Biomass waste carbon materials for post-combustion CO2 capture

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SUMMARY:

Low-carbon energy systems based on carbon capture and storage (CCS) have become of great interest due to the imperative necessity of mitigating the carbon footprint derived from the currently fossil fuels-based energy technologies. In this sense, post-combustion CO_2 adsorption over porous solids results particularly attractive from several viewpoints. In a green context, the use of carbon-based materials as adsorbents would entail important economic and environmental profits, such as the valorization of different types of biomass and lignocellulosic waste.

In this work, six carbon materials were prepared from four types of low cost biomass residues. Electrospun carbon fibers, FCL, and a char, GCL, were obtained from Alcell® lignin. Two activated carbons, GAS and GAWBa, resulted from physical activation of olive stones and plywood waste, respectively. Finally, another activated carbon, GAL, and an activated carbon cloth, CAD, were synthesized by chemical activation of lignin and a denim cloth. These materials were evaluated as potential adsorbents for CO_2 capture under post-combustion conditions by means of equilibrium and dynamic experiments (fixed-bed system). Moreover, the regeneration capacity of the samples was also studied.

Figure 1 represents the equilibrium adsorption isotherms of pure CO_2, at 25 ºC, of the carbon materials prepared. At 101.3 kPa, the samples displayed CO_2 capacities between 2.0 and 3.1 mmol/g. Meaningfully, the uptake values, at typical CO_2 pressures in post-combustion applications (c.a. 15 kPa), remain in the range of 0.7 to 1.2 mmol/g, which are comparable to those of other complex and appealing materials. Additionally, a thorough characterization of the porous structure of the different adsorbents provided new insights into the influence of the pore size distribution on the CO_2 capture capacity. CO_2 retention capacities correlate well with the narrow micropore volume derived from the CO_2 adsorption data at 0 ºC, V_{DRCO2}, at 101.3 kPa (Figure 2). In contrast, at 15 kPa, analysis of the cumulative pore volumes of the samples pointed out that only pores of sizes below 0.7 nm are relevant for adsorption. Under dynamic conditions, the studied materials also showed remarkable adsorptive behaviors. For instance, the lignin-derived carbon fiber (FCL) exhibited a capacity value higher than 1.3 mmol/g. Likewise, it is noteworthy that excellent regeneration percentages (up to 99%) were achieved after simple, fast and no high energy demanding desorption treatment, as shown in Figure 3.

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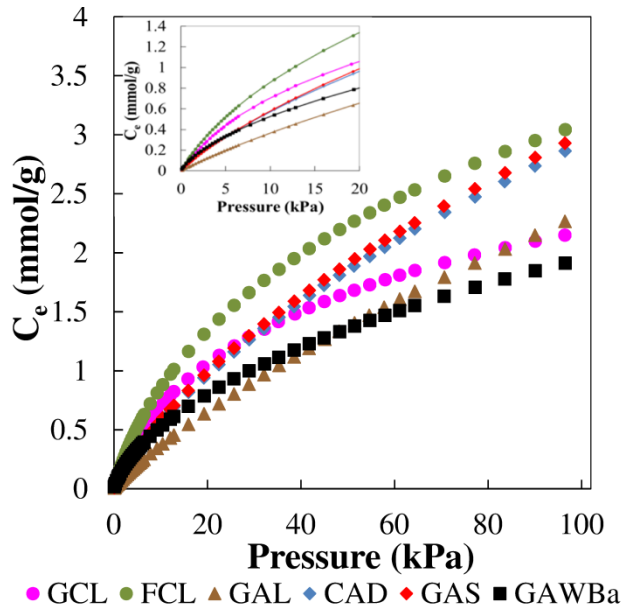

Figure 1. Equilibrium adsorption isotherms of CO_2 at 25 ºC over all the samples.

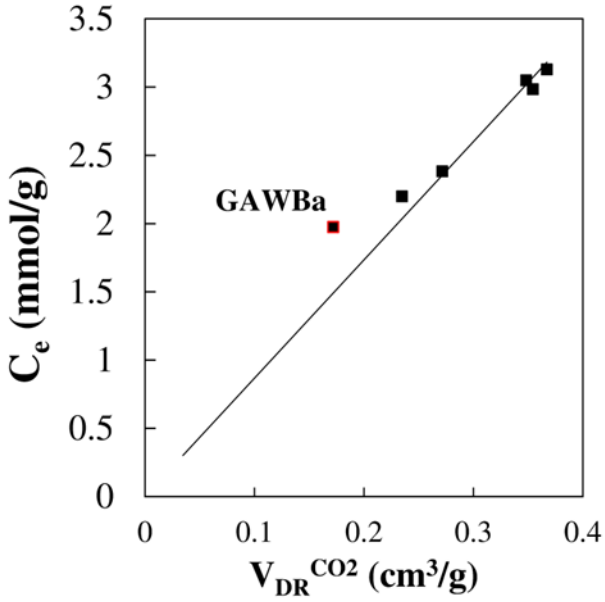

Figure 2. CO_2 adsorption capacity (25 ºC, 101.3 kPa) vs. the narrow micropore volume assessed from the CO_2 adsorption isotherms at 0 ºC by Dubinin-Radushkevich equation.

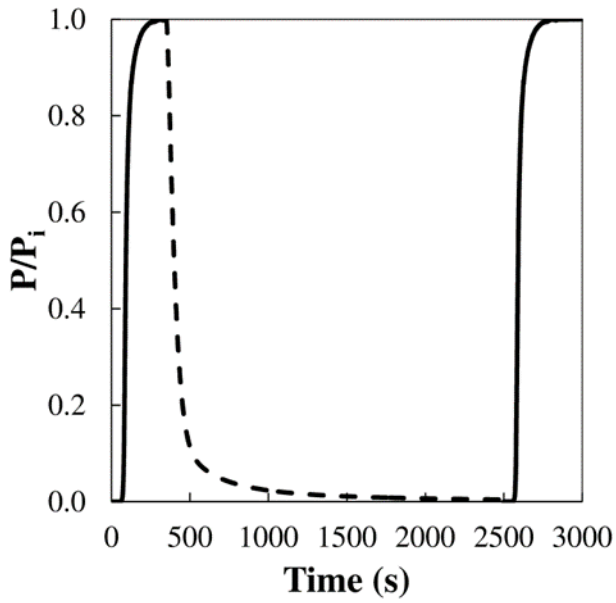

Figure 3. Cycle of adsorption-desorption-adsorption of CO_2 (25ºC, 15%CO_2) as a function of time over the activated carbon fiber FCL.