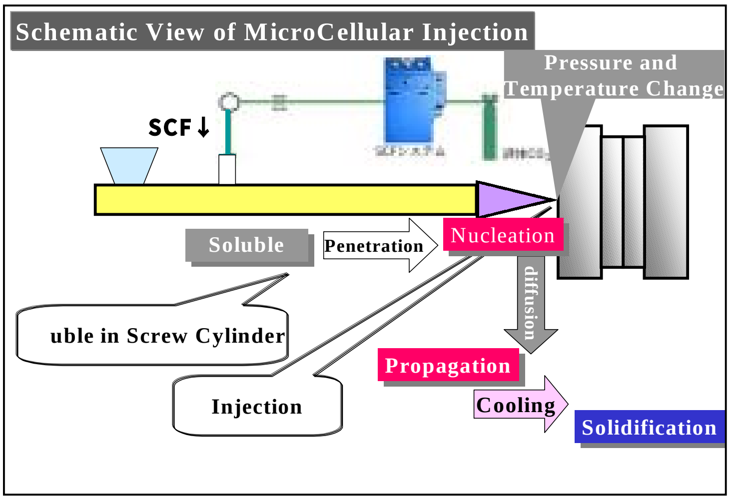


Fig.1 Equipment of Microcellular Injection Molding

parts is observed by the scanning electron microscope, the laser microscope and x-ray CT micro-analyzer. The weight reduction ratio, relative density and tensile modulus are also measured.

2.2 Materials and Process Conditions

The process conditions and resins are shown in Table 1. The resin temperature is set at 310℃ and SCF gas is inserted to injection machine at the pressure 17MPa which is higher than resin pressure 15MPa.

Table 1 Resins and Process Conditions

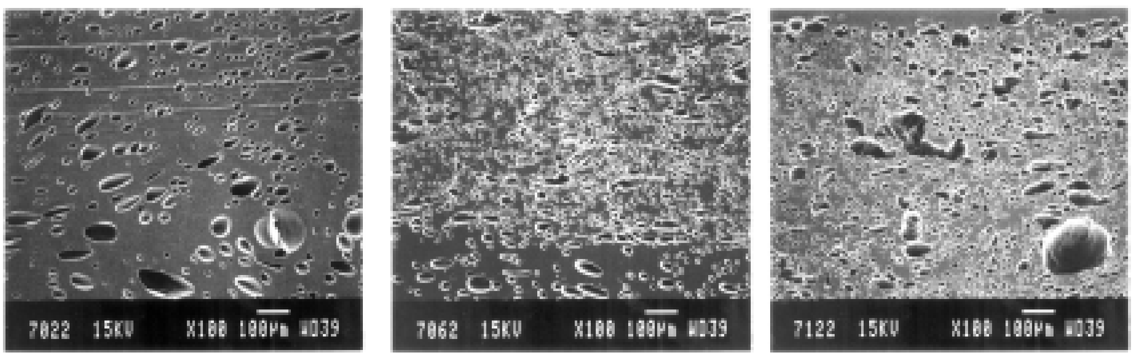
	General PC	Copolymer PC	Long Chain Branching PC
Resin Temperature	310℃	310℃	310℃
Resin Pressure	15MPａ	15MPａ	15MPａ
SCF gas	N_2	N_2	N_2
SCF Pressure	17MPａ	17MPａ	17MPａ
Gas Content of SCF	0.6wt%	0.6wt%	0.6wt%
Injection Speed	100mm/s	100mm/s	100mm/s
		400mm/s	
Cavity Thickness	2mm	2mm	2mm
		2→3mm	

3. Experimental Results and Discussion

The foam morphology is observed by an electron microscope in order to obtain the control factors for cell size and uniformity.

3.1 Materials

Three types of PCs namely general PC, copolymer PC and long chain branching PC, are used. Figure 2 shows the cell morphology for different PCs. The copolymer PC and long chain branching PC show smaller cell compared with the general PC at the same gas volume. The general PC has fewer nucleus and the number of cells are fewer. The copolymer PC and long chain branching PC may have more nucleate and higher viscosity during the solidification.



General PC Co-polymer PC Long chain branching PC

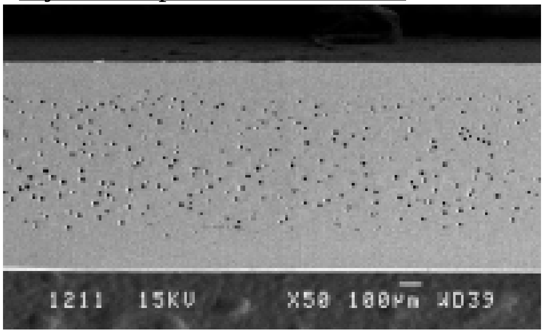
Fig.2 SEM photomicrograph of foamed General PC, co-polymer PC and long chain branching PC

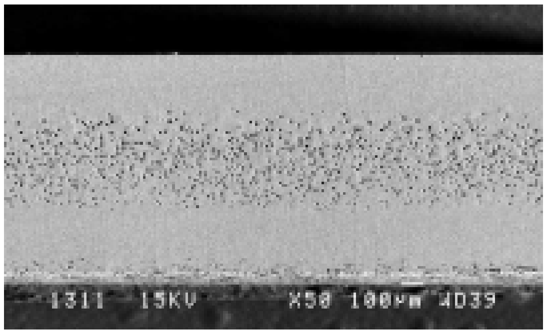
3.2 Injection Speed

The electron photomicrographs of copolymer PCs are shown in Fig.3 under the different injection speed and different cavity position. Under the low injection speed, the more the

number of cells are observed at the near the gate and on the contrary under the high injection speed, the more the number of cells are observed at the end of the cavity.
In case of injection molding, soluble and penetrated gas at 17Mpa began to foam just after the injection begins. The cell morphology is influenced by the mold pressure and pressure distribution and the cell is formed easier at the low pressure.

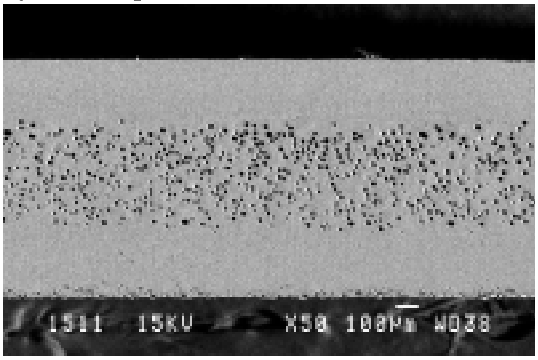
Injection Speed ：100mm/sec

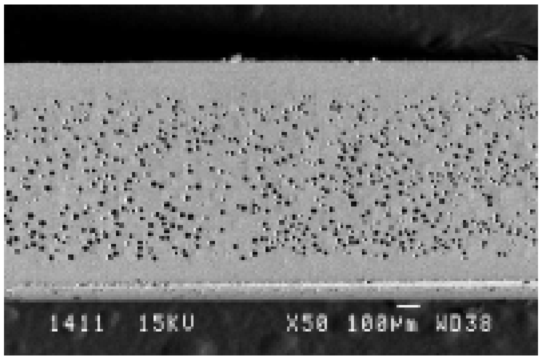




GATE AREA FLOW END

Injection Speed ：400mm/sec



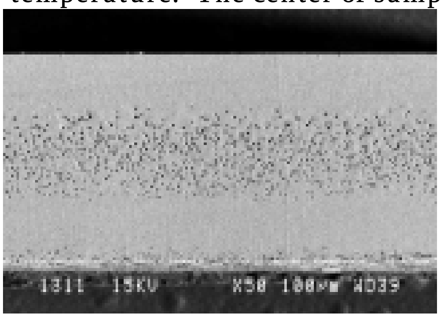


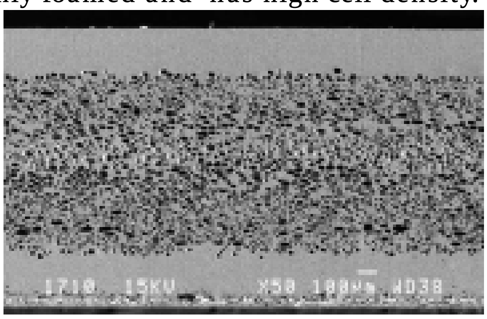
GATE AREA FLOW END

Fig.3 Effect of injection Speed for cell size by SCF N_2

3.3 Mold Pressure

Fig.4 shows the effect of core back process to the cell size and cell uniformity for copolymer PC. The core back process can control the inside mold pressure. After the filling process, the mold pressure is decreased suddenly by increasing the mold clearance. This makes very high cell density. At the same time, the cell size also increases. As the skin layer is not foamed and not changed by the cavity clearance, the foaming doesn't occur at the high viscosity and is required above the certain temperature. The center of sample is only foamed and has high cell density.





General Molding (2mm) Core back process (3mm)

Fig.4 Effect of core back process

Fig.5 is the example to improve cell size and uniformity by using the high melt tension PC with nucleating agent. Fig.6 shows the plot of the relative modulus as a function of relative density. If the uniform foam size and size distribution are obtained, the relative modulus is in proportional to the relative density between 0.80 and 1.0 and doesn't level down .

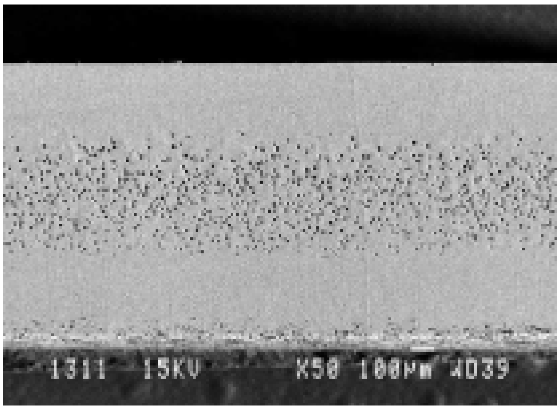


Fig.5 SEM photomicrograph of foamed high melt tension PC with nucleating agent by SCF N2

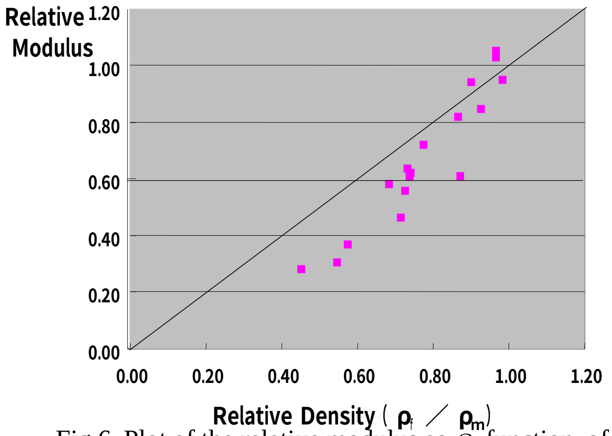
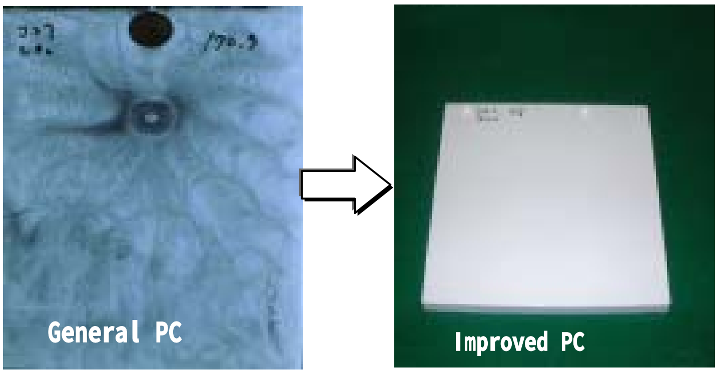


Fig.6 Plot of the relative modulus as a function of relative density

The co-polymer PC with inorganic materials gives plastic products having very fine and uniform foams and good appearance with high gross shown in Fig.7 and 8.



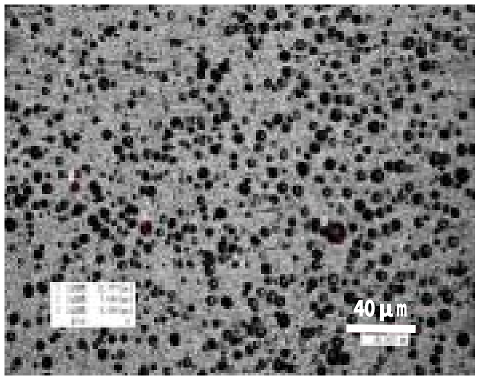
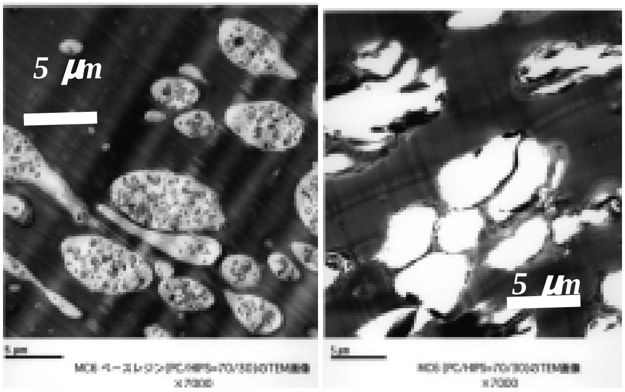


Fig.7ImprovedAppearance of Copolymer PC with inorganic materials Fig.8Laser Photomicrograph

3.3 Polymer Blend and Polymer Composite

Figure 9 and 10 are photomicrographs of blends PC/HIPS and PP nano-composite by using super critical fluid CO_2. It is found that blends and nano-composites have high potentiality to control the foam morphology.



After foaming

Fig.9 SEM Photomicrograph of PC/HIPS(70/30) by 15MPa SCF CO_2, 100°C

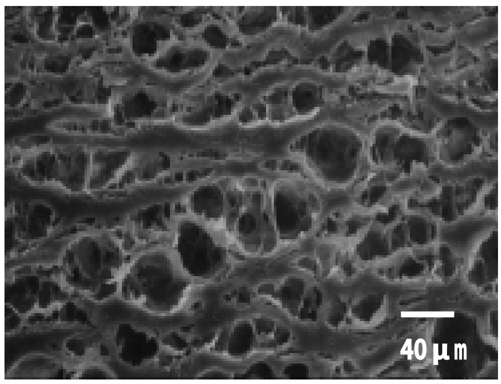


Fig.10 TEM photomicrograph of PP nano-composite at 135°C and 15MPa

4. Conclusion

This research presents the relationship among process conditions, material design and foam size for the microcellular injection molding. If the process conditions and material are carefully controlled, the problems such as the surface appearance and un-uniform foaming are solved. The co-polymer PC with inorganic materials gives plastic products having very fine and uniform foams and good appearance with high gross.