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CO_2 Adsorption Studies over Cao Supported On Activated Carbon

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Abstract

A series of CaO supported on activated carbon (2, 4, 6, 8, and 10 wt %) was prepared using the impregnation method. The samples were characterized by powder X-ray diffraction (PXRD), N_2 adsorption-desorption isotherms. Carbon dioxide capture was conducted using the fixed bed method at room temperature and atmospheric pressure. 4 wt% CaO supported on activated carbon has shown a high adsorption capacity of 125 µ mol/g at 30 °C and good recyclability up to 10 cycles without loss of adsorption capacity.

Keywords: CaO, activated carbon, Carbon dioxide capture and fixed bed method

1. Introduction

Anthropogenic CO_2 emissions from the combustion of fossil fuels, industrial processes and landfills are major cause of climate change [1-3]. Adsorption using porous materials is gaining importance for CO_2 capture due to their cost-effectiveness, ease application, and low energy demand compared absorption and membrane separation [4]. Among the porous materials, activated carbon is a promising adsorbent due its low cost, high surface, tunable porosity and high CO_2 selectivity [5, 6] . Impregnating AC with basic metal oxides introduces Chemisorption sites that interact with acidic CO_2 molecules, adding a chemical adsorption path way alongside the carbons physical adsorption [7, 8]. The presence of metal oxides on AC creates a basic surface with strong affinity toward CO_2, and the metal oxide basic sites interact with acidic CO_2 to increase uptake beyond what the carbon pore network alone achieves [9]. This dual physisorption-chemisorption mechanism is reported in CaO, MgO, CuO, Fe_2O_3 and CO_3O_4 [10]. Metal oxide impregnation and nitrogen incorporation are the important strategies for improving AC basicity for CO_2 adsorption [11].

2. Experimental

2.1 Materials

Calcium nitrate hexahydrate (Ca $(NO_3)_3.6H_2O$, 99%) and activated carbon were purchased from Sigma Aldrich, India. Laboratory prepared double distilled water was used for the synthesis of adsorbent. N_2 gas (UHP, 99.999%), 10% CO_2 balanced helium were purchased from BOC, India.

2.2 Synthesis of CaO supported on activated carbon

Desired quantity of calcium nitrate hexahydrate was dissolved in double distilled water then add required amount of purified activated carbon, stir for 1 h followed by dried at 100 °C for 12 h. Dried material was calcined at 450 °C for 4 h in N_2 flow and labelled as Xwt% CaO/AC, where X = 2, 4, 6, 8 and 10 weight percentage.

2.3 Characterizations

X-ray diffraction patterns were recorded on Rigaku X-ray diffractometer Ultima-IV having Ni filtered Cu Kα radiation in the scan range from 2θ = 10 – 80° with scan speed 4°/min, step size 0.01°/sec having tube voltage 40 KV and current 30 mA. N_2 adsorption-desorption isotherms were performed at 77 K using Quantachrome Quadrasorb SI surface area analyzer after evacuating the sample at 473 K for 12 h. Multipoint Brunauer-Emmet-Teller (BET) surface area was measured in the relative pressure range 0.05-0.30, total pore volume was determined at a relative pressure of 0.95, micropore volume was determined by t-plot method.

2.4 CO_2 adsorption study

Approximately 0.2 g of the sample was placed in a micro reactor with a 3 mm i.d. and 250 m.m quartz reactor and treated at 500 °C for 2 h in helium flow to remove physisorbed gas and moisture. Finally, the mixture was cooled to room temperature for the adsorption of CO_2. The outlet of the reactor was connected to a gas chromatography GC 7820 A GC system (Agilent Technologies, Switzerland) with a thermal conductivity detector with a Porapak Q column (3 m length and 3 mm ID). After pre-treatment, 10% CO_2 balanced helium was injected by pulses using a six-port valve with a 250 µl loop until the sample was saturated at room temperature. The sample was flushed with helium at the same temperature for 1 h to remove physisorbed CO_2 gas. Subsequently, the temperature was increased to 800 °C at ramping rate of 10 °C/min in helium flow. The desorbed CO_2 gas was monitored using TCD and GC software. For recyclability, the completely desorbed sample was again treated with 10% CO_2 balanced helium gas to study the stability of the CO_2 adsorption capacity up to 10 cycles.

3. Results and Discussion

3.1 XRD

Fig 1 shows the XRD diffraction pattern of 2, 4, 6, 8 and 10wt% CaO supported on activated carbon. In the lower loadings of CaO (2 and 4wt%) diffraction peaks of CaO was absent, which indicates that it was well dispersed on carbon materials and those are not detectable in the XRD. From 6 to 10wt% CaO supported catalysts showed the diffraction peaks related to CaO due to the increase in the percentage of metal oxide.

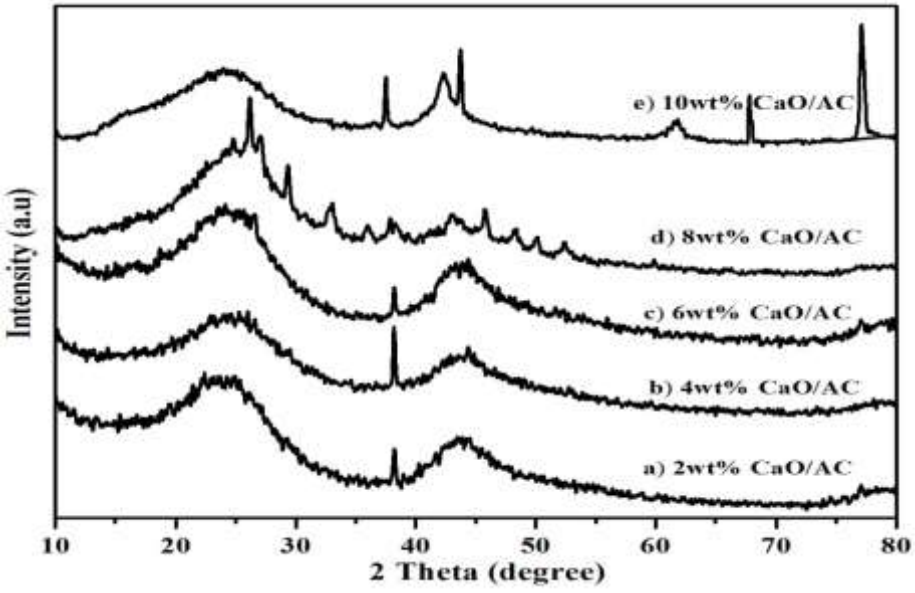

Fig 1: XRD patterns of calcium oxide supported activated carbon

3.2 N_2 adsorption-desorption isotherms:

Figure 2 shows N_2 adsorption desorption isotherms of CaO supported on activated carbon and textural properties were shown in table 1. 2wt% CaO/AC has shown surface area about 624 m^2/gm with total pore volume 0.39 cm^3/gm. As the loading increases, decrease in surface area to 125 m^2/gm and total pore volume to 0.08cm^3/gm observed in 10wt% CaO/ activated carbon which indicates some of the pores of carbon are blocked by the crystalline CaO.

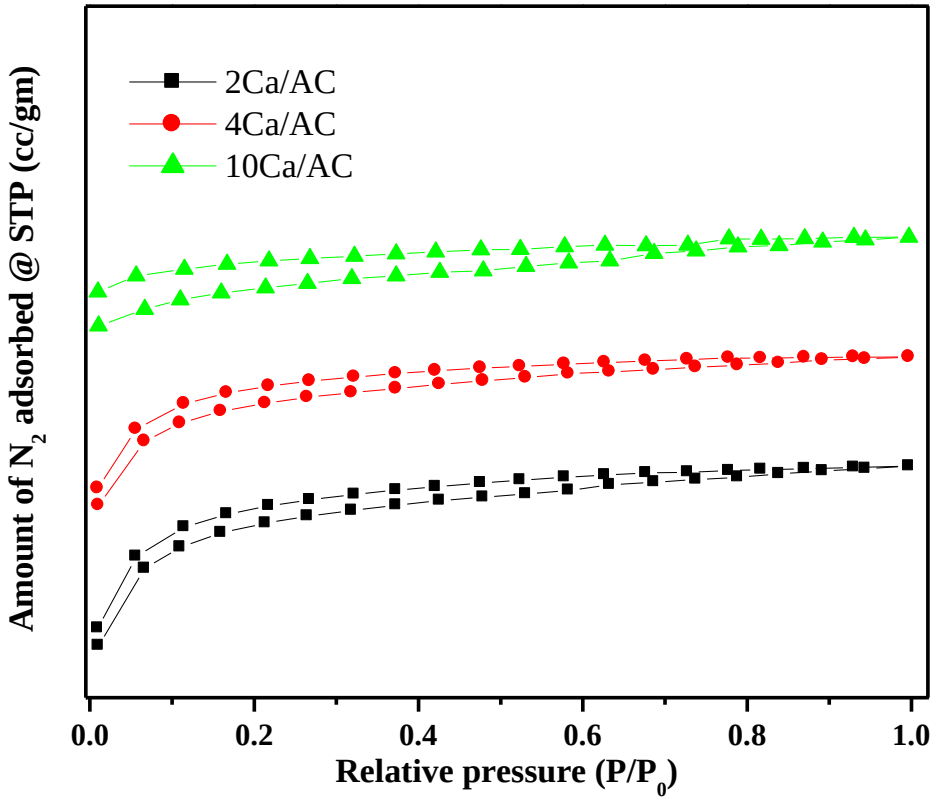

Fig 2: N_2 adsorption-desorption isotherm of calcium oxide supported on activated carbon catalysts

Table 1: Textural properties of Calcium oxide supported on activated carbon catalysts

Sample	S_{BET} [a] (m^2/gm)	S_{Ext} [b] (m^2/gm)	S_{micro} [c] (m^2/gm)	V_{total} [d] (cc/gm)	V_{micro} [e] (cc/gm)	Pore size [f] (n.m)
2CaO/AC	690	40	650	0.39	0.34	2.27
4CaO/AC	551	44	507	0.30	0.26	2.23
10CaO/AC	125	30	95	0.08	0.05	2.76

[a] BET surface area
[b] External surface area by t-plot method
[c] Micro pore area by t-plot method
[d] Total pore volume at relative pressure P/P_0 of 0.99
[e] Micro pore volume by t-plot method
[f] Average pore size

3.3 CO_2 adsorption studies on CaO/AC

The adsorption capacities of CaO supported on activated carbon with various loadings were shown in

figure 23 and corresponding adsorption capacities were 91.2µmol/gm for 2CaO/AC, 125µmol/gm for 4CaO/AC, 90µmol/gm for 6CaO/AC, 82µmol/gm for 8CaO/AC and 75µmol/gm for 10CaO/AC respectively. 4CaO/AC has shown high adsorption capacity is due to strong interaction between CO_2 and CaO.

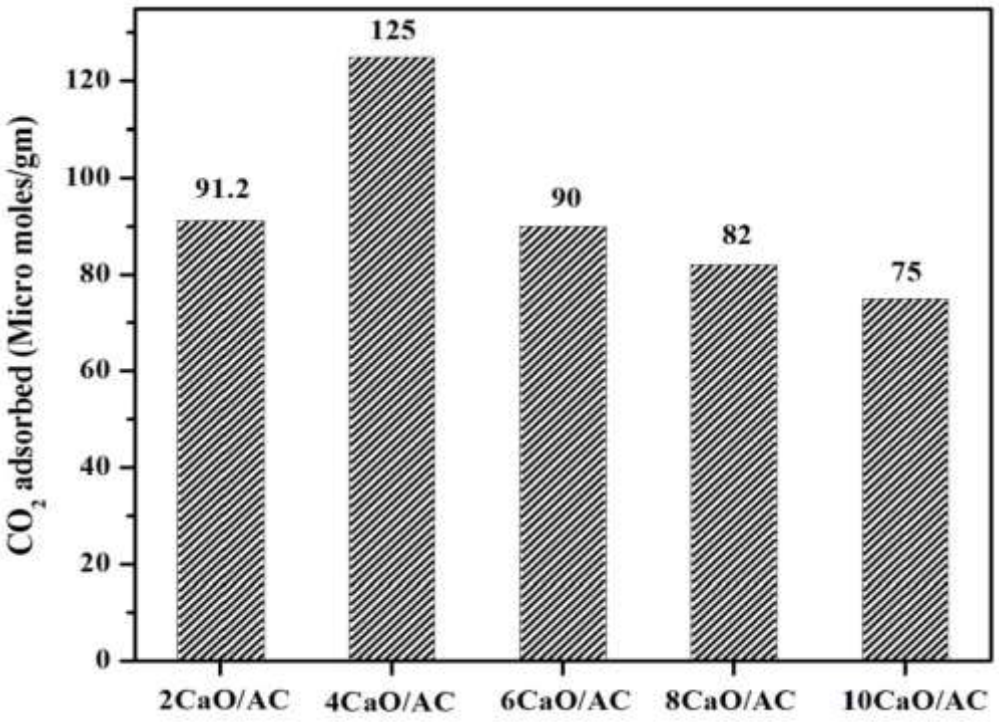

Fig 2: CO_2 adsorption studies over CaO supported activated carbon catalyst

Recyclability has been studied on 4wt% CaO/AC up to 10 cycles at room temperature and was shown in Fig 3. 4wt% CaO/AC has shown good stability without loss of adsorption capacity.

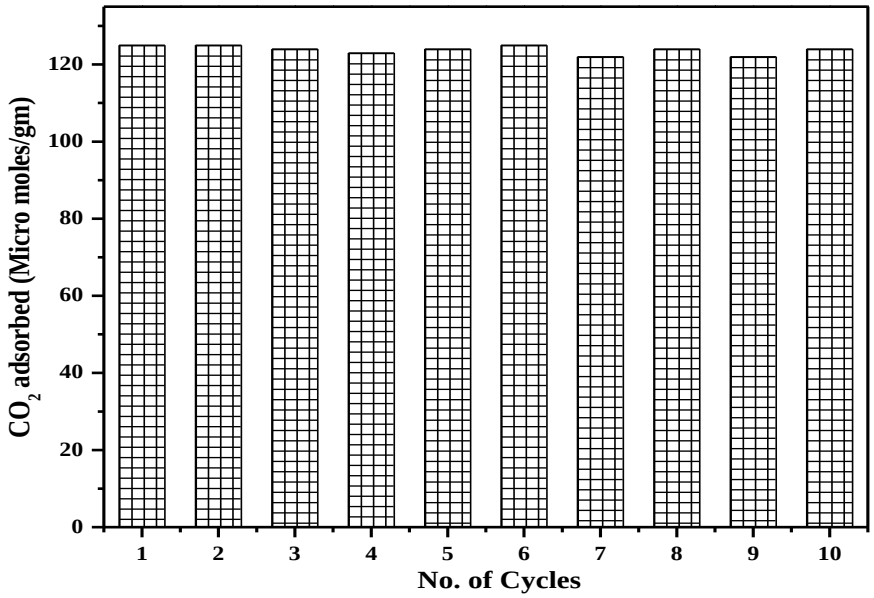

Fig. 3: Recyclability of 4wt% CaO/AC at 30 °C

CONCLUSIONS:

The CO_2 adsorption of CaO supported on activated carbon was studied, and the results revealed that 4wt% CaO/AC had a high adsorption capacity of 125 μmol/g at 30 °C compared to the remaining catalysts. High basic strength and a large number of micropores are responsible for the high adsorption. It exhibited good stability for up to 10 cycles without loss of adsorption capacity. Finally, it is a prominent CaO-supported activated carbon adsorbent for industrial CO_2 capture.

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