Brown coal derived carbon composite monolithic adsorbents for CO₂ capture

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Abstract

Growing concerns for global warming and climate changes have attracted widespread efforts to develop efficient and cost-effective technologies for post-combustion CO₂ capture from large point sources, such as coal-fired power plants. CO₂ capture using porous solid sorbents constitutes a promising solution. Among them, porous carbons are particularly suited to the PCC application owing to their abundant microporosity, ease of fabrication and excellent chemical, thermal and mechanical stability. Australia has vast brown coal resources accounting for about a quarter of the world’s known reserves. Being an abundant and low cost material, the brown coal has attracted great interests in R&D for its conversion to high value products. Much attention has been devoted to using brown coals to generate electricity and to produce chemicals via gasification. However, few attention has been paid to produce carbonaceous composite monoliths from brown coals.

CSIRO has conducted comprehensive research and development since 2006 on adsorption based post-combustion CO₂ capture technology by using honeycomb carbon monolithic adsorbents including adsorbent materials development, process configuration, prototype unit fabrication, and site trials and demonstration at a coal-fired power station in Australia [1-3]. Various adsorbent materials have been developed including carbon composite monoliths based on carbon fibres, carbon nanotubes, and low-cost abundant locally-available biomass macadamia nut shells and brown coals. In this contribution, the overview of the journey of CSIRO’s R&D on carbon composite adsorbents based CO₂ capture technology will be presented first. The major research results obtained at the laboratory-scale rig and large-scale test unit, and from site trials with the actual flue gas will be briefly introduced.

Next the paper will be focused on updating our research and development of carbon composite adsorbents from Victorian brown coals mixed with commercial phenolic resins and other additional components. The adsorbents were moulded into a cylindrical honeycomb monolith with multiple gas channels. This structure design is favourable to improving the flow resistance and pressure drop as well as reducing clogging when dealing with dusty flue gas streams. After de-moulding, the monolith was carbonised and activated with CO₂ for various durations. The porosity of the adsorbents was assessed by means of N₂ and CO₂ sorption at 77 K and 273 K, respectively. Characterisation also involved CO₂, N₂, O₂ and H₂O adsorption isotherms at temperatures between 0 and 50 °C. These are the major flue gas components and the selected conditions are relevant to post-combustion capture.

The pore structure development of brown coal carbon composites has been optimised by varying the composition of composites, types of brown coal feedstocks and conditions of carbonisation and CO₂ activation to achieve high adsorption capacities. The pore volumes, surface areas and pores size distributions are presented and discussed in relation to micropore and mesopore development. The
results show that brown coal derived composites exhibit a superior CO₂ adsorption capacity (53 mg CO₂ per g adsorbent at 25 °C and 0.15 bar) under low CO₂ partial pressures, which is of more relevance for flue gas applications. The dynamic CO₂ adsorption performance of the brown coal composite adsorbent was evaluated by means of breakthrough adsorption tests in a fixed-bed adsorption column using a simulated flue gas containing 12% CO₂. The breakthrough results show that the brown coal composites possess very high CO₂ removal efficiency of about 100% during adsorption and significantly high adsorption selectivity of CO₂ over O₂ and N₂.

References