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Enhancing Fe and Mn leaching efficiency from basic oxygen furnace slag: Investigation reductant effects for carbon mineralization

Soyoung Noh, purnaning triwigati, Ji-Woo Lee, seokyoon moon, youngjune park

Abstract

Carbon mineralization has garnered significant attention among Carbon Capture, Utilization, and Storage (CCUS) technologies. It involves the permanently sequestration of carbon dioxide (CO_2) through spontaneous reactions between CO_2 and alkaline sources such as calcium (Ca) and magnesium (Mg), resulting in the conversion of CO_2 into thermodynamically stable solid carbonates, such as $CaCO_3$ or $MgCO_3$. Carbon mineralization presents a promising avenue for CCUS because it can replace carbon-intensive products and produce value-added carbonates, such as those used in cement, medicine, and the paper industry. Ex-situ carbonation using steel slag is particularly notable among CO_2 fixation methods. Steel slag, which contains a substantial 30 ~ 60 wt% of Ca, is produced in significant quantities, making it a potential candidate for effective CO_2 sequestration. The most common type of steel slag, basic oxygen furnace (BOF) slag, has been extensively researched for carbon mineralization due to its high reactivity and free-CaO content. Additionally, BOF slag is a valuable resource as it contains not only Ca for carbon mineralization but also Fe and Mn for metal recovery. This study aims to recover Fe and Mn while simultaneously achieving carbon mineralization through indirect carbonation of BOF slag. However, the presence of a significant amount of insoluble Fe^{3+} and Mn^{3+} presents a challenge, resulting in low leaching efficiency of Fe and Mn. To address this issue, we investigated the effect of reductants on enhancing the leaching efficiency of Fe and Mn, transitioning them to leachable forms (Fe^{2+}, Mn^{2+}). In the leaching experiment, we employed reducing agents such as H_2O_2, $C_6H_8O_6$, Na_2SO_3, and $NaBH_4$. The use of reducing agents significantly improved the leaching efficiency of Fe and Mn, confirming a correlation with the oxidation state of Fe and Mn. Furthermore, we examined the influence of reductants on carbon mineralization to assess the viability of the entire process. We utilized various analytical techniques, including ICP-OES to investigate leaching efficiency and the slag composition, XPS to study oxidation states and changes in binding energies of major elements (Ca, Mg, Al, Si, Mn, Fe), XRD and SEM-EDS for crystal structure and elemental mapping, and XRF and ATR-FTIR to investigate the purity and polymorph of formed $CaCO_3$. Through these findings, we propose novel possibilities for resource recovery and carbon mineralization from BOF.