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BSc (Chemistry), University of Guelph, 2013

DEPARTMENT OF CHEMISTRY

TITLE OF THESIS: PHASE CHANGE MATERIALS FOR THERMAL ENERGY STORAGE
TIME/DATE: 1:30 pm, Monday, September 17, 2018
PLACE: Room 3107, The Mona Campbell Building, 1459 LeMarchant Street

EXAMINING COMMITTEE:

Dr. John M. Shaw, Department of Chemical and Materials Engineering, University of Alberta (External Examiner)

Dr. Josef Zwanziger, Department of Chemistry, Dalhousie University (Reader)

Dr. T. Bruce Grindley, Department of Chemistry, Dalhousie University (Reader)

Dr. Mark Obrovac, Department of Chemistry, Dalhousie University (Reader)

Dr. Mary Anne White, Department of Chemistry, Dalhousie University (Supervisor)

DEPARTMENTAL REPRESENTATIVE: Dr. Erin Johnson, Department of Chemistry, Dalhousie University

CHAIR: Dr. Robert Lee, PhD Defence Panel, Faculty of Graduate Studies

ABSTRACT

Phase change materials (PCM) offer promise for thermal energy storage. PCMs store heat primarily through the enthalpy change of a phase transition, typically melting. A PCM's melting and crystallization temperatures should both be within the application's temperature range. Thus, supercooling presents a challenge for some PCMs. Other challenges include low thermal conductivity and containment of the liquid phase.

Two types of organic molecular materials are identified here as promising for PCM use: compounds with long alkyl chains (*e.g.*, fatty acids), and materials with extensive hydrogen bonding in the solid phase (*e.g.*, sugar alcohols).

Fatty acids are attractive PCMs, in part because they crystallize with minimal supercooling. Fatty acid nucleation was studied here to understand why they crystallize so easily, as a step toward identifying potential mechanisms to suppress supercooling in other PCMs. The crystallization of fatty acids was studied by differential scanning calorimetry, and liquid phase organization was investigated by small-angle X-ray scattering, NMR spectroscopy, and dielectric constant measurements. It is proposed that fatty acids nucleate via a non-classical pathway involving aggregation of ordered clusters in the liquid, and that supercooling in sugar alcohols could be suppressed by templating similar regions of order using hydrogen bonding-active surfaces.

Novel freeze-cast form-stable PCMs were prepared to combat the low thermal conductivity of organic PCMs while containing the liquid phase. Thirteen types of freeze-cast scaffolds were prepared and were used in combination with six different PCMs. Composites were evaluated based on PCM loading, cyclability, heat capacity, thermal conductivity, melting point, enthalpy of fusion, microstructure, and hardness. Alumina/dodecanoic acid composites were found to be especially promising with thermal conductivity of $3.2 \text{ W m}^{-1} \text{ K}^{-1}$ at 300 K and 38 mass % loading.

NaOH-treated pyrolyzed chitosan scaffolds prepared with zirconium acetate were used to make form-stable PCMs with extremely high PCM loading. These scaffolds had active surfaces that promoted nucleation in erythritol. Supercooling of erythritol was reduced from $\sim 80 \text{ K}$ to $\sim 2 \text{ K}$ using the templating agent. This is the first report of near-total suppression of supercooling in erythritol by passive means.

