Study on Direct CO_2 Capture from Motorcycle Exhaust Gases (Part III) -Effect of Adsorbent Hydrophobicity on CO_2 Adsorption Performance-

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This study investigates a direct carbon dioxide (CO_2) capture technology from motorcycle exhaust gases, focusing on the effect of adsorbent hydrophobicity on CO_2 adsorption performance. Reducing CO_2 emissions from the transportation sector is a critical global challenge, and conventional approaches such as improving engine efficiency or adopting alternative fuels face significant limitations in terms of feasibility and implementation speed. Therefore, on-board CO_2 capture technologies have gained increasing attention as a promising solution.Previous studies by the authors demonstrated that amine-impregnated silica exhibits improved CO_2 adsorption performance under humid conditions, unlike zeolites, which suffer from performance degradation in the presence of water vapor. However, coexisting gases such as NO and SO_2 negatively affect adsorption by degrading the amine structure. Additionally, pore structure plays a crucial role in determining adsorption behavior. While these findings are important, long-term durability and degradation under practical conditions remain insufficiently understood.To address this issue, the present study focuses on hydrophobic amine-impregnated silica prepared by adding a hydrophobic polymer binder, styrene-butadiene-styrene (SBS). Although SBS has been reported to suppress thermal degradation caused by water vapor, it also significantly reduces initial CO_2 adsorption capacity. This study aims to clarify the mechanism behind this performance trade-off and propose strategies to improve both durability and adsorption performance.The adsorbent was synthesized by dissolving polyethyleneimine (PEI) and SBS in appropriate solvents, mixing them with silica gel, and subsequently removing the solvents using a custom-built vacuum heating drying system. Adsorption experiments were conducted using a fixed-bed reactor under conditions simulating motorcycle exhaust gas (approximately 10 vol.% CO_2 and 10 vol.% H_2O). CO_2 concentration was measured using an NDIR sensor.Experimental results showed that increasing SBS content initially enhances CO_2 adsorption and desorption capacity, followed by a decrease, and in some cases, a secondary increase before further decline(Fig.1). Structural analysis using SEM and nitrogen adsorption measurements revealed that small amounts of SBS increase pore volume and surface area, likely due to pore formation and improved amine dispersion(Fig.2). However, excessive SBS addition blocks pores, reducing surface area and adsorption performance. Notably, average pore diameter remained largely unchanged, while mesopores increased at low SBS content and decreased at higher content, with macropores increasing instead.These findings indicate that SBS plays a complex role in modifying pore structure and adsorption behavior. By optimizing SBS content and controlling pore structure, it is possible to achieve both high CO_2 adsorption performance and improved resistance to water-induced degradation.

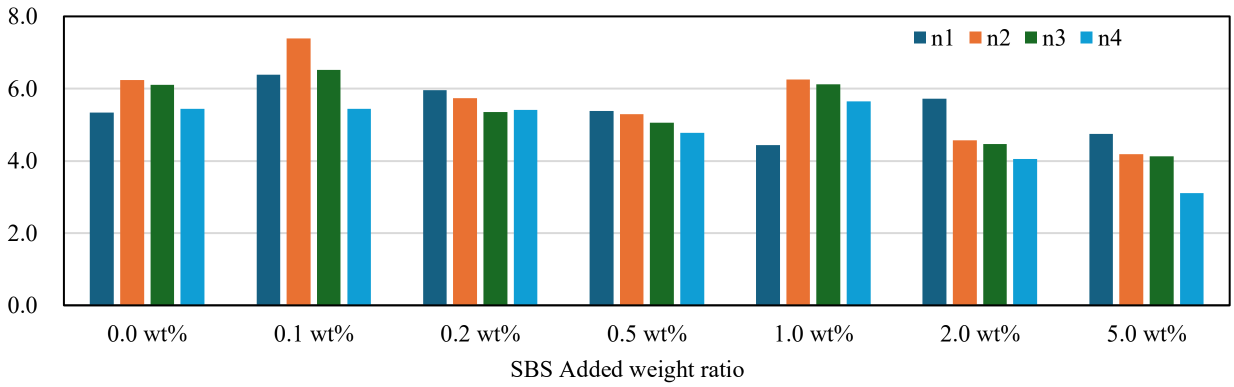
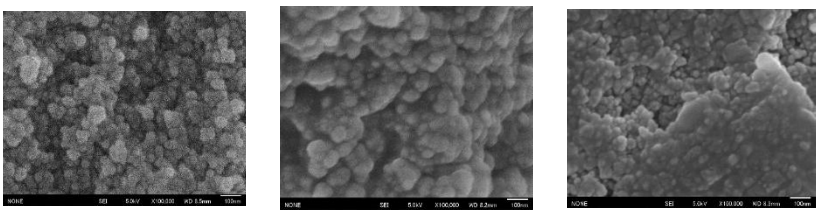


Fig.1 Effect of absorber pore diameter on the amount of carbon dioxide adsorption



(a) SBS content: 0.0 wt% (b) SBS content: 0.5 wt% (c) SBS content: 5.0 wt%

Fig.2 Surface morphology of hydrophobic amine-functionalized silica