

Label Behavior Property Attached on Microcellular Foamed Parts

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ABSTRACT: In comparison with the conventional foaming process, microcellular foaming by injection molding has the advantage of forming small bubbles of consistent size. Because of the reduction in the cycle time, the removal of sink marks, scale reliability, and weight lightening, microcellular foaming by injection molding is widely applied to electrical products, such as automotive parts, office automation equipment, and laptops. When microcellular foaming by injection molding is used with a resin such as polycarbonate, acrylonitrile butadiene styrene, or PC/ABS, microbubbles form. This enables the manufacture of cell phones,

notebooks, and personal digital assistants (PDAs), which are impossible to produce with the conventional foaming technique because these products require a thin wall. For most thin-wall products, spray and labeling processes are added. Therefore, research into the spray and labeling characteristics of injected foamed parts should come before applications. In this article, we analyze the swelling phenomenon that results from labeling on microcellular foamed parts. © 2005 Wiley Periodicals, Inc. *J Appl Polym Sci* 98: 289–293, 2005

Key words: injection molding; gas permeation

INTRODUCTION

Microcellular foaming technology was developed at MIT (Massachusetts Institute of Technology) in the 1980s for the purpose of foaming plastics without mechanical property loss through the generation of bubbles smaller than the existing plastic crack.¹

The concept behind this technology begins with thermodynamically unstable conditions. Plastic is foamed by being placed in a high-pressure nonactivated gas for a period, the gas being allowed to dissolve with the plastic.

This technology maintains and enhances the mechanical strength because of the remarkably small size of the bubbles and their increased number.²

Also, Cha³ reported in 1994 that he produced 0.1- μm foamed plastic with a supercritical fluid and developed microfoaming technology at the normal temperature.

In 1993, Park⁴ studied the application of microcellular technology developed from a batch process into a continuous process, such as extrusion and injection molding.

Because of the reduction of the cycle time, the enhanced scale reliability, better flatness, and weight lightening, microcellular foaming by injection molding as a continuous process is applied to automotive

valves, printer sashes, and ink cartridge containers. Now it is usually used for interior materials because of swirl marks on the surface.

Thin-wall products, such as PDAs, laptops, and computers, need to be sprayed for the removal of the weld line and the addition of various colors. In some cases, labeling on a product is necessary. For microcellular foaming technology to be applied to thin-wall products, labeling after the spray process should not cause any trouble.

In this article, we examine the causes of label trouble after the use of some harsh conditions to label injection-molded foamed specimens. We propose gas suction as a solution and measure the label trouble rate versus time.

THEORETICAL

For label adhesion on injection-molded parts, air should not be gathered during the labeling process.

Once air gets between the label and plastic parts, it causes large air holes over the label because of volume changes of the air with temperature. These air holes spoil the appearance of plastics.

To prevent this trouble and reduce the faulty appearance, the squeeze method, which lets minimal air gather between plastic parts and labels, is used in industry.

Most problems followed labeling or spraying are caused by the separation of the label or spray from the injection-molded parts. For labeling, these problems

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lower the appearance quality, and for spraying, they even increase product inferiority.

The primary reasons for these problems are air gathering, alien substances (dust, water, etc.) on the surface, and roughness of the surfaces of foamed parts.

For microcellular foaming by injection molding, there is one more trouble factor: high-density gas that has dissolved into foamed parts can escape.

Also, because the surface is rougher than that of conventionally molded parts, there is a greater possibility of label and spray problems.

Because of the dissolved gas and rough surface, it is hard to determine the primary cause of label and spray problems with microcellular plastics.

Therefore, we experimented with a batch process instead of an injection-molding process by dividing the primary factors into roughness and gas quantity.

EXPERIMENTAL

After adding a label with some adhesive property to the surface of an injection-molded part, we produced a harsh condition (a high temperature) and observed the label surface state.

Materials

Plastic/label

The plastic material was Lupoy GN5001RF (LG Chemical, Daejeon, Korea), which is used in electrical products and laptops.

The specimen was $70 \times 60 \times 1.5$ mm and was produced with a 75-ton injection-molding machine. The label adhesiveness was 360 gf/mm, and the label did not leave any adhesive on the surfaces of the molded parts after being put in and out several times.

Gas

Nonactivated gases, N_2 and CO_2 (for microcellular foaming), were used. The degree of purity was 99.99%, which is commercially normal.

Equipment and procedure

Figure 1 is a drawing of a high-pressure container designed to endure 60 MPa. It had a vessel temperature controller. A plastic specimen was placed in the high-pressure container, and the container was sealed tightly; then, 6.0 MPa of CO_2 or N_2 was provided. The container under the high-pressure condition was maintained for some time (6 h for this experiment) so that the gas could dissolve into the plastic. After 6 h, the gas-exhaust valve was opened, and the plastic specimen was taken out.

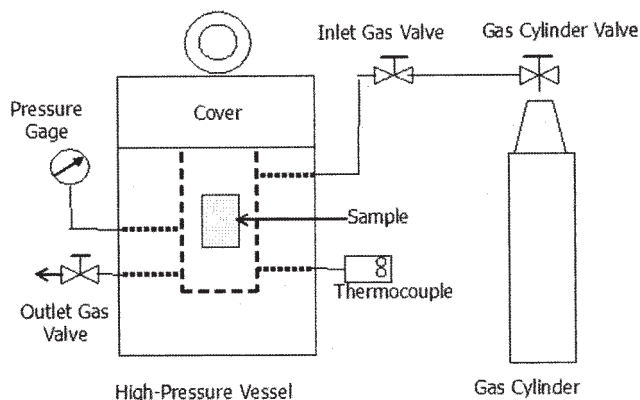


Figure 1 Schematic drawing of a high-pressure vessel system.

Specimen preparation

Because microcellular foamed parts by injection molding have rough surfaces and keep the gas inside, we experimented with conventionally injected parts. Using fine sandpaper on conventionally injected parts, we created the same degree of roughness found in foamed parts. Table II (shown later) lists the kinds of specimens used in this study. Standard specimens and roughness-added specimens were prepared (eight units of each).

To make roughness-added specimens, we measured the roughness of microcellular foamed plastics, and using this result, we controlled the surfaces of conventionally injected parts. Figure 2 compares the roughness of injection-molded foamed parts and conventionally molded parts. Figure 2(a) is an enlarged photograph of the surface of the solid parts, and Figure 2(c) presents the measured roughness of the solids. Figure 2(b) is an enlarged photograph of the surface of microcellular foamed parts, and Figure 2(d) provides the measured roughness of the microcellular foamed plastics.

The photographs show that the microcellular foamed parts had a rougher surface, and the R_y (maximum peak to valley roughness height) roughness was about $7 \mu\text{m}$. Figure 3 presents the results of atomic force microscopy (AFM), which is another way of checking the surface roughness. Figure 3(a) presents the results for solid parts, and Figure 3(b) presents the results for foamed parts. Comparing them, we found that there was a height difference between them of about 2 times.

Although it was hard to generalize the results because the AFM analysis was restricted to measurements in only a small range, considering the results of the surface roughness check, we concluded that the surfaces of the microcellular foamed parts were rougher than the solids.

On the basis of the measured results, we made the surface of the solids rough by rubbing with sandpaper and made their roughness similar to that of foamed parts.

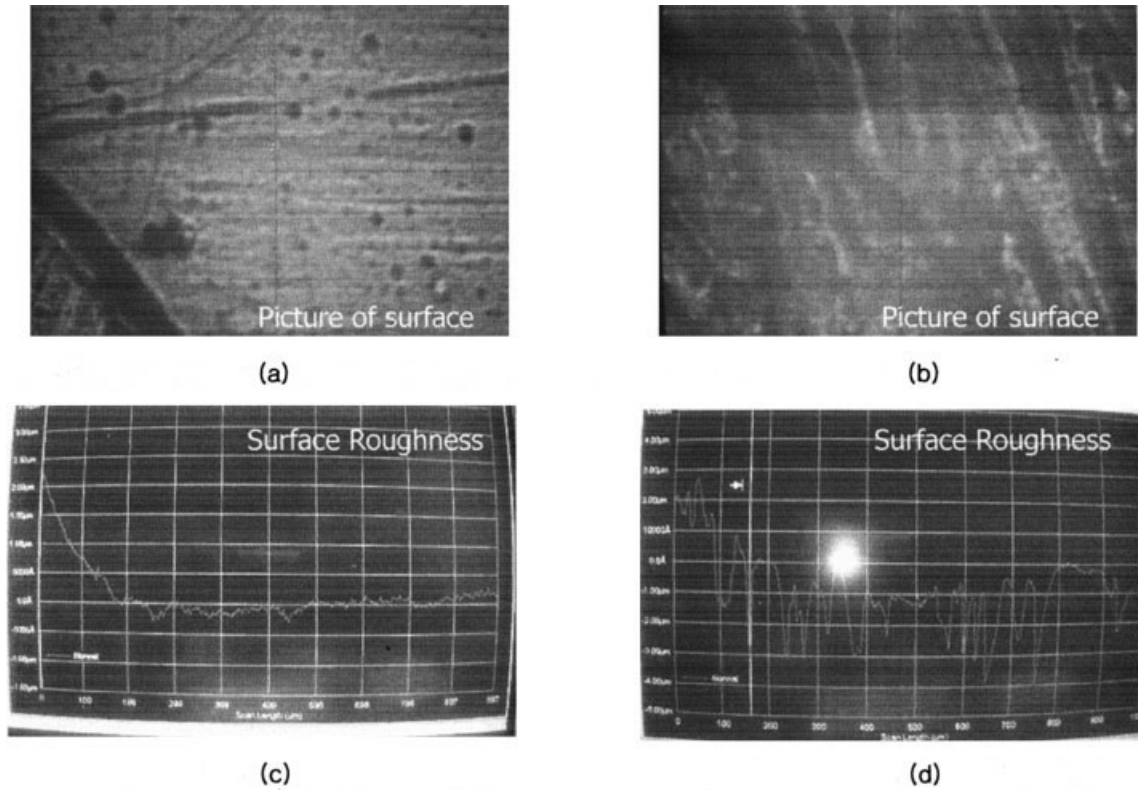


Figure 2 Surface and roughness results: (a,c) solid and (b,d) microcellular foamed plastics.

Method

Trouble factors

As shown in Table I, the prepared specimens (two standard specimens and two roughness-added specimens) were added to a high-pressure container (Fig. 1), 6.0 MPa of CO₂ was provided. Sealing prevented the CO₂ from escaping; it was left for 6 h so that the CO₂ could dissolve into the plastic material. After 6 h, the gas was released from the high-pressure container,

and the specimens were taken out. Labels were attached with the squeeze method to the specimens.

The labels were attached to the two injected specimens and two roughness-added specimens at the same time. Then, the eight labeled specimens were left in a constant-temperature chamber (70°C). After 3 h, the eight specimens were taken out, and the condition of the labels was checked.

The same experiments were performed for N₂-gas-dissolved plastic and normal (untreated) plastic.

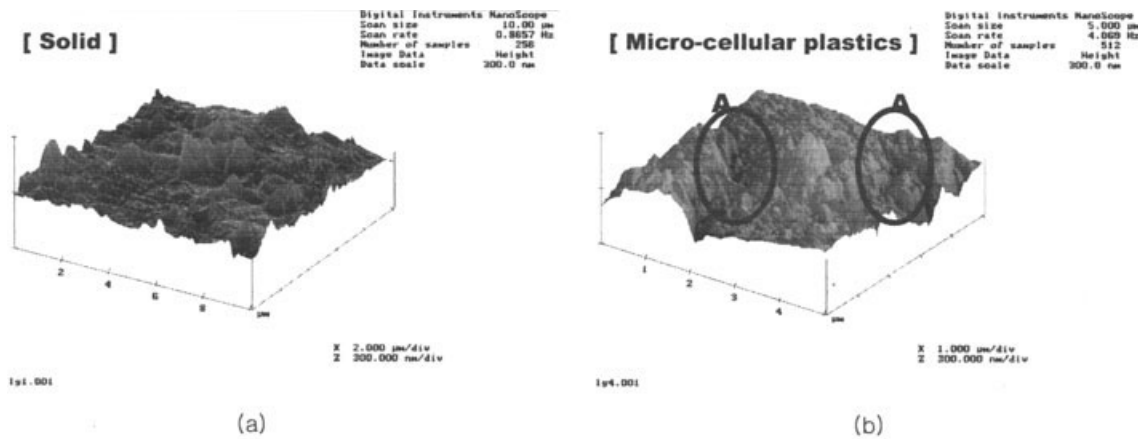


Figure 3 AFM results: (a) solid and (b) microcellular plastics.

TABLE 1
Types of Samples

	Standard		Roughness	
	No gas	CO ₂	No gas	CO ₂
Gas type	No gas	CO ₂	No gas	CO ₂
Number of specimens	2	2	2	2
Gas type	No gas	N ₂	No gas	N ₂
Number of specimens	2	2	2	2

Standard samples were solid plastics, and roughness samples were roughness-embodied samples.

Outgas quantity measurements

This experiment was used to check the escape of gas with time, this being considered a major reason for label trouble. The quantity of escaping gas was considered to solve the problem. Twenty normal specimens were prepared, and their weights were measured. Then, they were placed in a high-pressure container, and 6.0 MPa of CO₂ or N₂ was provided. After 6 h, the plastics were taken out, and the weights were measured. These 20 specimens were placed in constant-temperature chamber A (60°C). After 2 h, two samples were taken out, and the weights were checked. Then, the labels were attached to the samples, and the samples were left in constant-temperature chamber B (70°C). The label surface was checked after an hour.

As for the remaining 18 samples, two were taken out every 2 h and placed in chamber B after labeling. After an hour, the label surface was checked.

RESULTS AND DISCUSSION

Trouble factors

Table II presents the experimental results for the trouble factors. Only the gas, not the roughness, was found to be responsible. We obtained the same results with both N₂ and CO₂. Although surface roughness produced space between the surface and label, it was not a critical factor in producing label problems.

TABLE II
Label Test Results

	Standard			Roughness		
	No Gas	CO ₂	N ₂	No Gas	CO ₂	N ₂
Number of specimens	4	2	2	4	2	2
NG ratio	0/4	2/2	2/2	0/4	2/2	2/2

NG ratio, the number of NG samples over total samples; NG sample, the sample that has label problems such as bubble and blister after the label test.

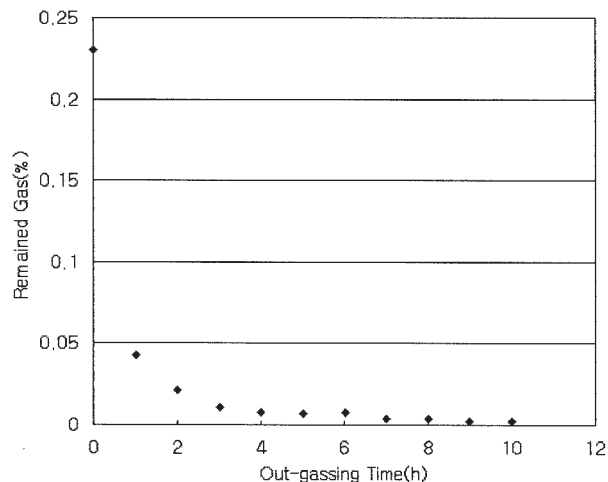


Figure 4 Remaining N₂ gas as a function of the outgassing time.

Outgas quantity measurements

Figure 4 shows the weight changes in the plastic specimens containing N₂ with time. As time went by, gas escaped because the weights of the samples were decreasing. However, the variance of the gas quantity became smaller. This concerned diffusion, which showed an exponential diffusing trend.

Table III indicates the changes in the specimens with time and the label state of each. Label problems occurred even with a small amount of gas. Trouble happened for 7 h, even though the amount of gas was small. We could eliminate label problems by getting rid of the gas under 60°C for at least 8 h.

Figure 5 shows changes in the weights of the plastic specimens containing CO₂ with time. As with N₂, the weight decreased as gas escaped. In comparison with N₂, CO₂ had a faster dissolution rate. However, when the diffusion speed became fast and made the disso-

TABLE III
Label Test Results as a Function of the Remaining N₂ Gas

No.	Remaining gas (%)	Result
0	0.23	NG
1	0.043	NG
2	0.021	NG
3	0.011	NG
4	0.008	NG
5	0.007	NG
6	0.008	NG
7	0.004	NG
8	0.004	OK
9	0.002	OK
10	0.002	OK

NG, the sample that has label problems such as bubble and blister after the label test; OK, the sample that has no label problem after the test.

lution quicker, gas also escaped at a slightly faster speed. Table IV presents the weight changes of specimens with time and the label state of each. Unlike N_2 , CO_2 had to be treated with a 5-h gas-escaping process to prevent label trouble. In other words, it took less time because the speed of diffusion was fast and so gas escaped more quickly. Generally, spray problems show results similar to those of label problems. Therefore, spraying with the removal of gas leads to a quite high defect rate. However, for spraying, it was hard to keep a constant thickness, so we were not able to deal with it in the experiments. Therefore, this label experiment was expected to be helpful in understanding spraying.

CONCLUSIONS

In this study, we set the gas and roughness as variables and carried out experiments to analyze the cause of label problems for foam-molded parts. We drew the following conclusions:

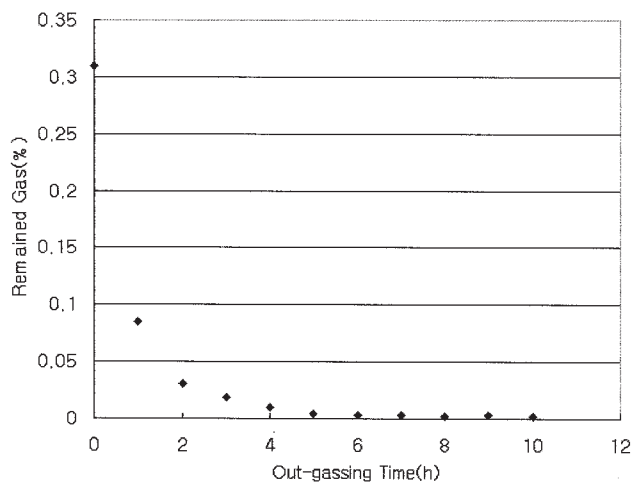


Figure 5 Remaining CO_2 gas as a function of the outgassing time.

TABLE IV
Label Test Results as a Function of the Remaining CO_2 Gas

No.	Remaining gas (%)	Result
0	0.31	NG
1	0.085	NG
2	0.031	NG
3	0.019	NG
4	0.01	NG
5	0.004	OK
6	0.003	OK
7	0.003	OK
8	0.002	OK
9	0.003	OK
10	0.002	OK

1. The roughness of a microcellular foamed part formed by injection molding is not a source of label problems.
2. Dissolved gas in plastic is a major source of label problems.
3. Through the removal of gas from plastic, which contains 6.0 MPa CO_2 or N_2 , problems can be eliminated. For N_2 , 8 h of outgassing time is required at 60°C; for CO_2 , 5 h of outgassing time is required at the same temperature.

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