Let carbon nanostructures do the job

CO_2 emission, from burning of fossil fuels and industrial processes is estimated to contribute more than 70% of all greenhouse gases. The prospects of a clean energy economy demands the efficient removal of CO_2. Absorption of CO_2 using chemical methods like wet scrubbing with amine compounds is the established method for capturing CO_2 in power plants. High energy requirement for regeneration which is carried out at elevated temperatures as well as its corrosive nature are the main drawbacks of this method. Reversible physical adsorption and desorption might represent an alternative route towards effective gas removal.

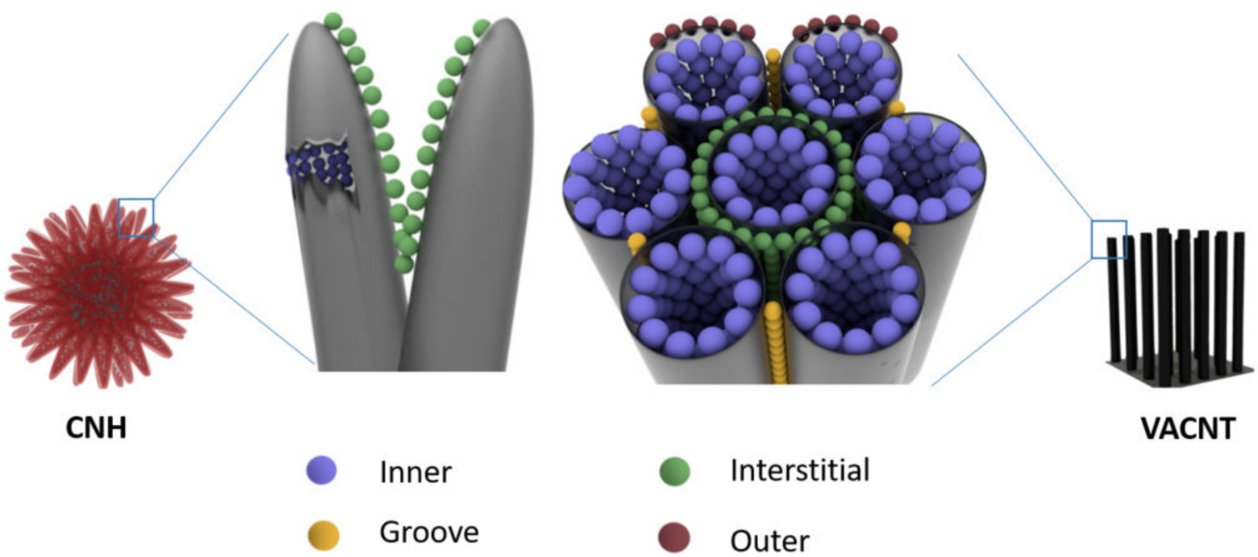

Fig. 1. Possible gas adsorption sites in (a) opened CNHs and (b) opened VACNTs.

Among the different types of physical adsorbents, zeolites, metal–organic frameworks (MOFs) and porous carbons are widely used as CO_2 adsorbents due to their large surface area and high porosity. Compared with zeolites and MOFs, carbon based adsorbents exhibit better stability towards moisture and even corrosive flue gases like SO_2 and H_2S. Among the variety of carbon adsorbents carbon nanotubes (CNTs) and carbon nanohorns (CNHs) are interesting materials for gas adsorption. Besides their high adsorptivity they have defined adsorption sites on their outside as well as in their interior. However, to explore their capacity in full, their tip endings have to be selectively opened in order to allow full access to their inner compartments. This could be achieved by a mild oxidation at high temperature under CO_2 gas which opened selectively the tip ends of the VACNTs and the CNHs.

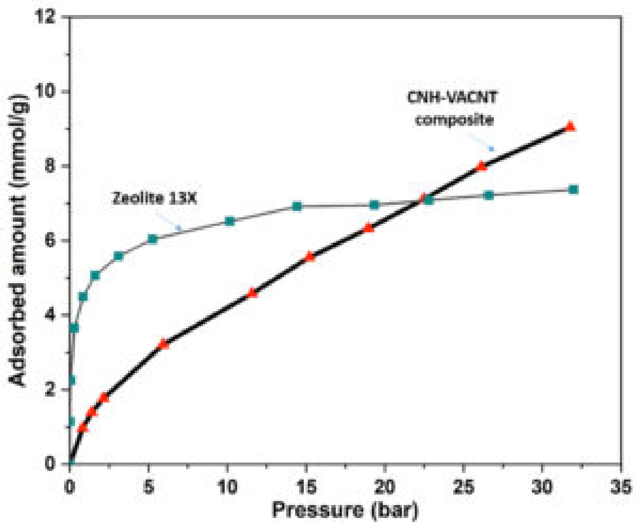

Fig. 2. CO_2 gas adsorption in a typical zeolite adsorbent vs. the all carbon VACNT/CNH composite.

We have investigated the suitability of an all carbon composite composed of opened carbon nanohorns (CNHs) and opened vertically aligned carbon nanotubes (VACNTs) for CO_2 adsorption. Whereas VACNTs typically show a promising adsorption behavior at high pressures, CNHs show superior gas adsorption properties in the low pressure regime due to their inherent microporosity. These adsorption characteristics are further enhanced when both materials are opened at their tip ends. The so prepared carbon composite material allows to investigate the effect of physical entrapment of CO_2 molecules within the specific adsorption sites of VACNTs as well as in those created by spherically aggregated opened single walled CNHs. When combining 50 wt% of tip opened VACNTs with tip opened CNHs the CO_2 adsorption capacity of this composite increases by about 24% at 30 bar and 298 K compared to CNHs alone. With an isosteric heat of adsorption of 31 kJ mol^{-1} the physisorptive nature of the CO_2 adsorption for the all carbon composite VACNTs/CNHs was proven. One main advantage of employing such an all carbon composite material lies in the fact to combine different adsorption regimes by combining adsorbents from the same elemental type and thus allowing to expand the active adsorption range from the low to the high pressure regime by introducing controlled micro and mesopority structures when using VACNTs and CNHs.

Jörg J. Schneider
Technische Universität Darmstadt, Eduard-Zintl-Institut für Anorganische und Physikalische Chemie,
Darmstadt, Germany

Publication

Gas adsorption capacity in an all carbon nanomaterial composed of carbon nanohorns and vertically aligned carbon nanotubes.
Puthusseri D, Babu DJ, Okeil S, Schneider JJ
Phys Chem Chem Phys. 2017 Oct 4