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Thermal-Electrochemical Co-drive System for carbon capture

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Abstract

Cost-effective and large-scale carbon dioxide capture system is a critical technology for greenhouse gas abatement. However, current capture technologies are energy and capital intensive, which prohibits the deployment in power plants. Particularly, the need for elevated temperature steam is a troublesome problem for plants. In this work, we proposed a technology of Thermal-Electrochemical Co-drive System (TECS), which integrates electrochemical process and benign thermal process, as the solution of the above-mentioned problems. Since the fact that the binding site of metal-amine is identical with that of carbon dioxide (CO_2)-amine, CO_2 can be released easily. TECS is a technology based on coordination reactions, utilizing electrochemical method and thermodynamic principle to desorb CO_2 and regenerate amine. In addition, experiments study on TECS based on Cu(II) and monoethanolamine (MEA) was conducted. Results of CO_2 capacity of MEA aqueous solutions added Cu(II) suggest that Cu(II) shows strong inhibitory effects on the absorption process. In addition, the electrochemical impedance spectroscopy (EIS) was measured at different polarization potentials.

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Keywords: electrochemical, coordination, CO_2 capacity, EIS

1. Introduction

The Paris Agreement, adopted in the 21st session of the Conference of the Parties (COP 21) to the United Nations Framework on Climate Change (UNFCCC), proposed the targets of holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels [1]. Climate change has aroused public concern and underlined the need to pursue

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a green, low-carbon economy. The increase of global average temperature is ascribed to greenhouse gases. Among all the greenhouse gases, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), HFCs, PFCs, SF_6, anthropogenic carbon dioxide is taken for the main contributor to global warming [2].

Despite recent vigorous efforts to increase the share of renewable energy, fossil fuel is expected to remain a dominant fuel in the foreseeable future [3]. Carbon capture and storage (CCS) is now the only available technology that can cut up to 90% of carbon dioxide emissions from large industrial processes like power plants based on coal and other fossil fuels. CCS is also the only option for reducing CO_2 emissions in carbon-intensive coal–chemical, steel, cement, and refinery plants [4]. However, in the absence of lower incremental capital costs and parasitic energy loss, there is hardly any economic driver for CCS [5]. As the most practical method for carbon capture, chemical absorption, based on amine solutions, also cannot be an exception.

Traditional thermal amine scrubbing is the current benchmark technology for separating CO_2 from combustion flue gases in CCS systems [6]. CO_2 is usually absorbed by amine solutions at 40 °C in a packed absorption column, and then the rich solution is pumped to a stripper, where CO_2 is desorbed by low-pressure steam at a temperature above120 °C. The desorbed CO_2 is carried out of the stripper by sweep gas and compressed to about 12 MPa for the storage process [7]. The need for elevated temperature steam generally results in huge energy consumption, and it is troublesome for the plants without steam source, like cement plants, steel plants and coal-chemical plants. The retrofitting cost of such plants would be extremely high [8].

In this work, we introduce a novel technology, Thermal-Electrochemical Co-drive System (TECS), which integrates electrochemical process and benign thermal process, showing great potential to provide higher removal efficiency, lower parasitic energy loss and capital costs compared to traditional thermal amine scrubbing system. In addition, experimental investigation on the properties of TECS based on Cu(II) and monoethanolamine (MEA) was performed, including CO_2 capacity of solutions containing Cu(II)-MEA complex and electrochemical impedance spectroscopy.

Nomenclature

α	CO_2 loading
b	molality
L	equivalent inductance
R	equivalent resistance
R_{ct}	charge transfer resistance
R_L	equivalent resistance of inductive loop
Rs	the resistance of solution between work electrode and Luggin capillary
T	temperature (°C)
ω	angular frequency
W	Warburg impedance (element)
Z	total impedance

2. The TECS system

The full process of TECS system is illustrated in Fig. 1. CO_2 is scrubbed from the flue gas in a packed column using aqueous amine solution firstly. The CO_2-saturated sorbent solution is then pumped to the desorber where an electrolysis system, consisting of a regulated power supply, a metal anode and a graphite cathode, is pre-installed. The metal anode is oxidized to release metal cations that will complex with the N atoms in amine molecules.