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Crystal growth kinetics of sugar alcohols as phase change materials for thermal energy storage

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Abstract

Among bio-based materials, Sugar Alcohols (SA) are very promising Phase Change Materials (PCMs) for thermal energy storage at low temperatures due to their low melting temperature, their high energy density, their high and stable undercooling allowing long-term storage with reduced thermal losses. When heating is needed, the storage system is discharged by activating SA crystallization and its discharge power depends on the SA crystal growth kinetics. This work aims at measuring and modeling crystal growth rates in undercooled melts of SA according to the temperature and at determining the involved crystal growth mechanisms. Crystal morphologies and morphological transitions are also observed and discussed.

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Keywords: Thermal energy storage ; Phase Change Materials ; Undercooling ; Crystal Growth

1. Introduction

Considering the current energy and economic issues, the development of new PCMs for solar seasonal energy storage, matching building applications requirements, constitutes a technological challenge. Major assets of SA for these Thermal Energy Storage (TES) applications are their melting temperature (368-391K) which allows using cheap solar collectors, their outstanding energy density (4-5 times superior to the water energy density on a seasonal basis), which can lead to highly compact systems, and their high and stable undercooling allowing long-term storage

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with reduced thermal losses. Crystal growth kinetics of SA are an important issue for TES applications and are studied in this work.

Nomenclature

Roman letters

$C_{1,2}$	fit parameters
f	fraction of interface sites (active growth sites)
k	pre-factor
k_B	Boltzmann constant
L	diffusion jump distance
R	universal gas constant
v	crystal growth velocity
T	temperature at the crystal-melt interface (bulk temperature)
T_m	liquidus temperature
T_0	working temperature (bulk temperature)
η	viscosity of the liquid

Greek letters

ΔH_{ls}	latent heat of melting
ΔS_a	entropy difference
ΔT	undercooling T_m-T (with T, the temperature at the crystal-melt interface)

Acronyms

PCMs	phase change materials
SA	sugar alcohols
TES	thermal energy storage

2. Materials and experimental method

2.1. Samples

The crystal growth of four pure sugar alcohols (Erythritol, Xylitol, Adonitol and L-Arabitol) has been studied in this work. Table 1 summarizes their specific information.

Table 1. Specific product information for the studied SA

SA	CAS number	Provider	Purity (%)
Erythritol	149-32-6	Cargill	99.5
L-Arabitol	7643-75-6	Stanford Chemicals	98
Adonitol	488-81-3	Sigma Aldrich	≥ 99
Xylitol	87-99-0	Roquette	98.43

Their melting temperature and energy density are listed in Table 2. The latters and other properties (viscosity, density, conductivity etc.) as well as their measurements are detailed in [1]. The sample consists in 300 mg of SA deposited on a microscope glass with no control of the thickness. This sample is prepared as follows: 1) the product is first molten in a vessel; and 2) the molten product is then poured on the glass slide.

Table 2. Melting point and Latent heat of the studied SA

SA	Melting Temperature (K)	Latent heat (J/g)
Erythritol	391	340.00
L-Arabitol	376	230.00
Adonitol	373	250
Xylitol	368	267.00