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Effect on Capacitance of Porous Structure in Cellular Polymer

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ABSTRACT

Through previous research size of pore of cellular polymer effect to change of dielectric constant and capacitance was confirmed. In common science sense dielectric constant decreased, and as a result capacitance decreased too, when porosity increased. However, if size of pore minute, dielectric constant didn't decrease even though porosity increased. The reason is supposed affection of size and structure of pore. Therefore in this research we made cellular polymer which have minute pores by microcellular foaming process (MCPs) with general purpose plastics. And measurement of the change of capacitance of the cellular polymer has been performed. Furthermore, through SEM image we analyze morphology revolved around size and distribution of pore. Observing the relation between change of capacitance and morphology, as a result, morphology factor which effect to capacitance of cellular polymer was achieved.

1. INTRODUCTION

It has been known that as the pores of polymer foam are smaller and more, the drop of mechanical properties decreases at the same foaming ratio, and according to this, the technique of foaming has been continuously developed to be used in the industry. Recently, it has been confirmed that the physical phenomenon caused by small pores (cells) not only prevents the drop of mechanical properties but also leads to the change in the characteristics of reflection and penetration of light, sound and wave. In addition, a particular behavior of the electrical traits has been confirmed. When commonsense physical principle is considered, as the foaming ratio, that is, the porosity inside the material increases, the dielectric constant is supposed to decrease and consequently the electrical capacitance is supposed to decrease, too. However, the phenomenon has been observed that even though the porosity of the foamed polymer material with minute pores may increase, the value of dielectric constant doesn't decrease.

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Considering the foaming process, since the chemical change in the material is not likely to occur, the cause of the phenomenon that the value of dielectric constant does not change can be assumed to be the character of porous structure. Accordingly, this study, using Microcellular Foaming Process (MCPs), formed the porous structure for the general purpose polymer materials and measured the capacitance of the specimen of cellular polymer. Also, the morphology, sizes and distributions of cells, examined through SEM image and observed the relation with the electrical capacitance. As a result, morphology factor which effect to capacitance of cellular polymer was achieved.

2. EXPERIMENT AND ANALYSIS

2.1. Sample Preparation

ABS, PC and PP polymer materials carried out MCPs. Using of batch process which is one of the methods of MCPs, foaming performed with CO2 for blowing agent and glycerin for foaming media. Conditions of saturation process are 5MPa, the room temperature and 24 hours. The foaming temperature conditions changed for changing foaming ratio and morphology. The temperature-range set from the occurring of foaming to the melting of the specimen, and varied the experiment conditions by changing the temperatures by 10 ℃.

2.2. Capacitance Measurement

With Dielectric Analyzer, Capacitance measured, when the specimen was processed into the shape of disc with the diameter of 40mm, and according to the volume expansion by foaming the thickness corrected. The measured frequencies were 1Hz~1MHz, and since the values of capacitance of the specimens barely differ by frequency in this range of frequencies, the value of 1kHz used for the representative value.

2.3. Morphology Analysis

Cross-sectional image of the specimen obtained by SEM, then analyzed through the image processing-tool ImageJ Software. The distribution analyzed by cell size.

3. RESULT AND DISCUSSION

3*.1. Foaming Ratio*

Fig. 1 shows the change of foaming-rate depending on the changes of foaming temperature of each material. In cases of ABS and PC, as the foaming temperature increased, the foaming ratio also increased, and in the case of PP, the foaming ratio didn’t increased in the foaming temperature at more than 120℃.

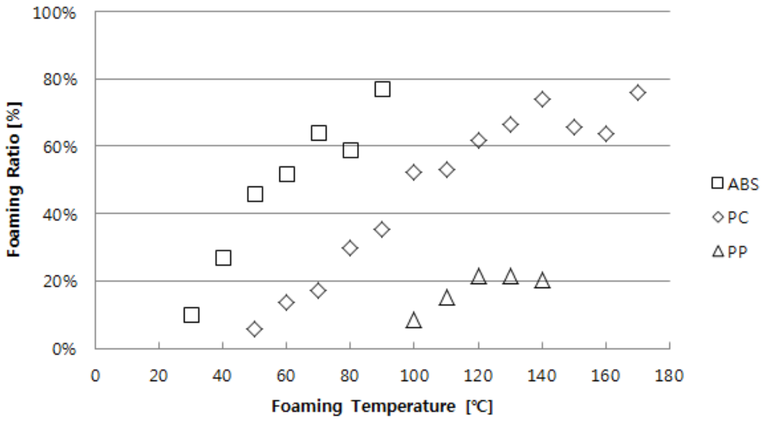

Fig. 1 Foaming Ratio on Foaming Temperature

3.2. Capacitance

Each material showed the behavior with different changes in capacitance depending on the foaming-rate. In the case of ABS, the capacitance kept constant until the 50% of foaming ratio, increased a little around 50%, then decreased. In the case of PC, the highest value was seen at 10%~30% of foaming ratio and after that the capacitance decreased as the foaming ratio increased. With PP, the capacitance change is not affected by foaming ratio. The results are shown at Fig 2.

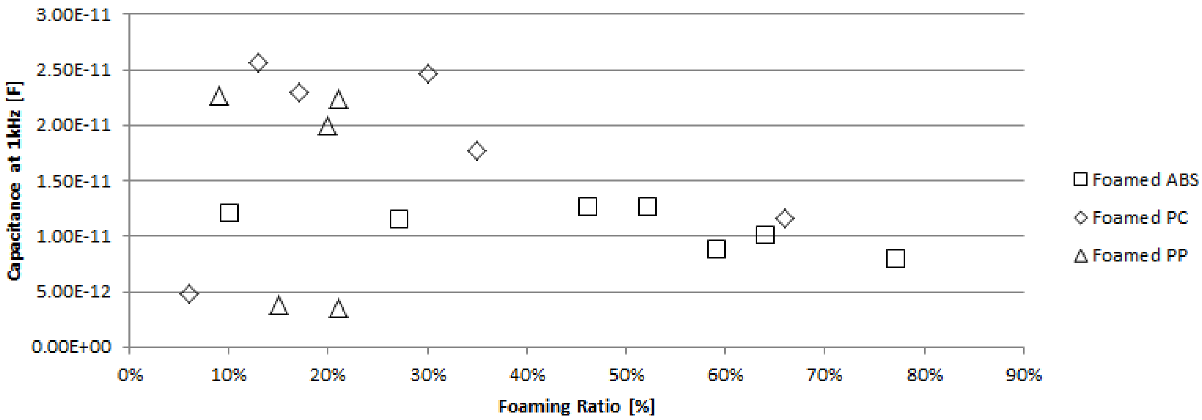

Fig. 2 Capacitance of Foamed Polymer

3.3. Cell Distribution

In Fig 3 to Fig 5, the cross sectional SEM images and the analyzed cell distribution are showed.

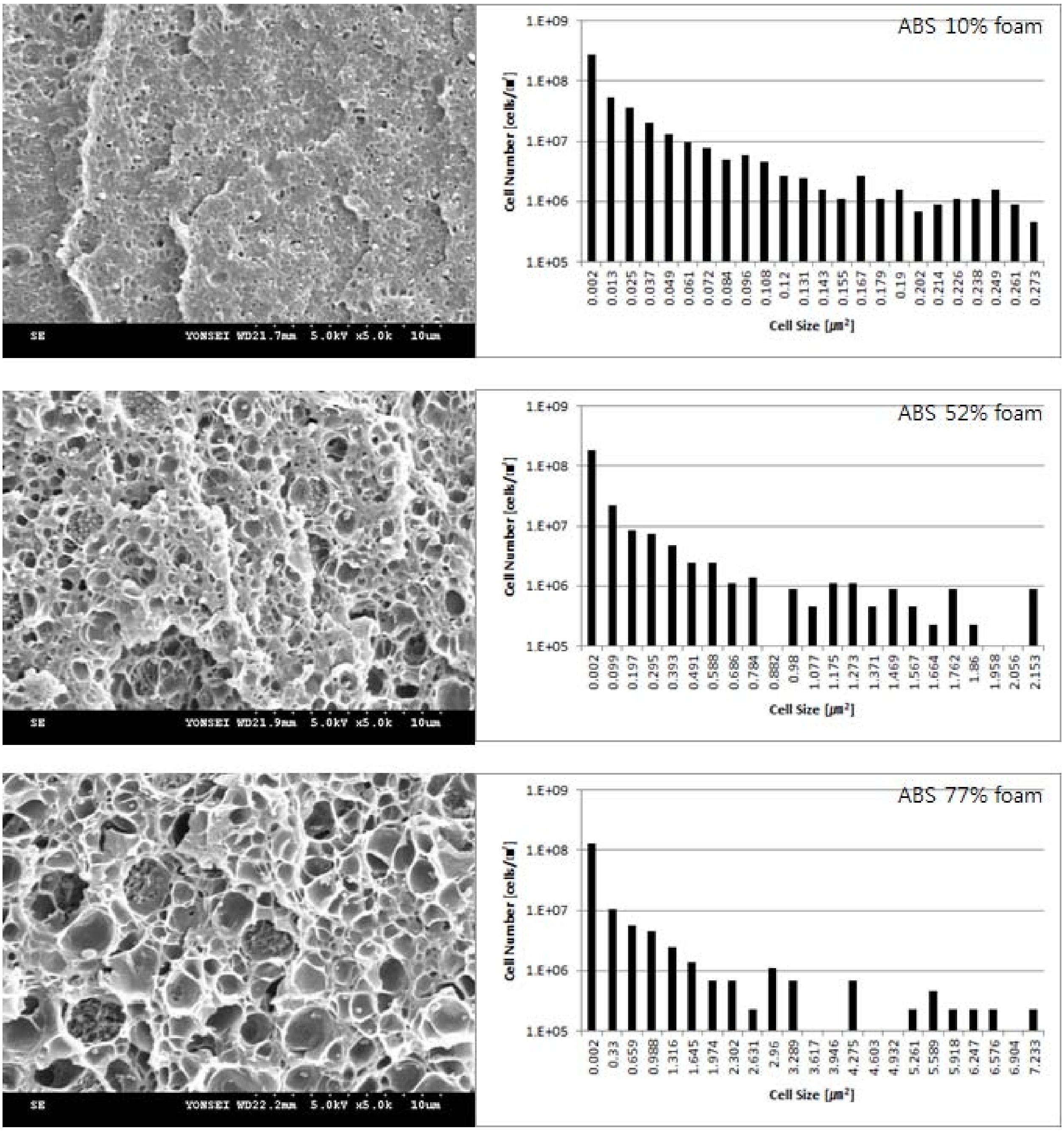

Fig. 3 SEM image and Cell Distribution of Foamed ABS

In the case of ABS, with the specimens foamed at 10% and 52% little difference of capacitance, the largest cell of each specimen is not over 0.3μm^2 and 3μm^2. But the largest cell of the specimen of 77% where the capacitance decreased is more than 7μm^2, and there are not a few cells with more than 3μm^2.

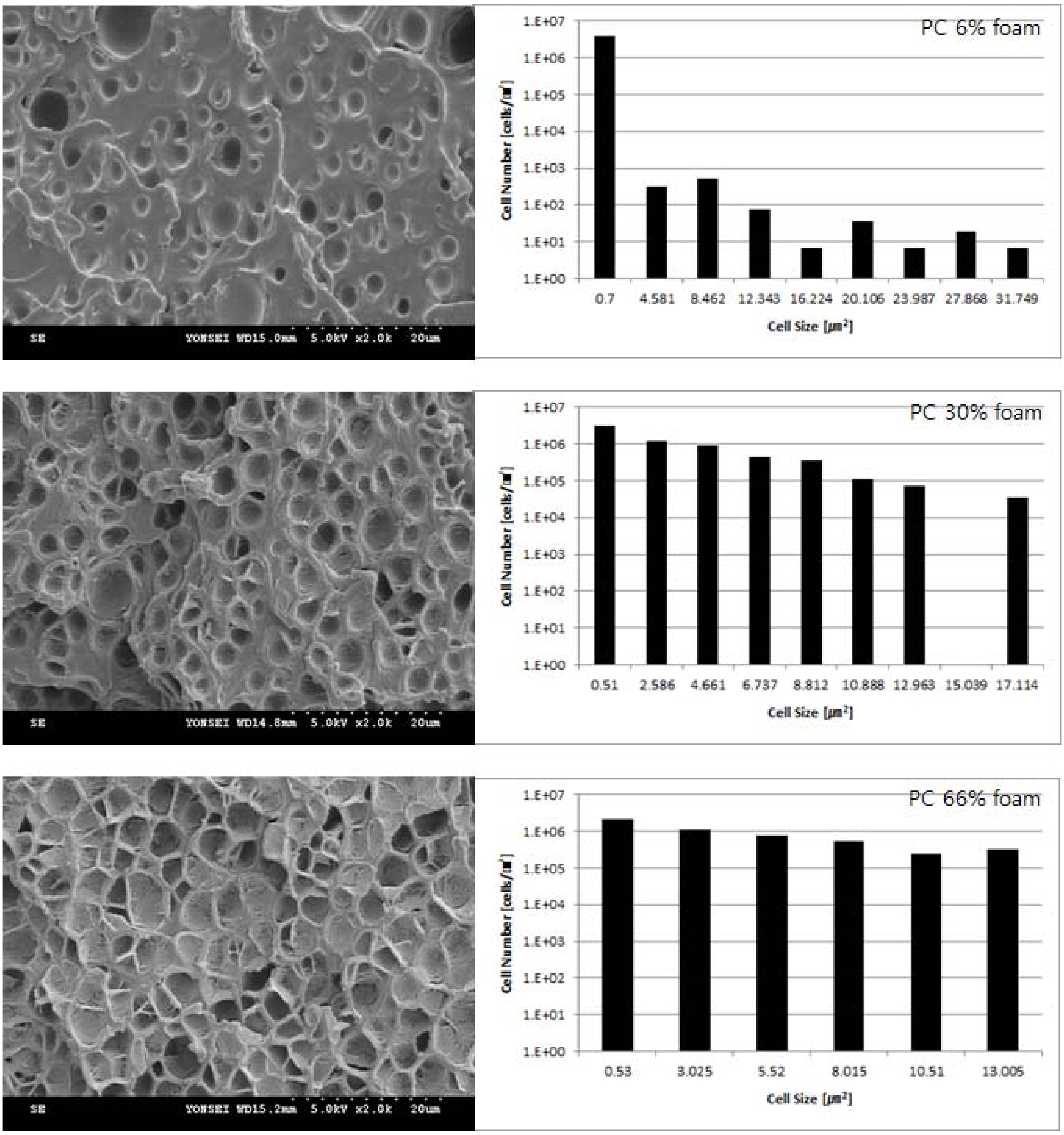

Fig. 4 SEM image and Cell Distribution of Foamed PC

While it is common that when the low foaming temperature is too low for the cell growth, the cell size gets small, in the case of PC material, a low foaming ratio specimen that foamed at the low temperature, large cells were observed. This supposed to concentration of blowing agent molecules to non-crystalline region. The smallest average cell size shown in case of 30% foaming ratio, the capacitance was highest.

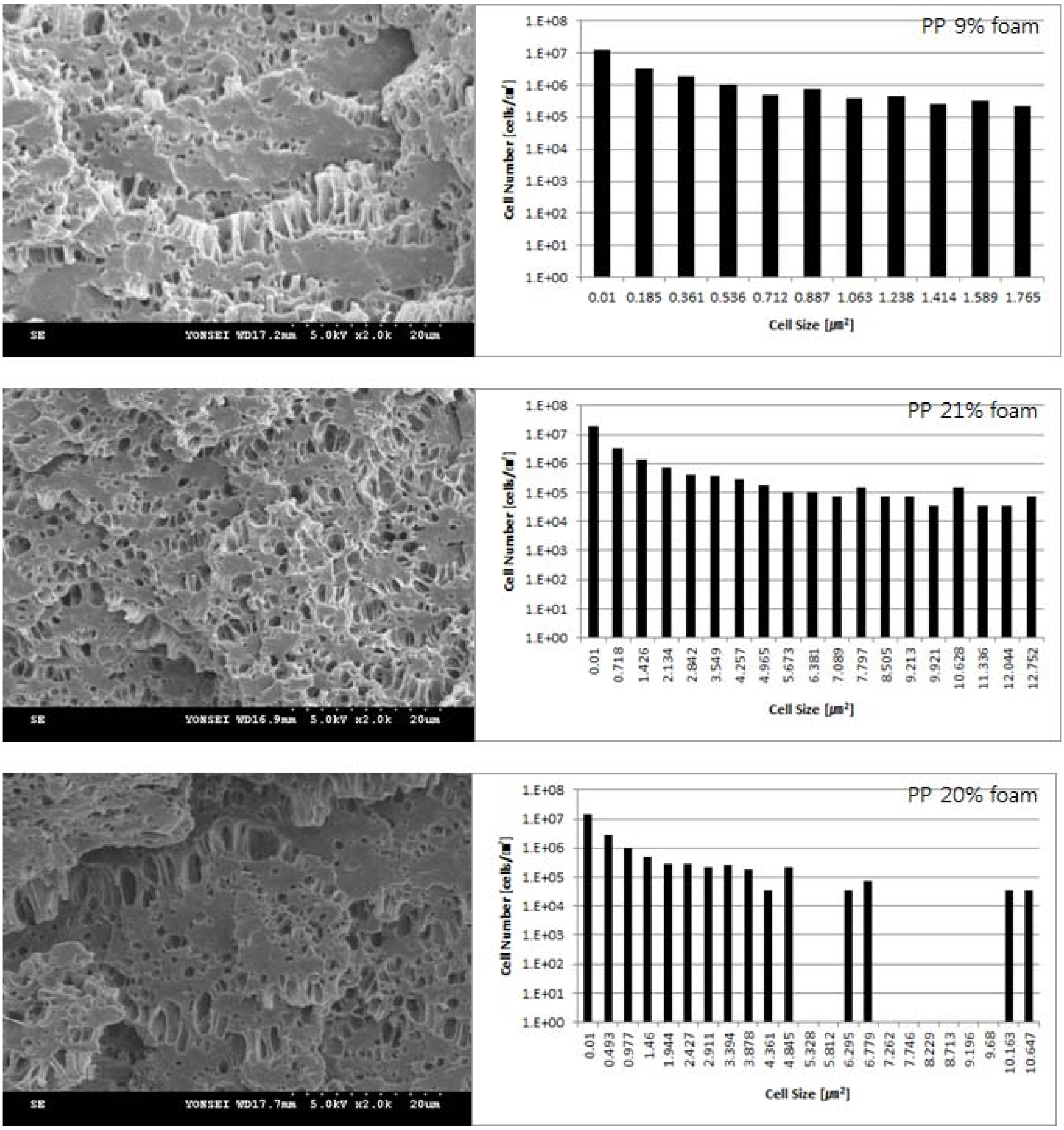

Fig. 5 SEM image and Cell Distribution of Foamed PP

The specimen of 9% foaming ratio, which showed the highest capacitance among PP materials, had its cell size not more than 2μm^2. It is confirmed that the cells shown at the cross section of the material with low capacitance had the trend of being distributed with various sizes the biggest one of which was 10 μm^2

With these above results, it is able to assume that the capacitance is kept or increases when the cell sizes are small. In the case of Ferroelectret, it is known that the secondary polarization is made on cell surfaces, to have piezoelectric effect. Since Ferroelectret also uses cellular polymer for piezoelectric element and the polymers are the olefin-series materials, such as PP, PE. In case capacitance, the additional polarization is supposed the identical principle with ferroelectret. However, considering that capacitance drops when the distribution portion of larger cells is may, it can be suggested that there is a certain size that with charges accumulated.

CONCLUSION

The capacitance of porous-polymer material measured and examined its relations with morphology. ABS, PC and PP, the general purpose polymers used and MCPs method for forming the porous-structure. Focusing cell size distribution, analyzed morphology by SEM image of the cross-section, it can be confirmed that as the size of cell gets smaller, the capacitance is kept or increases regardless of foaming ratio. This phenomenon can be guessed to be due to the additional polarization by cells. Consequently, additional study should be carried out by specifying the sizes of the cells where charges are stored and its applications

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