ENVIRONMENTALLY BENIGN EXTRACTION OF CRITICAL METALS USING SUPERCRITICAL CO$_2$ BASED SOLVENT

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DESCRIPTION OF TECHNOLOGY

A secure, reliable, and sustainable domestic supply of rare earth elements (REEs) and other mission critical metals is essential to national security. This Sandia-patented technology uses environmentally benign supercritical CO$_2$ (scCO$_2$)-H$_2$O-citrate solvent systems to extract rare earth elements (REE) and other critical metals from coal and coal byproducts (coal ash). The extraction efficiency can be achieved by up to 42% (see Fig. 1).

This extraction technique will also preferentially extract the most critical REEs. The economic value added by this technology ($ value/mass) is about 2 times higher than that using the traditional technologies and conventional sources.

SIGNIFICANCE OF TECHNOLOGY

Traditionally the REE extraction process is involved with mining and beneficiation followed by chemical treatment using acids to dissolve ores/minerals. These steps are not only labor-intensive but take a devastating toll on the environment. Similarly, the current state-of-the-art for industrial REE separations utilizes solvent extraction with phosphonic acids, a complex process notorious for its excessive chemical consumption, wastewater effluents, and hundreds of processing steps required to produce individual purified REE, which cause huge post ES&H issues, and the extraction process has to be substantially adjusted for each different deposits.

Currently, there are no commercial processes for extracting REEs or toxic metals from coal or coal ash. Existing work reported is involved with environment unfriendly combinations of strong acids of HCl, HNO$_3$, HF to extract as much as 18% of total REEs. The basic to advanced ion exchange ammonium sulfate is shown to extract only 0.5% of total REE.

The Sandia technology will lessen REE reliance on overseas sources. Furthermore, removal of metals from coal or coal ash will also alleviate an environmental burden for coal use and thus may help rejuvenate the coal industry (see Fig. 2). In addition, this technology will open a new avenue for CO$_2$ reutilization.

![Fig. 1. Comparison of extraction efficiency between Sandia's environmentally benign technology and existing method using strong acids - concentrated nitric acid and hydrogen peroxide.](image1)

![Fig. 2. Sandia technology can be used in extracting REE and other critical metals from coal ash, and also be used as coal cleanser to remove the toxic metals and sulfur.](image2)
WOW! FACTOR

The technology was conceived and pioneered by Sandia (pending patent: application # No. 16/909,198, filed on June 23, 2020). Sandia’s method greatly reduces cost and environmental burden. The economic value added by this technology ($ value/mass) is about two times higher than that using the traditional technologies and conventional sources. Additionally, this technology also impacts many other applications, such as treatment of produced water from shale fracking and coal cleanser to remove toxic metals and sulfur, which benefits our society.

Commercial company, D. J. Ferguson & Associates LLC, is very interested in this technology and has signed a nondisclosure agreement with Sandia to develop this technology for exacting gallium from coal ash for use in water treatment.

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COMPETITIVENESS

The Sandia method exhibits important competitive advantages over other existing alternatives. First, existing methods are involved with environment unfriendly combinations of strong acids of HCl, HNO$_3$, HF to dissolve REE-containing material. The process converts solid waste (coal ash) into aqueous acid waste which is very expensive in post-treatment. The Sandia method greatly reduces cost and environmental burden by using food grade citric acid that is the only chemical reagent involved during the extraction process and no new waste is generated. Second, the new method will dissolve only less than 20% of raw materials whereas extracting 42% of total REEs.

This technology extracts both REEs and other critical metals from waste and leads to cleaner waste for reuse and easy disposal without post ES&H issues.

This LDRD work resulted in one non-provisional pending patent (application # No. 16/909,198).