Acid Washing of Fe Catalyst with HCl and Recycling Strategy in Catalytic Graphitization

Jose Gonzalez-Aguirre (research assistant), Sunkyu Park (Faculty)
North Carolina State University, Department of Forest Biomaterials
Biltmore Hall, 2820 Faucette Dr, 27607
Raleigh, NC, US
sunkyu.park@ncsu.edu

The U.S. Department of Energy recently announced measures to secure the critical minerals supply chain, identifying graphite as essential for energy storage technologies. Biobased graphite (biographite) uses catalytic graphitization as a promising production route. However, current methods using iron-based catalysts and strong acids for purification undermine economic and environmental benefits. In this sense, catalyst recycling and energy integration becomes imperative to increase economic profitability. This study applies process design and technoeconomic analysis to evaluate a closed-loop catalyst and solvent recovery system for biographite production. Results indicate that three reactors optimally complete the washing process with an HCl-to-solid mass ratio of 2.9. The iron oxide reduction reactor was identified as the costliest operation, contributing 22% of total equipment costs and 35% of natural gas demand. Economic analysis shows that recovering Fe and HCl can reduce material consumption and waste generation by ~95%, albeit at the expense of an ~80% increase in capital costs. These savings define the minimum selling price (MSP) of anode-grade biographite at $5.8/kg for direct reduction and $6.2/kg for oxidation–reduction scenarios, with a 46% probability of achieving an MSP below $6/kg. Univariate Monte Carlo sensitivity analysis revealed that feedstock bio-carbon price accounts for ~60% of the MSP variance. Finally, a comparative technoeconomic summary of graphite and biographite technologies highlights the strong potential of catalytic graphitization within the graphite supply chain. Overall, these findings underscore the prospective economic viability of biographite production and emphasize the importance of catalyst/solvent recycling and energy integration in advancing sustainable carbon materials.