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Reactivity enhancement of lithium orthosilicate for thermochemical energy storage material usage

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Abstract

Recently, the advanced high temperature gas-cooled reactor (HTGR) was developed, and is recognized worldwide as a superior next-generation system due to its inherent safety and low environmental impact. Moreover, integrating thermal energy storage with HTGR can provide additional, more flexible options for meeting energy needs. Thermochemical energy storage (TcES) has several advantages, consequently, development of a TcES system for HTGR is desirable. The lithium orthosilicate/carbon dioxide reaction system (Li_4SiO_4/CO_2) is one candidate which can be used at 800 °C. In this work, effects of potassium carbonate (K_2CO_3) as an additive to Li_4SiO_4/CO_2 were focused on and investigated.

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Keywords: Thermochemical energy storage; Chemical heat pump; Lithium orthosilicate; Carbon dioxide, The advanced high temprerature gas-cooled reactor

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1. Introduction

Currently, technological developments are being conducted to solve global energy and environmental problems in various fields. In the nuclear energy sector, the advanced high temperature gas-cooled reactor (HTGR) has been developed and is recognized worldwide as inherently safe. The HTGR uses graphite as a neutron moderator and helium gas as a coolant. It can supply a high temperature heat output (> 700 °C) without greenhouse gas emissions, balancing stable energy supply. In Japan, the high temperature engineering test reactor (HTTR) achieved heat outputs of 850 °C and 950 °C in 2001 and 2004, respectively. This was the highest HTGR temperature output in the world. In China, the 10MW high temperature gas-cooled reactor-test module (HTR-10) was constructed and it demonstrated a 700 °C heat output. In 2005, China announced the scale up of HTR-10 and started to build HTR-PM for commercial power generation. HTGR can supply high temperatures and efficient energy generation. Moreover, high temperature heat can be used for hydrogen production. From these advantages, HTGR has potential for practical use. However, HTGR has a lower neutron moderation capacity than conventional light-water reactors. Thus, the internal core structure is larger. Therefore, when compared with light-water reactors, HTGR has a lower output density, and it is required to build and operate plural reactors. In addition, given the cost for power generation and responsiveness of HTGR, the load followability of HTGR to energy demand is not enough.

Integrating thermal energy storage with nuclear power plants is one potential solution to these problems. Integrated systems may provide additional, more flexible options for meeting energy needs (Fig. 1). Thermochemical energy storage (TcES) is a promising candidate due to several advantages including lower energy loss for long-term storage, high thermal storage density, and constant temperature output. So far, several TcES systems have been proposed such as MgO/H_2O, $CaCl_2/NH_3$, CaO/H_2O, and CaO/CO_2 [1-4]. However, there are few TcES systems which are technically compatible with the HTGR operation. Therefore, development of a TcES system that can operate at 700 °C is desirable.

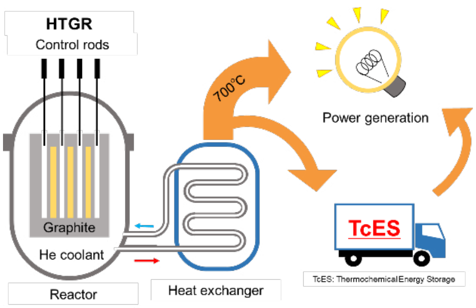

Fig. 1. Schematic diagram of HTGR and TcES

In order to find a new TcES reaction system, we focused on lithium orthosilicate/carbon dioxide (Li_4SiO_4/CO_2). The reaction of Li_4SiO_4/CO_2 can be described as Eq. (1).

$$Li_4SiO_4 + CO_2 \rightleftarrows Li_2CO_3 + Li_2SiO_3 \qquad \Delta H_r = -94 \text{ kJ mol}^{-1} \tag{1}$$

Carbonation of Li_4SiO_4 is an exothermic reaction that produces lithium carbonate (Li_2CO_3) and lithium metasilicate (Li_2SiO_3). Decarbonation of these species is endothermic, and produces Li_4SiO_4. Thus, decarbonation and carbonation are expected to be used for heat storage and heat output processes, respectively, in a TcES system.