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Enhancing Siderite Stability through Magnesium Doping for CO_2 Sequestration in Mine Tailings

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ABSTRACT

Mineral carbonation of iron-rich industrial wastes and mine tailings offers a promising pathway for permanent CO_2 sequestration. However, the long-term viability of this process relies heavily on the environmental stability of the resulting carbonate minerals. Siderite ($FeCO_3$), a primary carbonation product of iron-bearing silicates, is highly susceptible to rapid oxidative dissolution when exposed to atmospheric conditions. This rapid degradation severely compromises the integrity of the carbon sink, releasing captured CO_2 back into the environment. This study investigates the role of magnesium (Mg) doping in fundamentally enhancing the thermodynamic and environmental stability of siderite. By substituting Fe^{2+} with Mg^{2+} within the siderite lattice to form a solid solution, the crystal structure is strategically altered to resist degradation. To evaluate the efficacy of this structural modification, synthesized samples of both pure and Mg-doped siderite were subjected to atmospheric exposure. The morphological, structural, and thermal evolution of the carbonates were comprehensively analyzed using Scanning Electron Microscopy (SEM), X-ray Diffraction (XRD), and Thermogravimetric Analysis (TGA). The experimental results demonstrate a profound improvement in oxidation resistance. While pure siderite exhibited rapid degradation and breakdown within approximately 6 hours of exposure, the Mg-doped siderite maintained its structural integrity and chemical stability for over 30 days. Evaluating and ensuring the stability of these modified carbonates is a crucial step in process optimization. These findings definitively show that deliberately controlling process conditions to favour Mg-doped siderite formation yields a far more robust and reliable carbon sink. This optimization is critical for the practical, large-scale deployment of mineral carbonation technologies in the management of industrial waste, directly contributing to circular economy and sustainability targets within the resources sector.

KEY WORDS

Mineral Carbonation, Siderite Stability, Magnesium Doping, CO_2 Sequestration, Mine Tailings

BIOGRAPHY

Mohammad is a PhD candidate at Adelaide University, specializing in the development of sustainable chemical engineering processes. His current research project, "Development and Optimization of Mineral Carbonation Technology for Industrial Waste and Mine Tailings," focuses on transforming mining byproducts into stable carbon sinks. Mohammad's work evaluates the thermodynamic stability of carbonated minerals, such as siderite, to improve process yields and ensure the long-term viability of large-scale, industrial CO_2 sequestration technologies.

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