LNG trace CO_2 removal via new generation of advanced physisorbents.

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Abstract:

Methane, CH_4, as the main component of natural gas is critical to the dawning "Age of Gas"[1] for which new technologies are being developed around the use of gases as fuels and feedstock chemicals. Natural gas (NG) can provide higher energy and less CO_2 emission than other hydrocarbon fuels (i.e. coal and oil), and around 30% of global consumed energy is produced by NG today. Moreover, a large proportion of NG is transported globally in liquid form (LNG), and this is expected to grow to 10% of global crude production by 2020. However, before liquefaction of NG is possible, CO_2, as a significant impurity (several thousand ppms to 8%), must be reduced to below 50 ppm according to industry standards [2]. A cost and energy-effective technology for carbon capture and sequestration (CCS) is prerequisite to meet this target. The roll-out of CCS has been hampered by high costs (50-100 US€/t CO_2 captured), the techno-economic uncertainties of CCS technologies, and to date, the lack of suitable material alternatives to liquid amine based CCS technologies [3]. Liquid amine based CCS technology has been in existence for over half a century, however, liquid amine chemical capture relies upon chemical reactions and is energy intensive, therefore reducing the overall efficiency of a power plant by up to 40%. Liquid amines are thus not economically viable for broad deployment and offer little room for innovation. These innovative CCS technologies must improve both the environmental footprint and cost effectiveness of CCS.

This research addresses the need for innovative approaches to CCS through the development of a new generation of advanced physisorbents. Until recently, physisorbents such as metal-organic frameworks, (MOFs), and zeolites were handicapped by poor selectivity for CO_2 over the other components of industrial gas mixtures, high cost and/or poor stability.

The work focuses upon utilizing advanced physisorbent materials to efficiently remove trace levels of carbon dioxide (CO_2) from methane (CH_4). This application is especially relevant to natural gas purification (sweetening) prior to liquefaction, which requires CO_2 levels to be less than 50 ppm. Liquid amines are used to capture CO_2 in the conventional process for removing CO_2 and they require a high-energy cost to be regenerated. Physisorbents are treated as an important alternative because of lower regeneration energy. Whereas existing classes of physisorbent materials, such as MOFs and zeolites, are generally selective towards CO_2 over CH_4, their selectivity is not high enough to remove trace levels (e.g. 1%) of CO_2 from CH_4. The project will focus upon a new class of physisorbents, Hybrid Ultramicroporous Materials (HUMs), recently developed by the PI's research group. These HUMs have ultramicropores (<0.7 nm) that closely fit CO_2, and interactions are further enhanced by strong electrostatics from the presence of inorganic anions. Certain

families of HUMs exhibit extraordinary selectivity towards CO_2 that is superior to existing physisorbents. Whereas selective capture of CO_2 from gas mixtures in which CH_4 or N_2 are the major components has already been demonstrated, selective capture of trace levels of CO_2 from CH_4 relevant to natural gas sweetening has not yet been achieved by physisorbents.

The successful implementation of this work will provide necessary insight into processing technologies required to bring HUMs from the laboratory bench-top into commercialization. Moreover, the insight of CO_2 and CH_4 binding site in the scientific part will provide the guideline for design and synthesis of more advanced physisorbents for this application. The low cost and robust sorbents designed and evaluated in this proposal will ultimately enable greatly reduced energy consumption for industrial scale CO_2 removal from natural gas as a prerequisite to liquefaction.

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