Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.38253

Mechanistic Insights into Resource Recovery and Contaminant Immobilization using Sustainable Carbon Composites

BHOOPESH MISHRA

Illinois Institute of Technology

Lignocellulosic biomass waste (e.g., spent coffee and rice husk) can be used to synthesize scalable and sustainable porous carbon-negative materials via hydrothermal and thermochemical processes, promising a green alternative for resource recovery and contaminant immobilization across a wide range of environmental settings. Our work has resulted in high-efficiency biopolymer crosslinked hydrogels and transition-metal-oxide-functionalized carbon composites for such applications. Specifically, we have tailored carbon composites of mixed Fe(II/III)-oxide and Mn(IV)-oxides. A combination of electron microscopy (TEM and EELS) and synchrotron-based X-ray absorption spectroscopy (XAS) was used to determine the speciation of these resources and contaminants.

Batch uptake of MnOx-activated hydrogel biopolymer composites demonstrated a Strontium (II) uptake capacity of 109 mg/g, which was much higher than that of unactivated hydrogel controls or activated pyrolytic carbon. Activation more than doubled the decontamination factor at environmentally relevant concentrations. XAS analyses revealed an inner sphere binding of strontium to all three adsorbents – activated pyrolytic carbon, unactivated hydrogel, and activated hydrogel composites, indicating strong and irreversible binding of strontium to all three of these materials. Hydrogel encapsulation of activated carbon enhances its uptake capacity within a monolithic composite material.

Similarly, pyrolytic carbon showed remarkable capacity for the recovery of gold (Au), forming nano-particulate Au(0) to micron-sized clusters, primarily at the carbon surface. The average Au(0) particle size was inversely proportional to the initial Au(III) concentration. The largest average Au(0) particle size was observed between 13 - 26 mg/g gold:char ratio. Above this threshold ratio, ultrafine (< 5 nm) Au nanoparticles were formed. A combination of TEM and EELS illustrated that the reduction of Au(III) to nano-particulate Au(0) is driven by mixed Fe(II/III) oxides within the pyrolytic carbon. Electron shuttles, such as the condensed aromatic and sulfhydryl groups, served as secondary reduction sites. These findings provide mechanistic insight into the recovery of gold using pyrolytic carbon and form the basis for a rational design of sustainable approaches to the economic recovery of Au.