Renewable and Sustainable Energy Reviews 32 (2014) 178–191

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Carbon dioxide emission reduction using molten carbonate fuel cell systems

Jung-Ho Wee *

Department of Environmental Engineering, The Catholic University of Korea, 43 Jibong-ro, Wonmi-gu, Bucheon-si, Gyeonggi-do 420-743, Republic of Korea

ARTICLE INFO

Article history:
Received 12 July 2011
Received in revised form
18 November 2013
Accepted 4 January 2014
Available online 30 January 2014

Keywords:
Molten carbonate fuel cells
Carbon dioxide emission reduction
Carbon capture
Thermal power plant
Climate change

ABSTRACT

The contribution of the molten carbonate fuel cell system (MCFCs) to carbon dioxide (CO_2) emission reduction in power application is analyzed. MCFCs can separate and concentrate CO_2 emitted from traditional thermal power plants (PPs) without reducing the plant's overall energy efficiency. MCFCs can also be used by itself as an effective CO_2 separator or concentrator by managing the anode gas stream to increase the heat utilization of the system. The CO_2 separated and concentrated by MCFCs is most effectively captured by condensation. MCFCs is currently used as a CO_2 separator only to a limited extent due to its high cost and relatively small scale operation. However, MCFCs will substantially contribute to reduce CO_2 emissions in power generation applications in the near future.

Contents

1. Introduction

Climate change is believed to be one of the most important issues in this century. Carbon dioxide (CO_2) emissions should be reduced to prevent global warming. Although renewable and sustainable energy can significantly contribute to reduce CO_2 emissions, it will take a very long time for them to be easily exploited and widely used. Therefore, fossil fuels will continue to be used because they are relatively abundant and economic. However, because they necessarily involve great CO_2 emissions, CO_2 capture and storage (or utilization) technology should be developed and employed to mitigate CO_2 emissions.

Separation using membranes, chemical looping and molten carbonate fuel cell system (MCFCs) has been considered to utilize advanced CO_2 capture technologies because they can effectively

* Tel.: +82 221 644 866; fax: +82 221 644 765.
E-mail addresses: jhwee@catholic.ac.kr, jhwee@korea.ac.kr

1364-0321/$ - see front matter
http://dx.doi.org/10.1016/j.rser.2014.01.034

separate and relatively easily concentrate CO_2 emitted in the processes [1,2]. Therefore, they are believed to be one of the most promising options to reduce CO_2 emission. However, there are many challenges to be addressed in each technology. Regarding membrane technology, many selective membranes for CO_2 capture have been developed such as polymeric, mixed ionic–electronic (solid electrolyte–metal) films as well as metallic (palladium)-based materials [2,3–11]. However, the technology is subject to the limitations of high operation pressure, CO_2 concentration and process scale-up [9,10,12].

Chemical looping combustion has the great potential to separate CO_2 from flue gas. Many papers [13–23] have reported the efficiency of various metal oxide catalysts and their regeneration performance. Despite their promising results, further study on more reactive and stable catalysts, which can be regenerated for numerous cycles, is still required. Catalyst attrition and deactivation due to carbon deposition are another primary issue that needs to be addressed for practical use [24,25]. Although these two technologies may be successfully developed in the near future, they may be basically less competitive with MCFCs because the original purpose of membrane and chemical looping is solely to separate CO_2 in gas mixture, while the CO_2 separation potential of MCFCs is its surplus technology. MCFCs has particularly many technologically advantageous features for CO_2 capture [26–40]. Firstly, MCFCs is operated with a high electrical efficiency due to the absence of any mixing of air and fuel in the process. Secondly, CO_2 is used as a reactant in the cathode at a constant concentration and flow-rate during the operation. Finally, a MCFC-hybrid

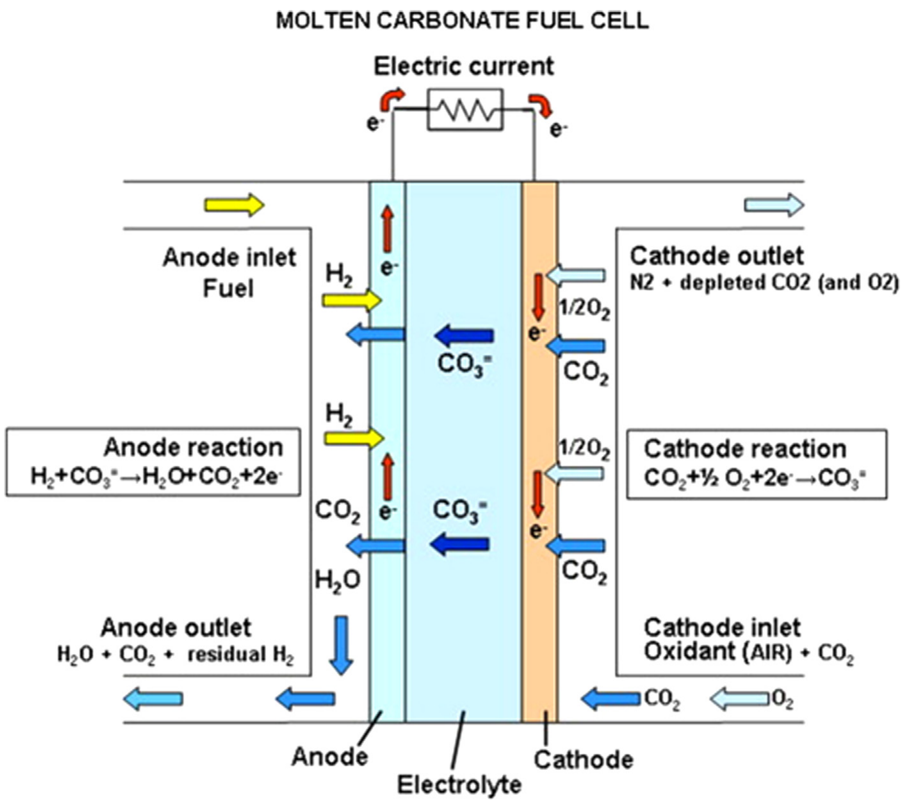

Fig. 1. Working scheme of MCFC [38].

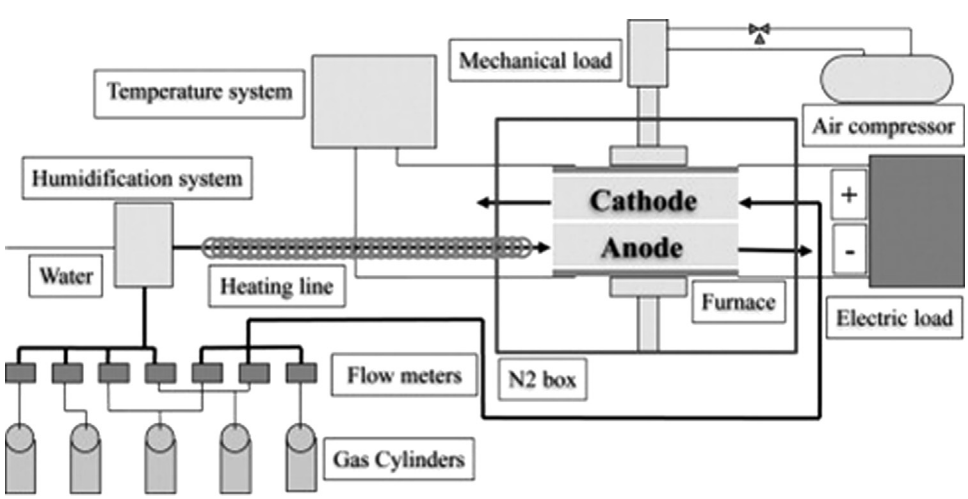

Fig. 2. Flowsheet of the experimental setup of the test bench [33].