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Carbonation of Industrial $CaSO_4$ Waste: Reaction Pathways and Downstream Utility

CARLOS PIMENTEL[1], GERMAN MONTES-HERNANDEZ[2], PABLO ALMARZA-CIFUENTES[3], NATASHA ACOSTA PEREZ[3], MATTHIAS KELLERMEIER[4] AND **DR. ALEXANDER E.S. VAN DRIESSCHE**[3]

[1]UCM
[2]ISTerre
[3]IACT-CSIC
[4]BASF SE

To actively remove CO_2 from the atmosphere and meet global climate targets, mineral carbonation utilizing industrial waste by-products is a useful complement to other methods and has the added advantage of being a long-term sequestration pathway. However, advancing these technologies requires overcoming economic barriers and refining our fundamental understanding of reaction pathways and kinetics. In this laboratory study, we present an sustainable carbon mineralization strategy that leverages the carbonation of calcium sulfate, an abundant industrial waste by-product, to sequester CO_2 while yielding a value-added product, applicable as, for example, alternative construction material [1].

Using in-situ observation tools to elucidate the fundamental reaction mechanisms, we demonstrate that phase-pure vaterite (a metastable calcium carbonate) can be synthesized without additives via the direct conversion of $CaSO_4$ powder in aqueous solution under ambient temperature and pressure conditions. By circumventing the slow kinetics often associated with mineral carbonation, this method yields particles exhibit high specific surface area and reactivity. To demonstrate the integration of CO_2 sequestration with sustainable industrial practices, this captured-carbon product was tested as a raw construction material. Upon hydration, the vaterite transforms into aragonite crystals via a dissolution-reprecipitation pathway, rapidly developing a compressive strength comparable to that of conventional cements. These fundamental insights into the carbonation pathways of industrial residues highlight a viable, dual-benefit approach: safely sequestering CO_2 while repurposing industrial waste into valuable materials with a significantly reduced environmental footprint.