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Preparation of a new foam/film structure poly (ethylene-*co*-octene) foam materials and its sound absorption properties

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ABSTRACT

Poly (ethylene-*co*-octene) foaming materials with alternating multilayered structure were successfully prepared through multilayer co-extrusion. Poly (ethylene-*co*-octene) was micro-crosslinked and fully cured before and after the foaming process with co-extrusion. The effects of the layer number on foam morphology and density of poly (ethylene-*co*-octene) foaming materials were investigated. It was found that with increasing the layer number, the cell size was reduced while the density was not obviously changed. Meanwhile, this technique provided the new idea to obtain the poly (ethylene-*co*-octene) foaming material with excellent sound absorption. The results indicated that the foam/film alternating multilayered structure could improve the sound absorption efficiency of the foaming sheet, which was increased with increasing the layer number and decreasing of cell size.

1. Introduction

Polymer foams were comprised of gas pore surrounded by a continuous solid phase so that the sound waves could be absorbed. It was widely used as sound absorbing materials in noise control engineering due to the good sound absorption performance [1–3]. Meanwhile, researches show that the sound absorption efficiency was dependent on the foam density, cell microstructure such as cell size, shape and type (open or close) and solid polymer properties [4–6]. Moreover, Olek reported that four factors were related to the sound absorption and the followings were included: (1) the porosity of surface layer, (2) airflow resistance of surface layer, (3) the curvature of the pore connectivity, and (4) the thickness of the porous layer [7]. The foam structure among these factors was most important to the sound absorption efficiency. In other words, the polymer foams with the small cell size, more uniform cell distribution had better sound absorption efficiency.

It was well known that the foam structure was strongly dependent on the preparation methods and foaming techniques [8–11]. Generally, the most of polymer foams were prepared through injection molding and extrusion [12,13]. However, the most cells in polymer foams were uneven and disordered in the two-dimensional or three-dimensional space. As our understanding of foams advances, the foam structure became one of increasingly important control parameters. Excellent control for the foam structure was provided by using cell designing and ordered foams. These foams were special due to their tendency to self-order into periodic structures under gravity or confinement, resulting in excellent properties such as mechanical properties, thermal insulation, sound absorption, etc. [14–16]. At present, ordered foams could be generated by the bubbling technique or self-assembly methods [2,17–19]. However, it was limited to the foaming liquid or block polymer and could not be applied in the injection molding and extrusion foaming.

We found the multilayer co-extrusion technology provided a new method for preparing ordered foaming materials by the introduction of foam layer/film layer alternating multilayered structure and this foam structure could improve the sound absorption efficiency of the foaming sheet. In this paper, the poly (ethylene-*co*-octene) (POE) foaming sheet with the alternating multilayered structure was prepared through multilayer co-extrusion technology. The foam structure and sound absorption for POE foaming sheets were investigated.

2. Material and methods

POE (ENGAGE^{TM} 8150) containing 25 wt% co-monomer was supplied by Dow Chemical Company (USA). Talc was purchased from Guangxi Longguang Talc Development Co., Ltd. (China).

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Azodicarbonamide (AC) and dicumyl peroxide (DCP) was purchased from Chengdu Kelong Chemical Reagent Factory (China).

100 phr POE, 0.3 phr DCP, 0.5 phr AC, 1 phr Talc and 0.5 phr white oil was mixed by a high-speed mixer. Then, the composites were mixed through twin screw extrusion at 150 °C as the foaming layers materials. Meanwhile, the composite with 100 phr POE, 0.2 phr DCP and 0.5 phr white oil was also prepared through process as the film layers materials.

A multilayer co-extrusion system (as Fig. 1) contained two extruders, feed block, multiplying elements, water chill block, and haulage dram. An assembly of n multiplying elements produced $2^{(n+1)}$ layers [20] and was used to co-extrude the POE foaming sheets with alternating multilayered structure (as Fig. 2). Two extruders contained POE foaming materials and POE film materials, respectively. After merging in the two-component feedblock, two kinds of the melts were formed into multiplying element by using the 0, 2, 3 multipliers. The temperatures from the hopper to the exit of the extruder were set at 120, 190, 200 and 190 °C, respectively. The temperature of multiplying element was 180 °C. Exit die was maintained at a colder temperature (160 °C) in order to create a pressure drop. A nip roll set-up was used as a sheet take-off.

The prepared foaming sheets were measured and weighed to calculate densities. Scanning electron microscope (SEM) was used to examine the foam structure. It is a Hitachi S3400+EDY SEM (Japan) at an accelerating voltage of 20 kV. All specimens were sputtered with gold.

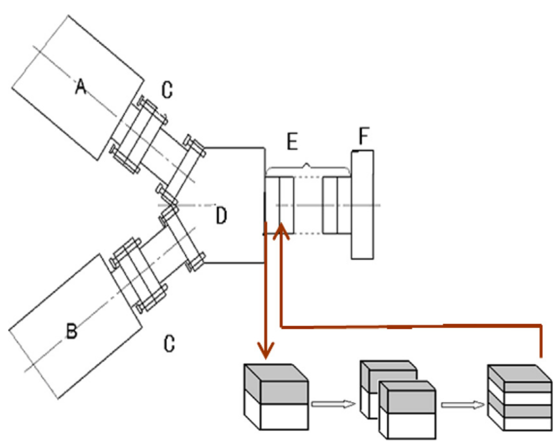

Fig. 1. Schematic of alternate multilayer co-extrusion system (A, B-extruder, C-connector, D-*co*-extrusion block, E-multiplying elements, F-die).

3. Results and discussion

The foaming process of multilayered co-extrusion could be divided into three stages; nucleation, bubble growth and stabilization stages [21]. As the chemical blowing agent decomposes in the extruder, the gas was released and mixed with POE melt. If the amount of the released gas was below the estimated solubility limit, then the released gas was totally dissolved in the POE melt, indicating that no nucleation took place in the extruder or in the multiplying element. The alternating multilayered sheet experienced a pressure drop when it exited the die. Therefore,

the dissolved gas started to nucleate in the form of bubbles. The bubbles grew as more gas diffused into the bubbles. Then, a nip roll set-up at room temperature was used to cool the foaming sheet. Meanwhile, the bubbles growth was stabilized.

The morphology of monolayer foaming sheet was shown in Fig. 3a. The cell is too large and have plenty perforation. It was ascribed to the free growth of the cell during the extrusion and a lot of bubble coalescence. The morphology of the foam/film foaming sheet with 8 layers and 16 layers was shown in Fig. 3b and c. By foaming process of multilayered co-extrusion, the foaming space in each layer was reduced with increasing the layer number since the thickness of the sheet is constant. The growth of the cell was confined due to the decreased thickness of each layer. The cell size was reduced considerably (as Fig. 4). The isotropic cell morphology was observed. The cell distribution was changed from disorder to order by increasing the layer number. Meanwhile, the reduction of the cell size was attributed to the enhanced nucleation and/or the suppressed cell coalescence under the confinement of alternating multilayered structure. It has been observed that the cells with small size were obtained when the foaming took place under geometrical confinement between two impermeable plates.

The density of monolayer foaming sheets and the foam/film foaming sheet with 8 layers and 16 layers were 0.624 g/cm^3, 0.630 g/cm^3, 0.634 g/cm^3, respectively. The density of foaming sheet was not obviously changed with increasing the layer number, since the density of foaming sheet was governed by the total amount of gas released in the system. However, the foaming materials with small cell size had the greater surface area for gas and resin. This phenomenon and alternating multilayered structure were beneficial to sound absorption.

Generally, the sound wave was reflected by the interface and absorbed by the foaming materials. The effect of alternating multilayered structure on sound absorption efficiency of the

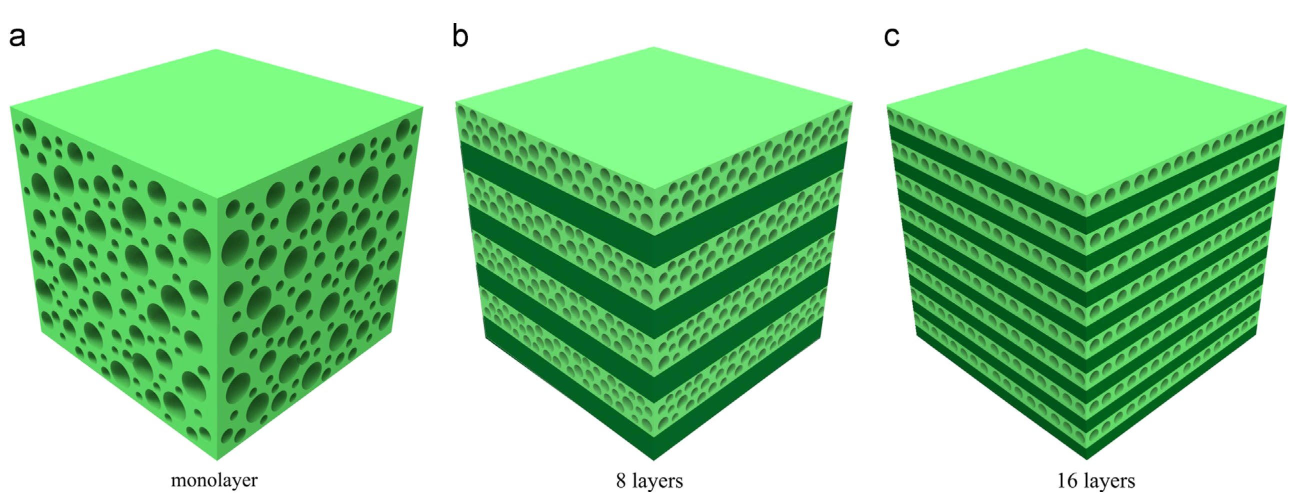

Fig. 2. Schematic of monolayer foaming sheet, 8 layers foam/film foaming sheet and 16 layers foam/film foaming sheet.