Thermal and Sound Absorption Properties of Porous Epoxy Resin Modified by Organic Silicon

Xiaobin Gou*, Longgui Peng¹, Siyuan Wu¹, Lifei Du¹, Qirui He¹ and Pu Zhao¹
¹College of Materials Science and Engineering, Xi’an University of Science and Technology, Xi’an 710054, China
Corresponding author email: gxb1158319786@qq.com

Abstract. The organic silicon modified epoxy resin is prepared by the dehydration reaction between diphenyl silicon diol and the hydroxyl group on the epoxy resin, and the foamed material is prepared by the mass ratio NaHCO₃:H:OBSH=5:5:3 composite foaming agent. The foams was characterized by infrared spectroscopy (FT-IR), Thermogravimetric (TG) and standard wave tube method. The results indicate that: The heat resistance of the cured resin of modified resin is better than that of cured epoxy resin, and the sound absorption coefficient of the sample with opening rate of about 54.4% can reach more than 0.8 for high frequency sound waves (>1000 Hz).

1. Introduction

In recent years, the impact of noise pollution on people’s lives and health has become more and more intense[1, 2], leading to the increasing need for noise prevention and control[3-5]. Foam materials with Open-cell structures are capable in noise absorption and reduction due to their interpenetrating three-dimensional porous structure, that have been widely applied in the field of sound absorption and insulation[6].

Up to now, various sound-absorption and noise-insulation have been successfullly prepared with specific performances. Zhao et al. prepared polyolefin elastic composites with alternate membrane and foam structures by a multi-layer co-extrusion method, and found that the cell size of the composite material was reduced as the number of alternating layers increases, and its sound absorption performance is improved in the high-frequency frequency range[7]. Jopnmo et al. prepared a composite material containing silica and polyurethane foam, and found that the sound absorption coefficient of the composite material increases when the polyl When 0.5% silica is added[8]. Wang et al. designed multilayer composite materials that constructed of a sand board, porous fiber material and microporous film (with an air layer behind the microporous film), the results indicated that the designed composite materials not only broadened the sound absorption frequency, but also increased the sound absorption efficiency of porous materials (In the frequency range of 200 to 2000 Hz, the sound absorption coefficient of composite materials could reach 0.85)[9]. However, all these researches for outer open-cell foam materials is mainly related to polyurethane foam, polylactic acid (PLA) and polypropylene (PP)[10], few studies are carried out investigate the the open-cell epoxy materials. Therefore, in this study, the silicone modified epoxy resin foam with open-cell structure would be prepared, and the thermal and sound absorption properties of foams would be investigated.
2. Materials and Methodology

2.1 Materials and Preparation
The epoxy resin (E-44) and 2,4,6-Tris(dimethylaminomethyl)phenol(DMP-30) in a ratio of 4:1 were added into 250ml three-necked flask and heated for liquefaction. An appropriate amount of Silane Coupling Agent (KH-570) and dibutyltin laurate (T12) were then added into the liquid mixture and then mechanically stirred for 2 hours at 138 °C to achieve the silicone modified epoxy resin.

The open-cell foams were prepared via the traditional foaming method: 20g silicone-modified epoxy resin was put into a 50ml beaker and heated to 127°C, then an appropriate amount of accelerator DMP-30 and TMA curing agent were added. Stir and cool the mixture to 110°C with cold water in a 500ml beaker, and composite foaming agent of NaHCO₃, H, OBSH is added. Then the mixture was poured into a silicone mold and put in an oven to heat up for a period of time, and then solidified for 30 minutes. Take out the mold after the foam material becomes hard after cooling. Removed the silicone mold and put the samples into the oven to incubate for 2 hours at 250°C. Finally, the silicone modified epoxy resin foaming material was obtained successfully.

2.2 Characterization and Analysis
The FT-IR is used to analyze the structure of the samples(KBr tablet, the scanning range is 400~4000 cm⁻¹). The thermal performance of the sample is analyzed by TG in the temperature range of 3~800 °C, and the sound absorption coefficient of the material is measured by the standing wave tube method. The opening rate was measured by the drainage method, and the image was observed and analyzed by Image J software.

3. Results and Discussion

3.1 FT-IR Analysis

![Figure 1. FT-IR spectra before and after epoxy resin modification](image1)

![Figure 2. FT-IR spectrum of cured epoxy modified with or without accelerator](image2)

It can be seen from Figure 1 that the silicone-modified epoxy resin has a more obvious Si-O-C peak (1127 cm⁻¹), while the epoxy resin has no absorption peak here. The hydroxyl peak of the modified resin is weaker than that of the pure epoxy hydroxyl group, indicating that a part of the hydroxyl group is consumed and the Si-O bond may be inserted, and the modification is successful.

From the infrared analysis spectrum of the modified epoxy resin cured product with DMP-30 and without DMP-30 in Figure 2, it can be seen that the stretching vibration peak of the Si-O-C bond is about 1127 cm⁻¹, and the accelerator has little effect for the formation of Si-O-C bonds. In the infrared spectrum of the cured sample with DMP-30, the epoxy peak disappears, indicating that the curing consumes the epoxy peak and the curing is successful. In the spectrum of the cured sample without
DMP-30, the epoxy peak (911cm$^{-1}$) exists, indicating that the acid anhydride curing agent does not have a tertiary amine accelerator (R3N) to guide the attack on the epoxy group (-OH), and the reaction is difficult to proceed, resulting in the presence of epoxy peaks and incomplete curing.

3.2 TG Analysis

![Figure 3. Epoxy TG dotted line before and after modification](image)

It can be seen from Fig. 3 that the temperature corresponding to the turning point of weight loss, silicone resin is obviously higher than that of the epoxy resin (about 10 °C higher), indicating that the heat resistance of cured epoxy resin modified by silicone is better than that of the epoxy resin, which should be attributed to the formation of Si-O bonds in silicon modified epoxy resins. In addition, the elasticity of modified epoxy resin at high temperature is better than that of pure epoxy resin, which may also be related to the Si-O bonds.

3.3 Sound Absorption Test and Open Hole Rate Test

![Figure 4. Sound absorption coefficient of standing wave tube](image)

![Figure 5. Image J of silicone modified epoxy resin foam](image)

It can be seen from Figure 4 that the sound absorption efficiency of silicone modified epoxy resin foam is general in the frequency range of 0-500Hz, and the absorption for sound waves of 500-2000Hz is the best, and the absorption efficiency would be slightly deceased for sound wave of higher frequency. On the whole, the prepared epoxy resin foam modified by silicone shows more than 80% sound wave absorption efficiency for high frequency sound waves. Through software calculation
and analysis for the sample structure as shown in Fig.5, the porosity of the foam sample roughly is 54.4%, which might be the reason for the improved sound absorption performances.

4. Conclusion

In this paper, the silicone-modified epoxy resin foam was successfully fabricated, and the thermo and sound absorption performances were investigated. The following conclusions can be drawn based on the obtained results:

1. The insertion of Si-O bonds can improve the heat resistance of the epoxy resin (10 °C), and the elasticity of modified epoxy resin at high temperature is better than that of the pure epoxy resin.

2. The prepared sample shows high absorption efficiency (>0.8) for the high frequency sound waves (>1000 Hz).

5. References

[1] Zia Ur Rahman Farooqi, Muhammad Sabir, Junaid Latif, et al. Assessment of noise pollution and its effects on human health in industrial hub of Pakistan. 2020, 27(2):2819-2828.

[2] Kamble P. V., Patil. G. T., Er. Mali. D. S.. A Study of Noise Pollution in Kolhapur City with Special Reference to Silence Zone[J]. Journal of Trend in Scientific Research and Development, 2020, 4(4).

[3] Fan X, Li L, Zhao L, et al. Environmental noise pollution control of substation by passive vibration and acoustic reduction strategies[J]. Applied Acoustics, 2020, 165:107305.

[4] Songyu Wu, Wu Songyu, Li Xiang, Qi Xiaoyan, Li Chengjun, Xu Tianyuan. Study on Noise Pollution of 220kV Substations in Liaoning Province[J]. IOP Conference Series: Earth and Environmental Science, 2020, 526(1).

[5] Wu Q, Zhang X, Cao G. Study on the prevention and control measures of China's urban road traffic noise pollution[J]. E3S Web of Conferences, 2019, 96:03003.

[6] Sharma S K, Shukla S R, Sethy A K. Acoustical behaviour of natural fibres-based composite boards as sound-absorbing materials[J]. Journal of the Indian Academy of Wood, 2020(4).

[7] Zhao T, Yang M, Wu H, et al. Preparation of a new foam/film structure poly (ethylene-co-octene) foam materials and its sound absorption properties[J]. Materials Letters, 2015, 139(jan.15):275-278.

[8] Lee J, Kim G H, Ha C S. Sound absorption properties of polyurethane/nano-silica nanocomposite foams [J]. Journal of Applied Polymer ence, 2011, 123(4):2384-2390.

[9] Wang Y, Zhang C, Ren L, et al. Sound absorption of a new bionic multi-layer absorber[J]. Composite Structures, 2014, 108:400-408.

[10] Long Y, Sun F, Liu C, et al. Climate-friendly polyurethane blowing agent based on a carbon dioxide adduct from palmitic acid grafted polyethyleneimine[J]. Journal of Applied Polymer Science, 2016, 133(35).