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Pal, Animesh
Kyushu University Program for Leading Graduate School, Green Asia Education Center, Interdisciplinary Graduate School of Engineering Sciences, Kyushu University | International Institute for Carbon-Neutral Energy Research (WPI-I2CNER), Kyushu University

Mitra, Sourav
International Institute for Carbon-Neutral Energy Research (WPI-I2CNER), Kyushu University

Thu, Kyaw
Kyushu University Program for Leading Graduate School, Green Asia Education Center, Interdisciplinary Graduate School of Engineering Sciences, Kyushu University | International Institute for Carbon-Neutral Energy Research (WPI-I2CNER), Kyushu University

Saha, Bidyut Baran
Kyushu University Program for Leading Graduate School, Green Asia Education Center, Interdisciplinary Graduate School of Engineering Sciences, Kyushu University | International Institute for Carbon-Neutral Energy Research (WPI-I2CNER), Kyushu University | Mechanical Engineering Department, Kyushu University

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Improved adsorption uptake of ethanol and CO_2 onto biomass based activated carbons

Animesh Pal[1,2], Sourav Mitra[2], Kyaw Thu[1,2], Bidyut Baran Saha[1,2,3,*]

[1]Kyushu University Program for Leading Graduate School, Green Asia Education Center, Interdisciplinary Graduate School of Engineering Sciences, Kyushu University, Fukuoka, Japan
[2]International Institute for Carbon-Neutral Energy Research (WPI-I2CNER), Kyushu University, Fukuoka, Japan
[3]Mechanical Engineering Department, Kyushu University, Fukuoka, Japan

* Corresponding Author, E-mail: saha.baran.bidyut.213@m.kyushu-u.ac.jp

Abstract: *Thermally driven adsorption cooling systems have attracted much attention recently as it can be driven by low temperature waste heat and simultaneously utilize environmentally friendly refrigerants such as ethanol and CO_2. Activated carbon, owing to its high porosity, is a promising adsorbent for these refrigerant vapors. This study experimentally investigates ethanol and CO_2 adsorption onto synthesized biomass based highly functional activated carbons (ACs). Functional ACs have been synthesized by chemical activation of biomasses. Adsorption experiment has been conducted thermogravimetrically at assorted adsorption temperatures and evaporating pressures. It has been found that synthesized biomass based functional ACs show remarkably high adsorption uptake of ethanol and CO_2 compared to commercially prevalent AC (Maxsorb III). Therefore, the synthesized ACs with high adsorption uptake could be promising for development of next generation adsorption cooling systems.*

Keywords: Activated carbon; Adsorption uptake; Biomass; CO_2; Ethanol

1. INTRODUCTION

Adsorption cooling systems have been gaining much attention as next generation cooling systems owing to it can be driven by waste heat of temperature below 100°C and simultaneously utilize environmentally benign working fluids such as ethanol and CO_2 [1–4]. For these working fluid (refrigerants), activated carbons (ACs) are promising adsorbents due to its high porosity and hence high adsorption uptake. ACs can be synthesized different source of precursor materials such coke-petroleum residues [5] and biomasses [6,7]. Among those ACs, Maxsorb III is widely studied commercially available activated carbon made by Kansai Coke and Chemical Co. Ltd (Japan) [5]. Although it possesses high surface area about 3000 m^2 g^{-1}, uptake of ethanol and CO_2 are not so high because of low pore volume. Therefore, to improved adsorption uptake of those refrigerants, this study has been focused new source of biomasses (waste palm trunk and mangrove) based ACs with high surface area and pore volume. Adsorption experiment has been conducted thermogravimetrically at assorted adsorption temperatures and evaporating pressures. Experimental data have been compared with literature data of commercially prevalent Maxsorb III-ethanol/CO_2 pairs.

2. MATERIALS

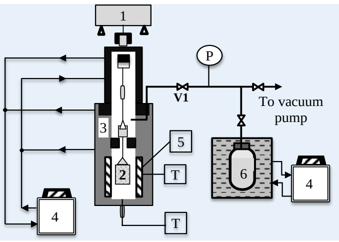
In this study, studied adsorbents were Waste Palm Trunk (WPT) and Mangrove (M) based ACs. Present authors synthesized these novel ACs using potassium hydroxide (KOH) as an activating agent. Detailed of the synthesized procedure of ACs can be found elsewhere [8,9]. N_2 adsorption experiment at 77K were conducted to obtain the surface porosity, which is the well-developed method. Porous properties of WPT-AC, M-AC and Maxsorb III have been furnished in Table 1.

Table 1. Porous properties of WPT-AC, M-AC and Maxsorb III.

Sample	Total Surface area [m^2 g^{-1}]	Total pore volume [cm^3 g^{-1}]	Average pore width [nm]
WPT-AC	2927	2.51	1.68
M-AC	2924	2.18	1.47
Maxsorb III	3045	1.7	1.12

3. EXPERIMENTAL

Equilibrium ethanol and CO_2 adsorption uptake on WPT-AC and M-AC has been measured gravimetrically using low and high pressure magnetic suspension adsorption measurement unit, which is supplied by MicrotracBEL, Japan. A simplified schematic diagram of the magnetic suspension adsorption measurement unit is shown in Fig. 1 and detailed can be found in reference [8]. Experiment has been conducted at temperatures ranging from 30°C to 70°C with various evaporator pressures.



1. Magnetic suspension balance; 2. Sample cell; 3. Circulation oil jacket; 4. Oil bath and circulator; 5. Sheathed heater; 6. Refrigerant cell; P: Pressure gauge; V1: Valve.

Fig. 1. Simplified schematic diagram of the magnetic suspension adsorption measurement unit.

4. RESULTS AND DISCUSSION

Porous properties of novel synthesized biomass based ACs shows promising for adsorption applications from the view point of high surface area and pore volume. For further feasibility study to adsorption cooling system, adsorption of ethanol and CO_2 as a refrigerant has been conducted. Ethanol adsorption has been performed various evaporator pressure and temperature ranging from 30-70°C. Fig. 2 illustrates the comparison of adsorption uptake of ethanol onto WPT-AC, M-AC and Maxsorb III at adsorption temperature 30°C. It can be highlighted that synthesized biomass based ACs (WPT-AC and M-AC) show 1.6 and 1.4 times higher equilibrium adsorption uptake of ethanol, respectively, compared to commercially available activated carbon Maxsorb III. Although BET surface area nearly the same for three samples, it is expected that pore volume makes significant difference of equilibrium adsorption amount.

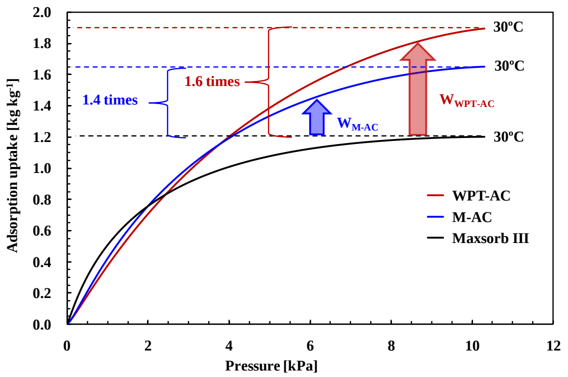


Fig. 2. Comparison of adsorption uptake of ethanol onto WPT-AC, M-AC, and Maxsorb III at 30°C.

Adsorption of CO_2 onto WPT-AC and M-AC has been conducted at temperature ranging from 25-70°C up to 7MPa. The data obtained from experiment is excess adsorption and mass adsorbed decreases due to the increase of CO_2 density at pressure higher than 5 MPa. Absolute adsorption has been estimated using an equation which can be found in reference [10]. Fig. 3 shows the comparison of absolute adsorption uptake of CO_2 onto WPT-AC, M-AC and Maxsorb III at adsorption temperature 30°C. It is found that WPT-AC and M-AC show 1.5 and 1.4 times higher adsorption uptake of CO_2 at about pressure 7MPa compared to Maxsorb III.

The reason of high adsorption uptake of both refrigerants onto biomass based ACs might be the higher pore volume and the affinity to surface functional groups of ACs which is beyond of this study.

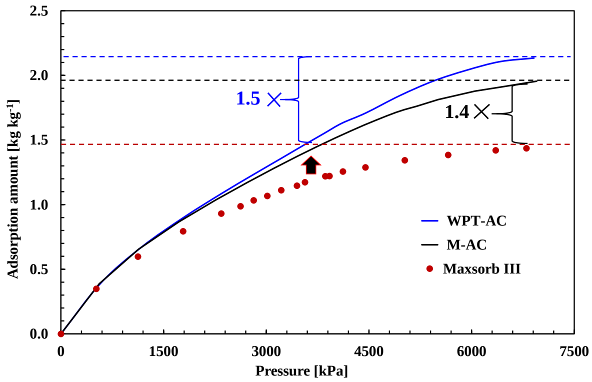


Fig. 3. Comparison of absolute adsorption uptake of CO_2 onto WPT-AC, M-AC, and Maxsorb III at 30°C.

5. CONCLUSIONS

High porous properties makes novel synthesized biomass based ACs for next generation adsorbent for adsorption cooling applications. Adsorption of ethanol and CO_2 onto WPT-AC and M-AC has been conducted at temperatures ranging from 30°C to 70°C with various evaporator pressures. Experimental data have been compared with the literature data of Maxsorb III. It can be mentioned that WPT-AC/ethanol and M-AC/ethanol show 1.6 and 1.4 times higher equilibrium adsorption uptake, respectively, whereas WPT-AC/CO_2 and M-AC/CO_2 shows 1.5 and 1.4 times higher, respectively, compared to commercially available activated carbon Maxsorb III.

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