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Specific heat capacity of mesoporous silica gel for adsorption heat pump applications

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Abstract

Silica gel has been extensively employing as an adsorbent in the field of separation process, purification of gases and adsorption heat pump in the last few decades. The specific heat capacity of such porous materials is a significant controlling parameter in adsorption characteristics simulation and system design. This research work is focused on the experimental evaluation of the specific heat capacities of several types of silica gel for adsorption cooling applications. The apparatus used in this measurement is a heat flux type differential scanning calorimeter (DSC) from 35°C to 100°C temperature range. The specific heat capacity values are found 0.85 to 1.10 kJ kg^{-1} K^{-1} in the measurement range. No phase transition or thermal anomaly is encountered within the measurement conditions. It is found that the specific heat capacity increases with increase in particle size.

1. Introduction

Silica gel has an incompletely dehydrated polymeric structure of colloidal silicic acid which exhibits an excellent capacity for adsorption of water. It is frequently used for commercial purposes like separation [1], cooling [2-3], dehumidification [4] and recently desalination [5-6]. The adsorption refrigeration technology employing silica gel is developing in recent decades because it is environment friendly and it requires low grade heat source to drive the system [7-8]. In design and optimization of such adsorption cycles, the specific heat capacity of the silica gel is one of the key thermophysical parameter to measure. In general, higher specific heat capacity of silica gel decreases the undesired thermal shock which arises from the heat of adsorption and rapid cooling/heating but higher specific heat hinders the performance of adsorption system since significant amount of the supplied energy is retained by the silica gel. It is obvious that the adsorption cycles involve rapid thermal fluctuation due to alternate heating and cooling [9-10]; hence, it is logical to perceive that specific heat capacity of the adsorbent is not constant instead a function of temperature. However, detailed analyses of specific heat capacity of porous silica gel at various temperatures are not available in open literature. In the present study, the specific heat capacities of several types of silica gel have been measured using a heat flux type DSC.

2. Experimental

2.1. Materials

RD (regular density) Silica gel of four different particle size, type A and type B silica gels are investigated in this study. System calibration is carried out using pure indium and α-alumina (Al_2O_3) powder as standards.

2.2. Basic components of DSC

The differential scanning calorimeter (DSC) has a typical heat flux cell which is enclosed by a heating block to dissipate heat to the specimen (S and R) via a constantan disc attached to the block. The constantan disc has two platforms on which the specimen (S) and reference (R) pans are placed. Several thermocouples are used to determine the differential temperature of interest for the

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programmed heating/cooling cycle. The schematic diagram of the differential scanning calorimeter is shown in Fig.1. The thermal analyzer regulates the temperature and provides an accurate heating rate to the sample and the reference section. The DSC maintains an inert environment by introducing nitrogen gas at a controlled flow rate of 50ml/min.

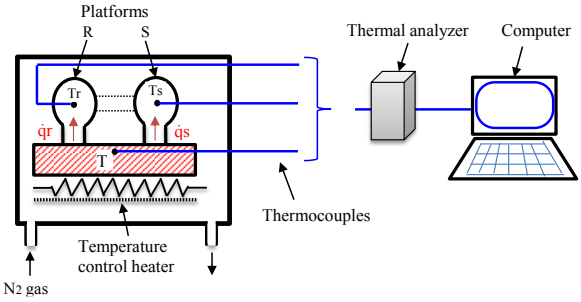

Fig. 1. Schematic diagram of the DSC apparatus

3. Experimental procedure

Aluminum pan of flat geometry and nearly identical weight and size is placed on S and R to hold sample materials. The sample is dried in an ordinary oven at 100°C for 10 hours and then in a vacuum oven at 100°C for 3 hours to eliminate any water vapor or other impurities in the sample. A complete experiment to measure the specific heat capacity comprises of blank run, reference sample (α-Al_2O_3) run and sample run.

4. Results and discussion

Specific heat capacity of different particle size RD Silica gels is shown in Fig. 2. The result clearly indicates that higher particle size samples have higher specific heat capacity. The reason is due to lack of homogeneity of the adsorbent sample with

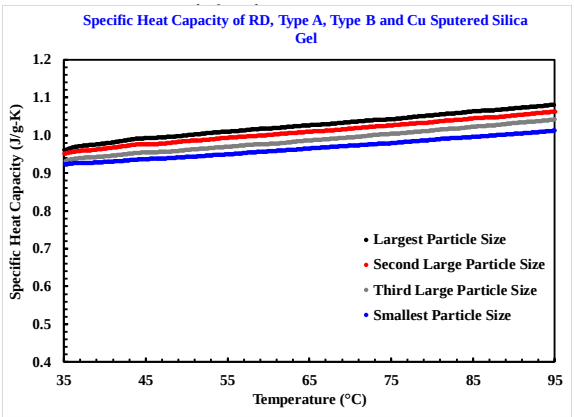

Fig. 2. Specific heat capacity of RD silica gel

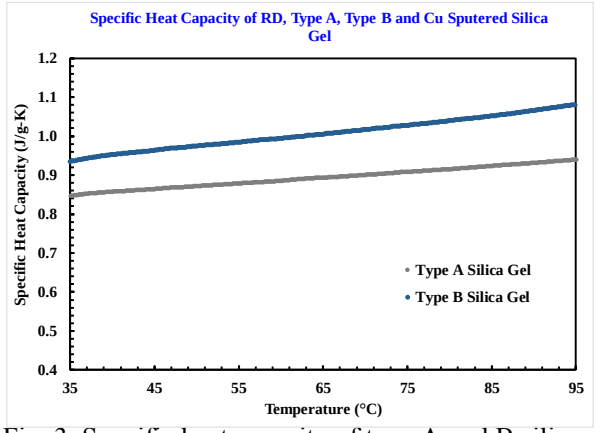

Fig. 3. Specific heat capacity of type A and B silica gel

The difference of specific heat capacity between type A and type B silica gel (Fig. 3.) is due to the pore size variation and physical structure.

5. Conclusion

Specific heat capacity of RD type (four different particle size), type A and type B silica gels were measured. RD silica gel of largest particle size is found to have the highest specific heat capacity (0.96 to 1.10 kJ kg^{-1} K^{-1}) among these six samples. On the other hand, type A silica gel have the lowest specific heat capacity (0.85 to 0.95 kJ kg^{-1} K^{-1}) in the measured temperature range. Specific heat capacity has the tendency to increase gradually with temperature.

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