SiO_2 캡슐화 파라핀 상변화 물질의 상전이 역학에 대한 캡슐화 비율의 영향

Effect of Encapsulation Ratio on the Phase Transition Kinetics of the SiO_2 Encapsulated Paraffin Phase Change Materials

소우멘 만달[1] · 이한승[2*]
Soumen, Mandal[1] · Lee, Han-Seung[2*]

Abstract : In this study, an approach has been made to understand the effect of encapsulation thickness of the nanoencapsulated PCMs on the phase transition kinetics. Paraffin is encapsulated by silica via single pot polycondensation reaction. Different ratios of silica precursor are chosen to encapsulate paraffin. The obtained encapsulated PCMs are identified as nano sized, as well as with increasing silica precursor, thicker silica encapsulations have been manifested with shrinking core diameter. The synthesized PCMs are characterized using various characterization techniques. Isochronal kinetic studies are done in differential scanning calorimeter (DSC) to understand about their phase transformation behaviors. This study can appreciate the cognition of the large-scale applications of PCMs into the building constructions as well as the fundamental conception on the phase transition kinetics of PCMs can also be amended.

키워드 : 파라핀, 상변화 물질, 상전이 역학
Keywords : paraffin, phase change materials, phase transition kinetic

1. Introduction

For a better and cleaner imminent of the globe, the entire energy infrastructure requires to be decarbonized to abate the greenhouse gas emissions. That can be possible if all the primary sources of energy can be carbon free, regardless the energy sources and their end use. Contemplating that, phase change materials (PCMs) are popularized as sustainable thermal energy storage materials for their superior latent heat charging and discharging capabilities, based on the ambience. However, encapsulation of PCMs is required to circumvent mechanical damage, thermal conductivity, and contamination related problems. Tremendous research efforts are being done to encapsulate the PCM for improving the working performance and to bypass the contamination related problems[1]. Several encapsulation materials viz. SiO_2, $CaCO_3$, AlOOH, PEG have also been the focus of research for the successful encapsulation of PCMs with better functionalities. However, the melting behavior on the thickness of the encapsulation shell is fundamental and crucial to evaluate the energy storage performance of the PCMs. Therefore, in this study, paraffin is encapsulated with silica shell of different thicknesses and the phase transformation kinetics of the PCMs inside different SiO_2 confined domains are evaluated by DSC scans.

2. Materials and Method

Pure paraffin and silica encapsulated paraffin PCMs are taken for this study. Paraffin and silica precursor ratios are taken into 1:1 and 1:2. Acquisition of raw materials, method of silica encapsulations on paraffin, and the microscopic, structural, & thermal characterization procedures are done in the same manner those have been mentioned in our earlier study[1].

1) 경북대학교, 연구원
2) 한양대학교 에리카캠퍼스 건축공학과, 정교수, 교신저자(ercleehs@hanyang.ac.kr)

3. Result and Discussion

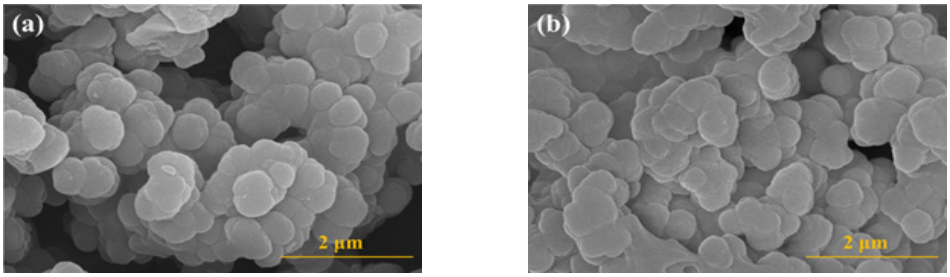

Figure 1. SEM micrographs of the silica encapsulated paraffine PCMs (a) 1P_1S, (b) 1P_2S

The scanning electron microscopy (Figure 1) of synthesized encapsulated PCMs shows the spherical shapes with the average size of 450 nm for 1P_1S (Figure 1(a)) and 480 nm for 1P_2S (Figure 1(b)) samples. The shell thicknesses by TEM are found to be around 40 and 100 nm for 1P_1S and 1P_2S, respectively. The XRD and SAED pattern show the fully amorphous structure of the silica shell.

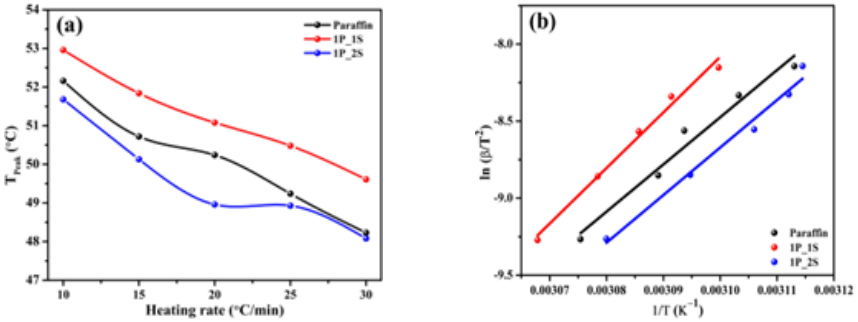

Figure 2. (a) Dependance of the phase transition temperature (TPeak) on heating rate, (b) Kissinger plots

The PCM samples are undertaken for the DSC scans at heating rates of 10, 15, 20, 25, 30°C/min. As expected, the phase transformations are observed to commence at an early temperature with increasing the heating rates (Figure 2(a)). However, the phase transitions are observed to occur at higher temperatures for 1P_1S than pure paraffin whereas for the 1P_2S sample the observation is opposite. The activation energy required for the phase transformations is calculated by Kissinger kinetic model and the plot originated from the Kissinger equation is presented in Figure 2(b). The calculated activation energies for the phase transitions are calculated to be 254.5, 249.8, and 260.1 kJ/mol for paraffin. 1P_1S, and 1P_2S, respectively.

4. Conclusions

The successful encapsulation can be done using silica precursor. The encapsulation of paraffin with silica by 1:1 ratio has shifted the phase transition temperatures at higher degrees though the activation energy required for the phase transition is the minimum for the same sample. Though the 1P_2S sample can provide higher mechanical and structural stabilities for applications, but 1P_1S sample can provide the easy phase transition for the thermal energy storage.

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참고문헌

1. S Mandal, S Ishak, JK Singh, DE Lee, T Park. Synthesis and application of paraffin/silica phase change nanocapsules: Experimental and numerical approach. Journal of Energy Storage. 2022. Vol.51. p. 104407.