

Study on Direct CO₂ Capture from Motorcycle Exhaust Gases (Part IV) -Effect of Adsorbent Impregnation Methods on CO₂ Adsorption Performance-

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This study investigates a direct carbon dioxide (CO₂) capture technology for motorcycle exhaust gases, focusing on the influence of adsorbent impregnation methods on CO₂ adsorption performance. Given the increasing need to reduce CO₂ emissions highlighted by global climate reports, the transportation sector—accounting for approximately 20% of emissions—requires innovative solutions beyond conventional efficiency improvements. Direct onboard CO₂ capture has emerged as a promising approach. Previous studies by the authors demonstrated that amine-impregnated silica, particularly using branched polyethyleneimine (PEI), shows improved CO₂ adsorption performance under humid conditions compared to zeolites, which suffer from competitive adsorption with water vapor. However, adsorption performance can deteriorate in the presence of gases such as NO and SO₂, and the pore structure of the adsorbent significantly influences both adsorption and degradation behavior. Additionally, hydrophobic modification using polymers such as SBS has been shown to improve durability. In prior work, complex impregnation methods such as vacuum-assisted rotary evaporation were employed, which present challenges in cost and manufacturability for practical applications. Therefore, this study aims to develop a simpler and more scalable synthesis method using a beaker and hot plate stirrer, and to compare its performance with conventional methods, including rotary evaporation and a custom vacuum drying system. Amine-impregnated silica samples were prepared using the three different methods while maintaining identical material properties and amine loading. CO₂ adsorption-desorption experiments were conducted using a model gas simulating motorcycle exhaust conditions (approximately 10 vol.% CO₂ and 10 vol.% H₂O). The experimental setup included controlled gas flow, temperature regulation, and CO₂ concentration measurement via NDIR sensors. Results show that the beaker-based method achieves stable CO₂ adsorption capacity over repeated cycles, whereas samples prepared by vacuum drying and rotary evaporation exhibit gradual performance degradation (Fig.1). Desorption performance remains relatively consistent across all methods. Structural analysis using SEM and nitrogen adsorption revealed differences in surface morphology, specific surface area, and pore volume among the samples; however, these variations did not show a clear correlation with adsorption performance (Fig.2). Overall, the simpler beaker and hot stirrer method provides comparable CO₂ adsorption performance to conventional methods, with advantages in simplicity and potential scalability. Future work will focus on optimizing pore structure and additive selection to enhance both adsorption capacity and resistance to degradation under realistic exhaust conditions.

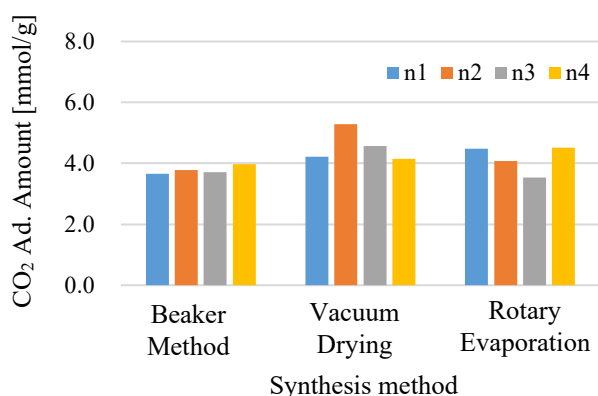


Fig.1 Effect of synthesis methodology on the amount of carbon dioxide desorption

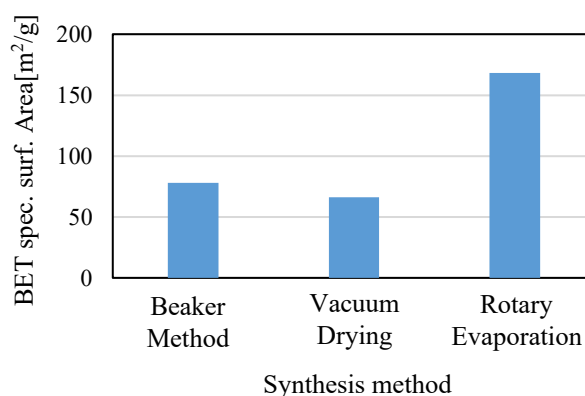


Fig.2 Effect of synthesis methodology on the BET specific surface area