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Canadian natural zeolites as stable host matrices for low-cost, high-performance composite thermochemical energy storage materials

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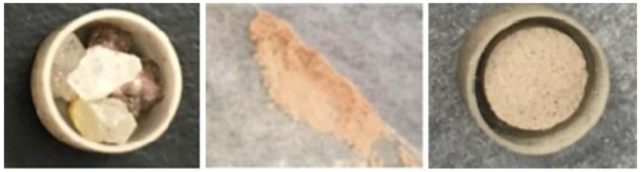
Abstract

Two Canadian natural zeolites were identified as promising host matrices for the development of composite thermochemical energy storage materials (TCM). Initial lab-scale cycling stability tests using a simultaneous thermal analyzer equipped with humidity generator indicated that the composite TCM and corresponding matrices were stable over ten cycles. A marked reduction in the cost of energy storage at the material-level was realized for the composite TCM, compared to the standalone host matrices.

Introduction

Researchers at CanmetENERGY-Ottawa screened 31 samples of natural zeolites provided by Canadian suppliers including ZMM Canada Minerals Corp for the application of thermal energy storage in residential buildings. Two samples of high purity zeolite crystals (HPC) from the Juniper Creek (J-HPC) and TransCanada (TC-HPC) mining deposits in British Columbia were selected for the development of composite TCM. J-HPC is a combination of heulandite, phillipsite and chabazite, whereas TC-HPC is composed of mostly analcime. The developed composite TCM and their corresponding matrices in different forms were subject to detailed thermal characterization and preliminary cycling stability testing (see Figure 1).



a) b) c)

Figure 1: Shapes of natural zeolite samples tested in the form of a) granules b) powder and c) pellet.

Methods & Materials

The selected HPC were grinded into powder and dried at 250°C before analyzing their physicochemical properties. Dried J-HPC and TC-HPC were then impregnated with varying concentrations of aqueous $CaCl_2{\cdot}6H_2O$ solution (1–5 M). To investigate the improvement of the thermal conductivity of select composite TCM, an additive was included in their composition.

A simultaneous thermal analyzer (Netzsch STA 449 F3 Jupiter) equipped with a modular humidity generator (ProUmid MHG32) was used to characterize the composite TCM and their corresponding zeolite matrices in terms of water uptake (g/g), enthalpy of hydration (J/g), and thermal stability over multiple cycles of dehydration/hydration (see Figure 2).

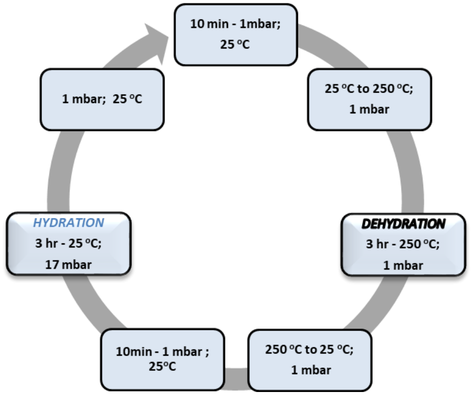


Figure 2: Procedure of experimental conditions for thermal properties characterization.

Results & Conclusions

The results of the thermal characterization study indicate that the composite TCM have higher thermal energy storage potential than their corresponding natural zeolite host matrices (see Table 1).

Table 1: Thermal characterization of J-HPC composite TCM.

Composite	Water Uptake (g/g)	Hydration Enthalpy (J/g)
#1 (0.08 mL 1M)	0.190	504
#2 (0.08 mL 2M)	0.195	446
#3 (0.1 mL 5M)	0.448	984
#4 (0.1 mL 5M + additive)	**0.500**	**1,030**
J-HPC Matrix	0.113	303

Considering the bulk price of the natural zeolites and salt hydrates ($/t), the estimated cost of energy storage ($CAD/GJ) of the composite TCM at the material-level was determined to be reduced by 9% and 71% compared to the TC-HPC and J-HPC host matrices, respectively. Additionally, the composite TCM were estimated to have a much lower cost of energy storage than commercial binderless zeolite 13X tested under the same conditions (see Figure 3).

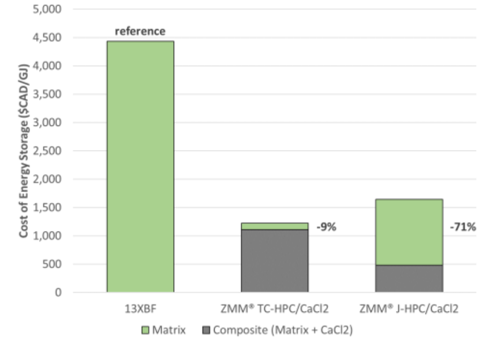


Figure 3: Reduced cost of thermal energy storage ($/GJ) at the material-level through composite TCM development.

Initial lab-scale thermal stability testing indicated that the performance of the composite TCM and the corresponding matrix were stable over ten charge/discharge cycles (see Figure 4). Additional equipment will be developed to conduct accelerated aging and evaluate the long-term durability of the composite TCM.

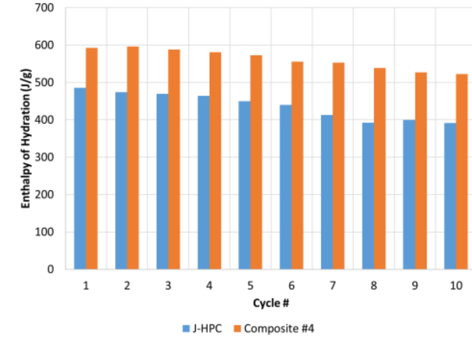


Figure 4: Preliminary cycling stability testing of J-HPC and corresponding composite #4.