PREPARATION OF POLYSTYRENE HOLLOW MICROSPHERES FROM WASTE FOAMED POLYSTYRENE PLASTICS BY MICROENCAPSULATION METHOD

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Abstract: Waste foamed polystyrene plastics were used as the main raw materials for the preparation of polystyrene hollow microspheres with high additional value by microencapsulation method. Firstly the preparation conditions were studied, such as the emulsifying time, the temperature and time of the solidification of oil phase, and then the method of removing the encapsulated water was discussed. The factors which influenced the average diameter and tap density of polystyrene hollow microspheres were also investigated, and finally the recycling technology of reagents used in experiment was discussed. Under optimum conditions, polystyrene hollow microspheres with the lowest tap density of $0.12 g\cdot cm^{-3}$ and average diameter from 40μm to 650μm were successfully produced.

Keywords: waste foamed polystyrene plastics; polystyrene hollow microspheres; microencapsulation method; preparation conditions; tap density;average diameter

1. Introduction

As waste foamed polystyrene plastics (FPS) have the characteristics of stable chemical properties, large volume, aging resistance, corrosion resistance, they can not degrade by themselves in natural environment, thus destroying ecological balance and causing “white pollution” at every corner of the society.[1,2]

This paper introduces a modified reuse method of waste FPS— Microencapsulation method, preparing polystyrene (PS) hollow microspheres with high additional value from waste FPS. PS hollow microsphere, characterized by its unique properties such as low density, optical scattering, high specific surface area and good surface permeability, has attracted considerable attention.[3-5]It can be utilized in inertial confinement fusion (ICF) targets, light weight fillers, high performance opacifying coating and anti-ultraviolet filler.[6-8] The technological process of microencapsulation method to prepare PS hollow microspheres is shown in Fig.1.[6,9]

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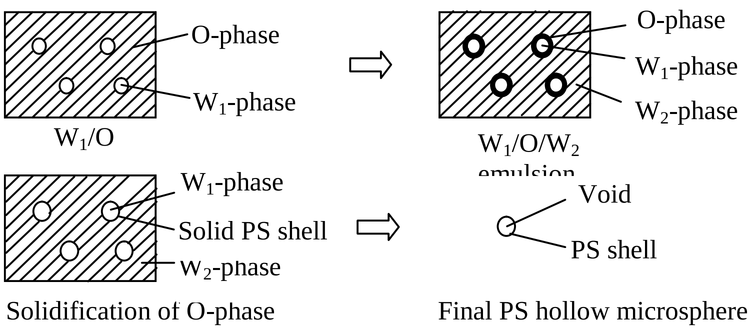

Fig.1 Schematic diagram for preparing PS hollow microspheres with the microencapsulation method

2. Definition of the preparation conditions and investigation of factors influencing PS hollow microspheres

2.1 Selection of emulsifier

Fig. 2 shows the relationship between the volume ratio of water/oil phases (V_{W_1}/V_O) when Span 80 is used as emulsifier in the experiment.

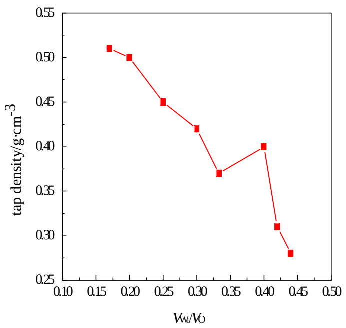

Fig. 2 Relationship between $VW1/VO$ and tap density of PS hollow microspheres (Span 80 as emulsifier)

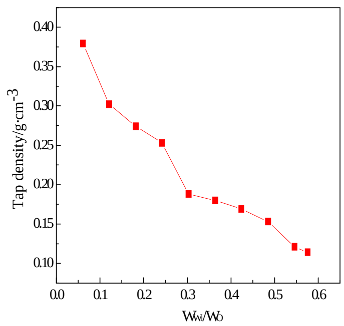

Fig. 3 Relationship between $WW1/WO$ and tap density (sodium dodecylbenzene ulfonate as emulsifier)

From Fig. 2 we can find that the density of PS hollow microspheres decreases when the volume ratio of water/oil phases increases. When the tap density is about 0.28 g·cm^{-3}, it is very hard to decrease. This shows that the cavity volume of PS hollow microspheres is small. Fig. 3 shows the relationship between the mass ratio of water/oil phases and the tap density of PS hollow microspheres when emulsifier is sodium dodecylbenzene sulfonate. After comparison with Fig. 2, it is found that the tap density of PS hollow microspheres decreases obviously when sodium dodecylbenzene sulfonate is used as emulsifier. Therefore sodium dodecylbenzene sulfonate is selected as emulsifier in this experiment.

2.2 Selection of the main dispersant agents of W_2-phase

Dispersant agent directly influences the dispersity of prepared microspheres. Improper selection of dispersant agent will cause agglomeration phenomenon. Gelatin and polyvinyl alcohol are selected as the main dispersant agents of W_2-phase in this experiment.

2.3 Factors influencing the average diameter of PS hollow microspheres

Varied factors of the average diameter of PS hollow microspheres are studied in this research. It defines that the second emulsifying rotating speed, the concentration of sodium dodecylbenzene sulfonate in W_1-phase, and the concentration of PS in O-phase play major roles in influencing the average diameter (choosing more than 100 microspheres from sample at random and working out the average diameter of these hollow microspheres as the average diameter of the sample). The concrete relationship is: 1) The average diameter of hollow microspheres decreases as the emulsifying rotating speed increases; 2) When the concentration of sodium dodecylbenzene sulfonate in W_1-phase is within a certain range (0.5wt%~2wt%), the average diameter of PS hollow microspheres goes up with concentration and it is a basically rectilinear relationship. While the concentration of sodium dodecylbenzene sulfonate is high enough (>2wt%), the average diameter of PS hollow microspheres stays the same; 3) The average diameter of PS hollow microspheres goes up with the increase of mass fraction of PS in O-phase.

2.4 Factors influencing the tap density of PS hollow microspheres

This experiment investigates the factors influencing the tap density of PS hollow microspheres and defines that the mass ratio of water/oil phases and the concentration of PS in O-phase are the factors which influence the tap density. The concrete relationship is: 1) the tap density of hollow microspheres decreases when the mass ratio of water/oil phases increases. When it arrives at certain value, PS hollow microspheres can not be prepared because water in oil type of emulsion cannot be formed; 2) in certain concentration range, the tap density of PS hollow microspheres increases when the concentration of PS in O-phase increases. The lowest tap density of PS hollow microspheres prepared at present is $0.12 g\cdot cm^{-3}$.

2.5 The second emulsifying time

Since the W/O emulsions prepared by using sodium dodecylbenzene sulfonate as emulsifier are unstable, the second emulsifying time should be lessened in order to avoid the demulsification of emulsion. It is experimentally found that W/O emulsion in the system will demulsify if stirred for over 30 minutes. Therefore, it should be heated immediately after W_1/O emulsion being added and the W_1/O emulsion should be stirred in the heating process.

2.6 Temperature and time of the solidification of O-phase

The solidification temperature should be higher than the boiling point of organic solvent of O-phase by 4°C~6°C, and heating lasts for two hours; then the system is heated to 70°C~75°C and is solidified for one hour to improve the compressive strength of PS hollow microspheres. During the second solidification, the temperature shall not exceed 80°C; otherwise parts of the microspheres will be softened and deformed.

2.7 Method of removing the encapsulated water

After the solidification of O-phase, we can get the particle of W_1-phase encapsulated with solid PS spherical shell. If W_1-phase is directly dried and removed, it is hard to spread on the surface of PS, because PS has a strong hydrophobicity and the contact angle of W_1-phase and PS is comparatively big. After being dried, surfactant in W_1- phase and microimpurity stay on the shell of microspheres and form spot, thus damaging the surface finish of microspheres. Therefore, first we should immerse the particle of W_1-phase encapsulated with solid PS spherical shell into absolute ethanol for one day and exchange the W_1-phase in the PS spherical shell and then we can dry it in WG 2003 type desktop drying oven for one day, PS hollow microspheres are obtained.

3. Recycling of experimental raw materials

The method adopted in the experiment to recycle the waste FPS is a kind of modified reuse method. Except for FPS, all other raw materials can be recycled. The organic solvent of O-phase can be recycled by connecting a reflux condensation equipment beside the four-port flask. Experiments found that the recovery ratio of solvent can reach up to 87%. Moreover, W_2-phase can also be used for several times. Because after the solvent evaporates, W_1-phase which is encapsulated by solid PS shell won't have a great influence on the mass ratio of water, gelatin and sodium dodecylbenzene sulfonate in W_2-phase.

3. Characteristics of PS hollow microspheres

Under optimum conditions, PS hollow microspheres with the lowest tap density of $0.12 g\cdot cm^{-3}$ and average diameter from 40μm to 650μm are prepared.

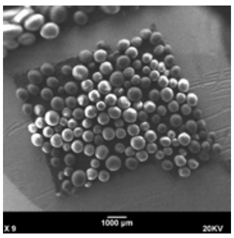

Fig. 4 SEM diagram of the hollow microspheres

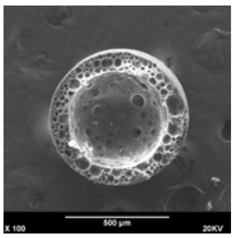

Fig. 5 SEM diagram of incised PS hollow microspheres

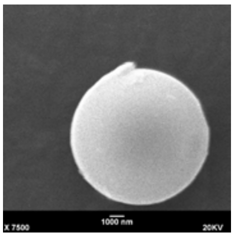

Fig. 6 SEM diagram of of smaller particle size microspheres

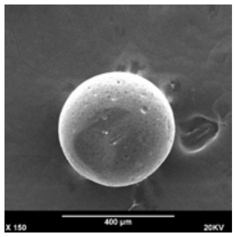

Fig. 7 SEM diagram of the bigger particle size microspheres

Fig.4 is the SEM diagram of the hollow microspheres randomly extracted in sample. It is used to calculate the average diameter of samples; Fig.5 is the section SEM diagram of incised PS hollow microspheres. From the diagram we can see that there is a comparatively big cavity in the middle and many other small cavities; Fig.6 is microsphere of smaller particle size (PS hollow microsphere is prepared by using polyvinyl alcohol as dispersant agent). Fig.7 is microsphere of bigger particle size (PS hollow microsphere is prepared by using gelatin and sodium dodecylbenzene sulfonate as dispersant agents)

4. Conclusions

Microencapsulation method is an effective way to recycle waste FPS to prepare PS hollow microspheres. With the characteristics of easy operation, simple equipment and low cost, the microencapsulation method is suitable for batch production of PS hollow microspheres with various particle sizes.

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