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Ascorbic Acid Coated Magnetite as Nanoabsorbent for CO_2 Capture

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Extended Abstract

As the increase of CO_2 level in the atmosphere is becoming a major threat to human beings, various research on carbon capture utilization and storage (CCUS) technologies have been conducted. Among the various CO_2 capture technologies, physical absorption is widely used due to their economic feasibility, commercialization, and continuous development [1]. Methanol is conventionally used as physical absorbent for acid gas removal; however, the absorption process must be maintained at -40 ^oC for the process to be efficient [2]. This low temperature condition makes the process energy inefficient due to immense refrigeration and heating energy required for absorption and regeneration, respectively. To reduce the energy expenses, studies on liquid nanoabsorbents have been conducted so that the absorption process can be energy-efficient by operating at ambient temperature [3, 4].

Liquid nanoabsorbents are manufactured by dispersing nanoparticles, such as Al_2O_3, SiO_2, TiO_2, MgO, and ZnO, to base fluid. When compared to base fluid, the nanoabsorbents showed higher absorption performance by mass transfer enhancement. Pineda et al. [5] reported the absorption enhancement of Al_2O_3/methanol and SiO_2/methanol by 9.4% and 9.7%, respectively. Also, Lee et al. [6] conducted a combined CO_2 absorption/regeneration cycle performance evaluation, using Al_2O_3/methanol and SiO_2/methanol, and verified the enhancement in both absorption and regeneration. Investigation on magnetic nanoparticles, such as Fe_3O_4 and NiO, have discovered that with the assistance of external magnetic fields, higher absorption enhancement can be obtained. Wu et al. [7] reported that increase in magnetic field intensity leads to decrease in viscosity and surface tension of nanoabsorbent, which contributes to higher absorption capacity. Sophisticated analysis by Salimi et al. [8] showed that by using an external magnetic field, mass transfer rates of Fe_3O_4/water and NiO/water were enhanced by 14% and 10.5%, respectively.

In this study, the surface of Fe_3O_4 nanoparticles is fabricated by coating with L(+)-ascorbic acid (AA) to obtain high surface area and dispersibility, which are advantageous characteristics for CO_2 absorption enhancement. The X-ray diffraction (XRD) analysis of fabricated AA-Fe_3O_4 showed diffraction peaks at $2\theta = 30.2^o$, 35.22^o, 42.88^o, 56.82^o, and 62.55^o, which matches well with the diffraction peaks of Fe_3O_4. The surface area of AA-Fe_3O_4, measured by Brunauer-Emmett-Teller (BET) method, was increased by approximately 28 times compared than Fe_3O_4 particles. It is visible from the FE-SEM results that the surface roughness of the particles is increased by the coating, and surface roughness values increased from 139.34 nm to 205.34 nm. The dispersion stability of the nanoabsorbents was assessed by measuring cluster size diameter, polydispersity index, and zeta potential. The cluster size diameter of AA-Fe_3O_4 was reduced, compared to Fe_3O_4, from 16,793 nm to 397 nm. Also, the polydispersity index and zeta potential values were 0.335 and 45.6 mV, respectively, which indicates that AA-Fe_3O_4/methanol is monodispersed. The absorption experiment with the assistance of external magnetic fields, showed the enhancements of 23.3%, compared to neat base fluid. Also, regeneration experiments with external magnetic fields showed an increase in the regeneration absorption ratio. This indicates that there is a significant difference in regeneration results by using magnetic fields and magnetic nanoparticles. It is expected that actual cyclic industrial application be feasible by designing a suitable magnetic-field-generating device to be installed in the absorber/regenerator.

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