Incorporation of Ionic Liquids on Mesoporous Silica SBA-15 as Efficient Sorbents for CO₂ Capture Applications

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Abstract

The utilization of ionic liquids (ILs) for CO₂ capture applications has recently gained considerable attention due to the several remarkable properties comprising high CO₂ solubility, low volatility, thermal stability, and the availability of thousands of cation/anion combinations that can be prepared with readily tunable structures. However, the cost and high viscosity of ILs are considered the major challenges for their applications in CO₂ capture. One of the promising approaches to overcome these limitations is to incorporate ILs into solid porous materials that shown to enhance performance in various applications such as catalytic esterification reaction, ionic conductivity, and gas separation applications. The emerging class of materials called metal organic frameworks (MOFs) composed of metal ions bridged by organic ligands are well recognized for their extraordinary surface areas, ultrahigh porosity, and most importantly the flexibility to tune the porous structure as well as the surface functionality. These excellent features qualify MOFs to become an ideal host for the incorporation of ILs into their porous structure to improve their CO₂ capture efficiency while preserving their unique properties. Previous computational investigation has ascertained the positive impact of impregnating ILs into MOFs and was attributed to the confinement effects of the porous MOF structure on the ILs. Similarly, the incorporation of amines and ILs on mesoporous silica has been studied for various applications and is considered promising composite materials for CO₂ capture applications.

In this work, we report for the first time the preparation of ILs/SBA-15 as novel composite materials and their performance as solid sorbents for the adsorption-based CO₂ capture. The as-synthesized samples were activated at elevated temperature to evaporate the solvent and were subjected to various characterizations techniques (TGA, FTIR, BET, XRD, and SEM) to study the physio-chemical properties of the impregnated samples. Thermogravimetric analysis (TGA) were carried out under nitrogen environment to study the thermal stability of the composite materials and to quantify the composition of the ILs/SBA-15 composites using their decomposition profiles to confirm the nominal starting weight ratios. Fourier transform infrared spectroscopy (FTIR) was also used to confirm the impregnation of the ILs into the pores of the SBA-15 supports. The porosity and surface area of the composite materials were studied using N₂ adsorption isotherms to determine the BET surface area and the pore volume distribution. The crystal structure of the SBA-15 was observed after the impregnation of the ILs using x-ray diffraction analysis (XRD) and the morphological structure of the impregnated samples were monitored using scanning electron
microscopy (SEM) to study the influence of ILs on the crystallinity and phase stability of SBA-15. The CO₂ adsorption kinetic was performed using the TGA microbalance, at three different temperatures (303, 313, and 323 K). The solubility of CO₂ at different pressures was evaluated using intelligent gravimetric analyzer (IGA) to measure the CO₂ uptake up to 10 bar. The prepared composites exhibited substantially high CO₂/N₂ selectivity due to the presence of high-density ions inside the solid porous structure acting as bonding sites for CO₂ adsorption. Moreover, the impregnation of bmim-Ac increased the enthalpy of adsorption as well as increasing the low-pressure uptake of the composite materials.