COMPOSITE FOAMS PREPARED THROUGH HOLLOW GLASS MICROSPHERES ASSISTED BUBBLING

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ABSTRACT

Composite foamy structures were prepared through hollow glass microspheres (HGM) assisted bubbling of silicone rubber with ammonium hydrogen carbonate as the blowing agent. The presence of HGM not only favoured the foaming process (acted as nucleating agent for the formation of minute bubbles at the initial stage of the bubbling), but also bring heterogeneous close-cell bubbles with stable inorganic shells into the foamy structure, which played an important part in the improvement of the heat insulation property of the product. Compared to the foamy structures without HGM, The composite foamy structures possessed improved heat insulation and sound absorbing properties. This work provides an additional strategy to fabricate composite foams with tailored cell structure and properties.

Keywords: Composite materials; Functional; Thermal properties

1. INTRODUCTION

Although polymer materials have been widely used because of their lightweight, low cost and easy-manufacturing nature compared to metal or wood materials, the shortages in function, stability and mechanical strength always lead to inferior performance and greatly hampered the expansion of their application[1-3]. To overcome the disadvantages of pure polymer materials, controlled bubbling and mixing with various functional fillers have been proved to be effective strategies to obtain polymer-matrix composite materials with improved performance compared to their pure polymer counterparts[4-6]. The combination of hollow glass microspheres (HGM) with polymer matrices can significantly improve the physical properties without sacrificing the lightweight. Moreover, the employment of low density HGM can even contribute to the further decreased density of the composite foams, and bring enhanced performance such as heat insulation[7-8]. However, the controlled combination of polymer matrix, gas bubbles and functional fillers to form ternary composited with desired properties in a reliable way is still considerably difficult.

In this communication, HGM were employed in the preparation of foam structures, and silicon rubber/HGM/gas bubble composite foam structures were successfully fabricated. The presences of HGM on the structure and morphology of the products have been investigated. In addition, sound absorption and heat insulation study of the as obtained composite foamy structures were also carried out.

2. EXPERIMENTAL

Prior to the synthesis of the silicon rubber/HGM/gas bubble composite foam structures, the HGM obtained according to reference [9] were classified through wet separation with ethanol as the operating medium, and the floating HGM with low density (true density: $0.26g/cm^3$) were used for the preparation of the composite foam structures. On the other hand, the ammonium hydrogen carbonate was grinded manually before being added into the silicon rubber precursor. For the preparation of the silicon rubber/HGM/gas bubble composite foam structure (S1), the weight ratio of the silicon rubber precursor, the HGM and the ammonium hydrogen carbonate was controlled to be 8:1:1. A mixture with the above mentioned weight ratio was prepared by adding ammonium hydrogen carbonate and HGM in turn into the silicon rubber precursor under mechanical agitation. Then the mixture was transferred into an open cylindrical mould, and reaction at 60°C overnight in an oven. Contrast experiment was also carried out without adding HGM into the reaction system (S2), and without adding both HGM and blowing agent (S3).

The morphologies of the products were observed using scanning electron microscopy (SEM, Hitachi S-4300). The real densities of the HGM and the composite foam structures were measured by AccuPyc II 1340 gas displacement pycnometry system. The thermal conductivities of the samples were measured by QTM-500 rapid thermal conductivity meter. The acoustic testing was performed on a JTZB

acoustic test system. The measurement was carried out at the centre frequency of 1/3 frequency multiplication The acoustic absorption coefficient (α) is defined as the ratio of the acoustic energy absorbed by the sample to the acoustic energy incident on the surface and is dependent on frequency.

3. RESULTS AND DISCUSSION

The morphology and structure of the foam samples were observed, the photographs SEM images are shown in Fig. 1. Low magnification photographs of Fig. 1(a) and (d) depict the panoramic image of the samples S1 and S2. It can be seen that both samples exhibit anisotropic structure with cells elongated parallel to the foaming direction. Moreover, the cells obtained with the presence of HGM are much smaller than those without HGM. This was reasonable if we take into consideration that in the case of polymer composites foams, heterogeneous nucleation theory is more suitable because the fillers can both provide a surface to nucleate on and lower the critical free energy of nucleation [5, 10]. An in depth study on the cell size distribution control and is still underway. The magnified SEM images also confirmed that S1 possess smaller cells (Fig. 1(b) and (e)). It is known that the properties of the composites are strongly dependent on the distribution of filler and the interaction of the filler and matrix. The microstructures of the samples were investigated by further magnified SEM image, as shown in Fig. 1(c) and (f). Compared with S2 (without HGM), it can be seen that the HGM in S1 are embedded in the matrix or peeled from the matrix to form holes, and the dispersion is uniform.
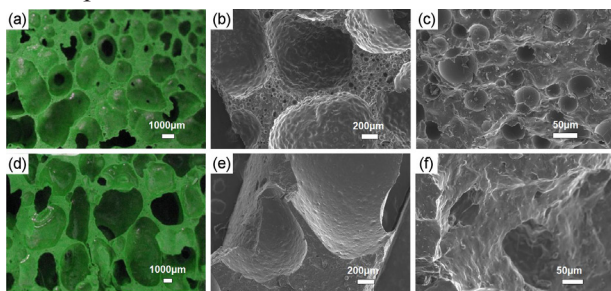

Fig.1: Photographs ((a) and (d)) and SEM images at different magnifications ((c)-(f)) of the as-obtained samples. (a), (b) and (c): S1; (d), (e) and (f): S2.

Table 1: Thermal conductivity (λ), true density (ρ_t), apparent density (ρ_a) and material density (density of the solid phase, ρ_m) of different samples.

Items		λ (W/m·K)	ρ_t (g/cm³)	ρ_a (g/cm³)	ρ_m (g/cm³)
	S1	0.0634	0.8191	0.2608	0.8346
Samples	S2	0.0966	1.0887	0.3177	1.1532
	S3	0.2050	1.1532	1.1528	1.1532

The values of the thermal conductivity for different samples are listed in TABLE 1, it can be seen that, compared to solid rubber matrix (S3), the thermal conductivity of the foam samples are much lower. The thermal conductivity of neat rubber (S3) is 0.205 W/mK, and reduced remarkably to 0.0966 W/mK for S2. Moreover, with the presence of HGM, the composite foam (S1) possessed an even lower thermal conductivity of 0.0634 W/mK. The schematic illustration of the structures and the heat fluxes of different samples are shown in Fig. 2. Different from that in the neat matrix, heat fluxes in the foam samples contained two fluxes from both the gas phase ($\mathbf{\Phi_g}$) and the solid phase ($\mathbf{\Phi_s}$). The small size of the cells reduces the convection, and the heat-conduction coefficient of the gas phase is relatively lower, which lead to lower thermal conductivity contribution of the cell gas compared to the rubber matrix. On the other side, for the heat transfer through the solid phase, the transfer area is reduced and the distance is lengthened, leading to decreased thermal conductivity [11]. Moreover, it can also be seen in Table 1 that the true densities (ρ_t) of S1 and S2 are slightly smaller than the material density (ρ_m), and much higher than the apparent density (ρ_a), indicating that the foams contain both open cells and close cells. The presence of close cells can also lead to reduced thermal conductivity. As for the further lowered thermal conductivity of the composite foam with HGM (S1), the reason may lie in the fact that the inner gas in the hollow core of HGM also results in low thermal conductivity [8].
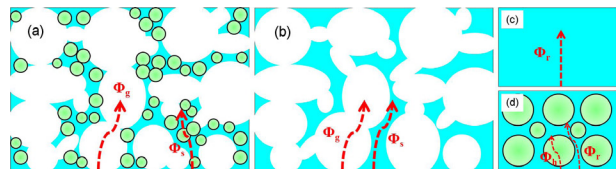

Fig. 2: Schematic illustration of the structures and the heat fluxes of different samples. (a) S1; (b) S2; (c) S3; (d) the rubber/HGM solid phase of S1. ($\mathbf{\Phi_g}$ heat flux through gas phase, $\mathbf{\Phi_s}$ heat flux through solid phase, $\mathbf{\Phi_r}$ heat flux through rubber, $\mathbf{\Phi_h}$ heat flux through HGM).

The experimental results for the acoustic absorption coefficient of different samples as a function of frequency are shown in Fig. 3. It can be seen that the acoustic absorption coefficient of neat rubber (S3) changes slightly at a low level over the whole measuring frequency. But both the foam samples show a clear absorption peak over the range of 500–2000 Hz. By comparing the two curves of S1 and S2, it is obvious that on the addition of HGM, the acoustic absorption of the system get worse over the entire frequency. This may be attributed to that the pres-
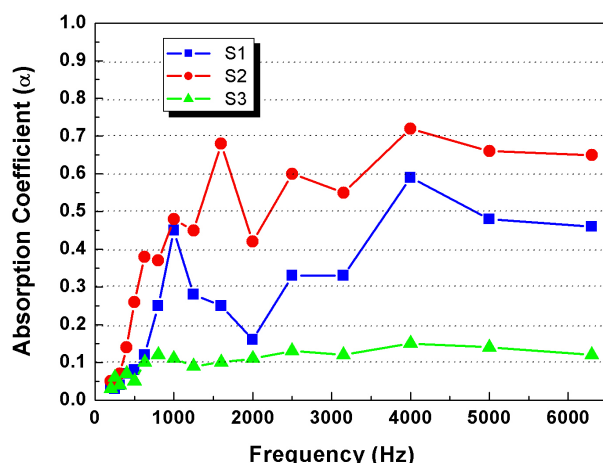
Fig. 3: Absorption coefficient as a function of frequency for different samples.

ence of HGM enhanced the hardness of the system and bring more close cells with rigid shells, which always leads to better insulation properties but inferior absorptive capability[5]. It seems that the presence of HGM cannot improve the thermal conductivity and the acoustic absorption of the composite simultaneously. If we use a combination of HGM and other nanofillers (e.g. carbon nanotube) [6, 12] to fill a polymer-matrix, a composite with high acoustic absorption and low thermal conductivity may be obtained by properly varying the composition and structure of the system. These experiments will be carried out in our future research.

4. CONCLUSIONS

In summary, we report here the early stage of the study on the preparation and properties of composite foam materials through controlled bubbling. Hollow glass microspheres (HGM) were employed in the formation of foam structures, and silicon rubber/HGM/gas bubble composite foam materials were successfully fabricated. It was found that the presences of HGM favoured the formation of more uniform bubbles, and leaded to improved heat insulation property of the composite foam. It can be expected that by properly design and controlling the component of the reaction system and the reaction condition, the fabrication strategy reported here hold the potential to be extended to the controlled bubbling of other matrix to form composite foams with various composition and properties.

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