OVERVIEW

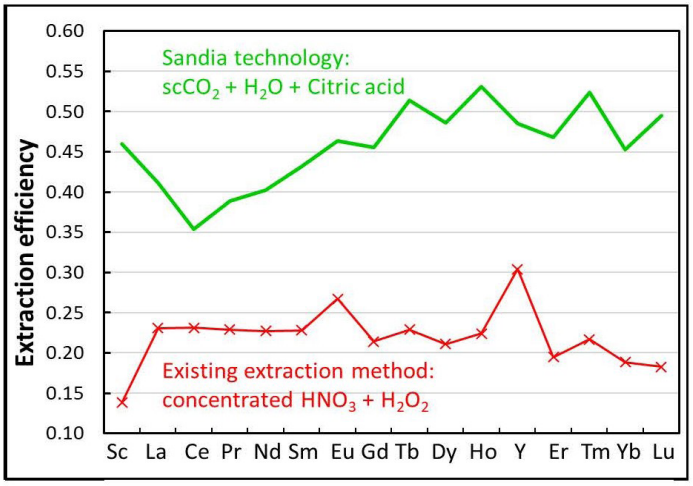
Green Extraction of Rare Earth Elements from Coal Waste

Sandia National Laboratories

Patent Pending
SD 15352
Technology Readiness Level: 3
The concept has been tested and validated in lab environment

This new approach converts coal waste into a domestic source of rare earth elements with significantly improved environment, health, and safety outcomes over existing methods

Sandia researchers have developed a new approach for converting coal ash, a by-product of coal combustion, into a viable domestic source of rare earth elements using just three readily available ingredients: water, supercritical carbon dioxide (SCO2), and food grade citric acid. By combining thermodynamic and DFT modeling and experimental tests, researchers were able to successfully remove target metals from coal and coal ash using these environmentally benign ingredients. The method has been shown to achieve a 42% extraction efficiency and can preferentially extract some of the most critical REEs.



Comparison of extraction efficiency between Sandia's environmentally benign technology and existing methods using strong acids– concentrated nitric acid and hydrogen peroxide.

Technical Benefits

- Converts coal industry waste into a reliable domestic source of REEs
- Provides 2x the value of conventional sources and approaches ($ value / mass)
- Environmentally benign
- Provides a greener, lower cost, and domestic REE source

Industries & Applications

- Recycling and cleaning of coal ash and/or coal combustion residuals
- Mining and extraction of rare earth elements (REEs)
- Recycling of other waste sources for extraction of REE

ip@sandia.gov
ip.sandia.gov

U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA-0003525. SAND2021-13177 M

MARKET SHEET

Green Extraction of Rare Earth Elements from Coal Waste

Sandia National Laboratories

This new approach converts coal waste into a domestic source of rare earth elements with significantly improved environment, health, and safety outcomes over existing methods

Business Problem

Current methods of mining and separating rare earth elements are not only expensive and labor intensive, they also take a devastating toll on the environment. As demand continues to increase, a secure, reliable, and sustainable domestic supply of rare earth elements from alternate sources is essential for the energy and electronics industries.

Customer Need

Sometimes referred to as lanthanides, REEs are a subset of 17 elements with unique properties needed to produce materials such as metals, glass, magnets, catalysts, high-performance alloys, and electronic displays for high-tech components and devices. In 2019, the U.S. imported nearly its entire supply of REEs for a total estimated value of $160 million. Import reliance creates dependencies on foreign sources, poses supply chain risks, and may constrain potential high-growth sectors. More efficient REE extraction methods with low or no environmental footprint are needed to relieve import reliance and secure a domestic supply of this strategically important resource.

REEs are present in a range of sources, including secondary waste streams, yet remain difficult to isolate because of their tendency to form mixtures. Extraction is a highly complex process that can vary significantly between material types and even individual deposits. In traditional mining processes, initial physical separation consumes a high volume of raw materials and produces significant amount of waste in the form of tailings. Follow-up processing to extract the desired metals from mineral concentrates typically requires industrial-grade chemicals and solvents. The resulting hazardous liquid wastes, radionuclides, and heavy metal residues must be carefully managed according to environmental and occupational health standards, adding significant risk and increased costs.

Sandia's approach can extract rare earth elements from coal ash, a waste resulting from coal-fired power plants.

Approach: Supercritical CO_2 and Citric Acid

Sandia researchers have developed a groundbreaking approach for converting coal ash, a by-product of coal combustion, into a viable domestic source of rare earth elements using just three readily available ingredients: water, supercritical carbon dioxide ($scCO_2$),

U.S. DEPARTMENT OF ENERGY NNSA National Nuclear Security Administration

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA-0003525. SAND2021-13177 M

MARKET SHEET

Green Extraction of Rare Earth Elements from Coal Waste

Sandia National Laboratories

and food grade citric acid. By combining thermodynamic and DFT modeling and experimental tests, researchers were able to successfully remove target metals from coal and coal ash using these environmentally benign ingredients. The method has been shown to achieve a 42% extraction efficiency and can preferentially extract some of the most critical REEs. In addition to recovering REEs, this method can also remove other heavy metals from coal and coal ash to make cleaner coal before combustion or cleaner coal ash to facilitate its reuse or final disposal.

Benefits

Coal and coal ash are both abundant in the U.S. and are known to have high concentrations of REEs and metals, yet no current methods exist for industrial-scale REE extraction from this material. By sourcing REEs from an existing solid waste stream, this method eliminates the need to mine from virgin ore and creates a beneficial use for coal ash. It also reduces the environmental and occupational hazards of the REE extraction process by eliminating environmentally hazardous chemicals and solvents. Furthermore, it establishes a viable domestic source of REEs to reduce the reliance on imports, secure future market growth, and enhance U.S. national security.

Competitive Advantage

Compared to existing methods, Sandia's approach offers a greatly simplified and significantly less hazardous means of REE extraction. The economic value added by this approach is estimated to be 2 times higher than traditional technologies and conventional sources ($ value / mass).

Compared with industrial solvents, food grade citric acid does not require hazardous waste disposal, is lower cost, safer to use, and more readily available. With reduced environmental, occupational health and safety, and regulatory burden, this approach offers improved feasibility and new market opportunities.

Next Steps

Current work is focused on optimizing the method's extraction efficiency, understanding the method's controlling factors, and exploring additional useful applications for this process, including the removal of metals and sulfur from shale fracking and coal as well as the removal of actinides from nuclear waste.

To learn more, contact:

Sandia National Laboratories
Licensing & Technology Transfer

ip@sandia.gov
ip.sandia.gov

SD 15352.0
Patent Pending

References

U.S. Geological Survey, Mineral Commodity Summaries, January 2021

U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA-0003525. SAND2021-13177 M