

NOVEL K<sub>2</sub>CO<sub>3</sub>-BASED COMPOSITE SORBENT FOR CO<sub>2</sub> CAPTURE FROM AMBIENT AIR

J.V. Veselovskaya

Boreskov Institute of Catalysis SB RAS, Russia, Novosibirsk, Akademika Lavrentieva avenue 5, 630090

E-mail: [jvv@catalysis.ru](mailto:jvv@catalysis.ru)НОВЫЙ КОМПОЗИТНЫЙ СОРБЕНТ НА ОСНОВЕ K<sub>2</sub>CO<sub>3</sub> ДЛЯ ПОГЛОЩЕНИЯ  
УГЛЕКИСЛОГО ГАЗА ИЗ ВОЗДУХА

Ж.В. Веселовская

Институт катализа им. Г.К. Борескова СО РАН,

Россия, г. Новосибирск, пр. Академика Лаврентьева, 5, 630090

E-mail: [jvv@catalysis.ru](mailto:jvv@catalysis.ru)

***Аннотация.** Сорбционные свойства композитного сорбента K<sub>2</sub>CO<sub>3</sub>/активированный уголь были изучены в циклическом процессе при чередовании стадий сорбции CO<sub>2</sub> из воздуха и термической регенерации сорбента. Установлено, что значения абсорбционной емкости по диоксиду углерода существенно зависят от относительной влажности воздуха. Показано, что композитный сорбент может быть эффективно регенирован при нагреве до 150 °С, а при повышении температуры регенерации до 200 °С начинается процесс окисления углеродного материала кислородом воздуха.*

**Introduction.** It is well known that CO<sub>2</sub> is the major anthropogenic greenhouse gas, which contributes to global climate change. Potassium carbonate is a solid inorganic chemisorbent, which reacts with atmospheric CO<sub>2</sub> in the presence of water vapor forming potassium bicarbonate:  $K_2CO_3 + H_2O + CO_2 \rightarrow 2KHCO_3$ . However, bulk potassium carbonate is not widely used as a material for CO<sub>2</sub> capture due to low reaction rate and insufficient mechanical strength. These problems can be solved by dispersing K<sub>2</sub>CO<sub>3</sub> in pores of a support material. Recently, it was shown that K<sub>2</sub>CO<sub>3</sub>/γ-Al<sub>2</sub>O<sub>3</sub> composite is a promising material for absorbing CO<sub>2</sub> directly from ambient air [1]. However, this material needs to be heated up to 300 °C in order to be fully regenerated, unlike bulk KHCO<sub>3</sub>, which decomposes around 130 °C releasing CO<sub>2</sub> and H<sub>2</sub>O. K<sub>2</sub>CO<sub>3</sub>/γ-Al<sub>2</sub>O<sub>3</sub> needs higher regeneration temperature due to interaction between the active component and the porous support, which results in formation of potassium dawsonite KAlCO<sub>3</sub>(OH)<sub>2</sub> [1, 2]. Increase in the regeneration temperature raises energy costs and narrows the range of heat sources that can be used. Therefore, there is a need for developing new sorbents for CO<sub>2</sub> absorption from ambient air, which can be effectively regenerated at T=150-200 °C. To solve this problem, it is necessary to select a porous support that does not interact with potassium carbonate. Other widely used porous oxides, such as SiO<sub>2</sub>, MgO, TiO<sub>2</sub>, do not fit, because they also react with K<sub>2</sub>CO<sub>3</sub>, forming either mixed oxides or mixed carbonates [2]. Activated carbons (AC), on the other hand, are considered to be perspective porous supports for K<sub>2</sub>CO<sub>3</sub>, but the major concern is a possibility of carbon material oxidation/destruction upon heating in air. Thus, this work is focused on performance of K<sub>2</sub>CO<sub>3</sub>/AC material in temperature-swing absorption cycles with regeneration temperatures of 150 and 200 °C. In order to separate KHCO<sub>3</sub> decomposition and carbon oxidation processes, both of which result in CO<sub>2</sub> release upon heating, the composite sorbent regeneration was carried out in both oxidative atmosphere (air) and inert atmosphere (argon).

**Experimental.** Composite sorbent  $K_2CO_3/AC$  was prepared by dry impregnation method, described in detail in [1]. Granules of a mesoporous active carbon AG-3 ( $S_{BET} = 860 \text{ m}^2/\text{g}$ ,  $V_{\text{pore}} = 0.5 \text{ cm}^3/\text{g}$ ) were filled with 40 wt. % aqueous solution of  $K_2CO_3$ , followed by drying at  $100^\circ\text{C}$  for 12 h and then at  $200^\circ\text{C}$  for 1 h. Estimated  $K_2CO_3$  content in the resulted composite material is 14 wt. %.

Processes of carbon dioxide absorption from ambient air and consecutive thermal desorption was studied in a temperature-swing adsorption cycles using an experimental set-up, schematically presented in Fig. 1. The composite sorbent was placed into a cylindrical fixed bed adsorber with the inner diameter of 19 mm, which was located inside an electrical heater. The mass of the composite sorbent inside the adsorber was 2 g. A single TSA cycle comprised 3 steps: 1)  $\text{CO}_2$  absorption from ambient air for 2 h; 2) thermal desorption of  $\text{CO}_2$  for 2 h; 3) the adsorber cooling for 2 h. The experimental conditions are summarized in Table 1. During the first step of each TSA cycle the composite sorbent was saturated with  $\text{CO}_2$  as indoor air with was pumped through the adsorber using a gas pump. Relative humidity of the inlet air was 7 - 25 %. During the regeneration step the adsorber was rapidly heated up to the preset temperature ( $150$  or  $200^\circ\text{C}$ ), while the inlet flow rate of air or argon was maintained at  $50 \text{ mL}/\text{min}$ . Outlet concentrations of  $\text{CO}_2$  were measured using a NDIR  $\text{CO}_2$  sensor.

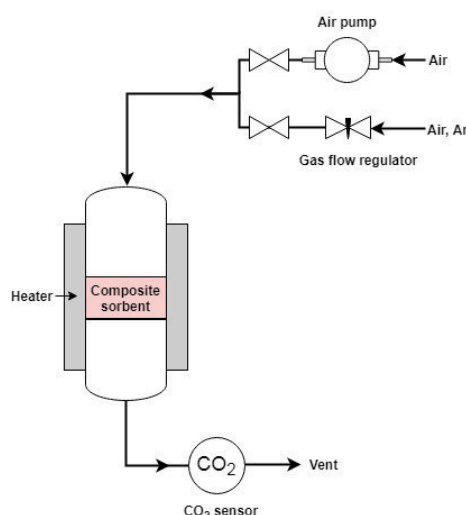


Fig. 1. The experimental set-up for performing TSA tests

Table 1

Parameters of TSA cycles

№	Description of a step	Parameter	Value
1	$\text{CO}_2$ absorption from air	Duration	2 h
		Gas flow	Air, $1300 \text{ mL}/\text{min}$
		Adsorber temperature	$30^\circ\text{C}$
2	$\text{CO}_2$ desorption	Duration	2 h
		Gas flow	Air or Ar, $50 \text{ mL}/\text{min}$
		Adsorber temperature	$30^\circ\text{C} \rightarrow 150; 200^\circ\text{C}$
3	Cooling	Duration	2 h
		Gas flow	No flow
		Adsorber temperature	$150; 200^\circ\text{C} \rightarrow 30^\circ\text{C}$

**Results and Discussion.** It was shown that amount of CO<sub>2</sub> desorbed at 150°C in either argon or air flow strongly depended on relative humidity (RH) of indoor air during the previous CO<sub>2</sub> absorption step (Fig. 2). The maximal CO<sub>2</sub> uptake was obtained when RH was 12-14 %. Increase of regeneration temperature up to 200°C in argon atmosphere does not lead to any additional desorption of CO<sub>2</sub>. However, when the material was heated up to 200°C in air flow, the amount of released CO<sub>2</sub> was significantly higher than the previous results, which is likely to be a result of carbon support oxidation by oxygen containing in air.

It should be noted that K<sub>2</sub>CO<sub>3</sub> utilization extent in the TSA cycles is < 30%. XRD analysis showed that the composite sorbent K<sub>2</sub>CO<sub>3</sub>/AC after 12 h of CO<sub>2</sub> absorption from ambient air contains crystalline phases of KHCO<sub>3</sub> and K<sub>2</sub>H<sub>4</sub>(CO<sub>3</sub>)<sub>3</sub>·1.5H<sub>2</sub>O, which means that even after much longer CO<sub>2</sub> absorption step this material absorbs less than 1 mol of CO<sub>2</sub> per 1 mol of K<sub>2</sub>CO<sub>3</sub>.

**Conclusions.** The obtained results show that the composite material can be effectively regenerated at 150°C in air flow, but the major drawback is that K<sub>2</sub>CO<sub>3</sub> does not fully convert to KHCO<sub>3</sub> during the CO<sub>2</sub> absorption step. Further research is needed to improve performance of K<sub>2</sub>CO<sub>3</sub>/AC materials in the process of CO<sub>2</sub> absorption from ambient air.

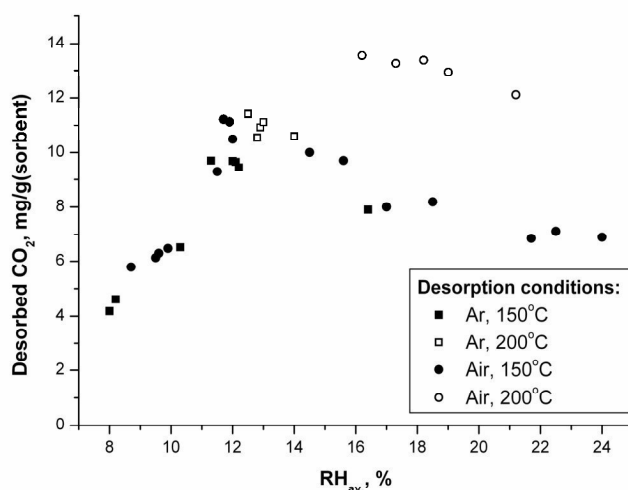


Fig. 2. Amount of desorbed CO<sub>2</sub> (in mg per 1 g of the composite sorbent) depending on average relative humidity throughout the CO<sub>2</sub> absorption step and conditions of the CO<sub>2</sub> desorption step (gas-carrier: argon or air; temperature: 150 °C or 200 °C)

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## REFERENCES

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