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Enhanced thermal conductivity of PEG/diatomite shape-stabilized phase change materials with Ag nanoparticles for thermal energy storage

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Experimental

Modification of diatomite with AgNPs

Acid treatment

In a typical step, 20 g diatomite powders and 100 mL 20 wt.% H₂SO₄ solution were placed into a 3-mouth flask in the heated thermostatic water bath, which was connected to a mechanical agitator equipped with twin-bladed impeller. The mixture was heated to 70 °C (±0.5 °C) for 2 h. Then, the slurry was filtered and the residue was washed with distilled water for several times until the pH value equaled 7. The acid treated diatomite was dried at 105 °C for 12 h, ground into to powder.

Alkali leaching

After acid treatment, the obtained diatomite powder was treated with sodium hydroxide to enhance its adsorption performance of PEG. The diatomite samples were immersed in sufficient amount of 5% (w/w) sodium hydroxide solution at 80 °C for 5 min. The digested diatomite was washed several times by deionized water, filtered, dried at 105°C, sieved and stored in closed containers for further tests.

Preparation of PEG/DtAg composite PCMs

10 g of DtAg powder was placed inside a filtering flask, which was connected to a

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vacuum pump apparatus to evacuate air from its porous surface. Then, the valve between the flask and a container filled with liquid PEG was opened to let liquid PEG flow into the flask to cover the DtAg powder. After a period of time, air was allowed to enter the flask again to force the liquid PEG to penetrate into the pore space of DtAg. The porous DtAg materials filled with the PEG were taken out from liquid PCM and then for removing liquid PCM captured by the surface of composites or not supported in pore. They were kept in the furnace which was keeping at 80 °C. Finally, the products were taken out from the furnace and dried. Besides, the adsorption capacity results obtained with/without vacuuming were compared. The differences between the two methods can be neglected.

Analysis methods

The specific surface area and pore volume of diatomite were determined by a N₂ adsorption analyzer (Quantachrome Instruments, US). The microstructures of the samples were examined by scanning electron microscopy (SEM, S-4800, Hitachi, Japan) and high-resolution transmission electron microscopy (HRTEM, JEOL JEM-2010, Japan, accelerating voltage 200 KeV). The energy dispersive x-ray spectroscopies (EDS) linked with the SEM and the HRTEM were employed to assist the phase identification. A PHI-5300 X-ray photoelectron spectroscopy system (XPS, Perkin Elmer, America) was used to analyze the chemical state of Ag on the diatomite surface. Ag mass ratio in the DtAg sample was determined by X-ray fluorescence spectroscopy (XRF, ARL ADVANT XP+). The chemical compatibility of composite PCMs was obtained via Fourier transform infrared spectroscopy (FT-IR, Model Frontier) and X-ray diffraction (XRD, Model XD-3) method. Besides, thermal property and stability of the ss-PCMs were explored through differential scanning calorimeter (DSC, Q2000) and thermo-gravimetric analysis (TGA, Q50), respectively. The hot disk thermal constant analyzer (TPS2500) was employed to measure thermal conductivity.

Results and discussion

Thermal performance of the prepared composite PCM

Melting and freezing characteristics

In order to determine the melting and freezing characteristics of the prepared PEG/diatomite and PEG/DtAg composite PCMs, 30 g PEG/diatomite and 30 g PEG/DtAg were placed into three glass vessels, respectively. A thermometer with the temperature accuracy of 0.5 °C was placed in the center of the vessels. The two testing vessels were put into a drying oven at 60 °C for complete melting and then immediately put into the water bath with a constant temperature of 25 °C for the solidification process. The temperature variations of the two composite PCMs during melting and solidifying periods were measured and recorded. The enhancement in thermal conductivity of the prepared composites was investigated by comparing its melting and freezing time.