

CO₂ Capture and Electrochemical Mineralisation

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This presentation will present recent results from two complementary projects, both of which capture impure CO₂ from a gas stream. In one case the CO₂ is subsequently released as pure CO₂, whilst in the other it is electrochemically mineralised.

Aqueous amines are widely investigated for carbon capture applications, but suffer from decomposition and poor energetics.¹ Solid absorbants such as MOFs, zeolites or carbon based materials² provide an alternative approach. Recently, the Clark group have developed a template-free route to mesoporous carbons from waste biomass such as starch or alginic acid, leading to materials called Starbon[®].³ Therefore we decided to investigate the use of these novel mesoporous materials for CO₂ capture and release even though conventional wisdom is that a microporous solid should be more effective at gas capture than a mesoporous material. CO₂ capture and release experiments were carried out using a pressure swing method with capture at 5-10 bar CO₂ and release at atmospheric pressure and the results were compared with those obtained using activated carbon under identical conditions. The performance of the Starbon[®] materials depended greatly on the temperature of their carbonisation with optimal results being obtained at 800 °C for both starch and alginic acid derived materials and CO₂ absorption of 140-150% that achieved with activated carbon being obtained for capture at 5 bar.⁴ Kinetic studies on the rate of CO₂ release showed no significant difference between activated carbon and the optimal Starbon[®] materials. The optimal material could be reused at least 15 times with no significant change in activity and the adsorption of CO₂ was highly selective in the presence of water and nitrogen. Combined DSC and TGA analysis showed that the CO₂ was being physisorbed and a statistical analysis of the results showed that the role of the mesopores in the Starbon[®] materials was to enhance access to the micropores.

By combining graphite and a metal within the anode of an electrochemical cell, supercapitive charging can be used to increase the local concentration of CO₂, thus facilitating its reaction with a sacrificial anode. This previously unreported phenomenon has been demonstrated with anodes containing the two most abundant metals in the Earth's crust (aluminium and iron), with cathodes derived from platinum, nickel or iron and with electrolytes comprising aqueous solutions of sodium or lithium chloride. To illustrate the utility of this processes, the unprecedented electrochemical mineralisation of carbon dioxide into metal hydroxycarbonates⁵ is reported. Unlike conventional carbon dioxide electrochemical reduction which requires hydrogen as a reactant,⁶ this cell produces hydrogen as the cathodic product. Furthermore, it is shown that this can be achieved in a highly sustainable manner using waste metal within the anode, sea water as the electrolyte, an industrially-relevant stream of 5% carbon dioxide in nitrogen and a solar panel as the energy source. An energetic and scalability analysis and a CO₂ balance showing the large scale potential of the process will also be reported.

References

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