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# Microbial Surface Display for Indium Recovery from Coal and Associated Byproducts: A Novel Approach to Non-Traditional Critical Mineral Resources

**ZAIXING HUANG**[1,2], BEI ZHANG[1] AND YANFEI ZHANG[3]

[1]China University of Mining and Technology
[2]University of Wyoming
[3]Tianjin Institute of Industrial Biotechnology

Indium holds significant importance in various industrial applications due to its unique properties and versatile characteristics, contributing significantly to technological advancements, energy-efficient devices, and medical diagnostics. However, conventional extraction from primary mineral sources is technically complex, costly, and environmentally detrimental because of the use of acid leaching and reductive processing, which poses a considerable challenge in meeting the growing market demand. Coal and its byproducts represent an alternative, non-traditional source of indium, yet efficient and sustainable recovery methods remain underdeveloped. Biological approaches hold considerable promise for the separation and purification of critical metals. In this study, we explore the utilization of lanmodulin, a highly selective lanthanide-binding protein (LanM) that also exhibits a strong affinity for indium, by engineering it on the microbial cell surface for the extraction and purification of indium from solutions derived from coal and its byproducts. The protein was successfully displayed on the surface of *Saccharomyces cerevisiae* and *Escherichia coli*, confirmed by a split green fluorescent protein evaluation system. The adsorption results demonstrate that these engineered microbial cells effectively captured indium from coal-derived solutions (over 90% recovery efficiency). This work highlights the potential of microbial biotechnology for selective indium recovery from coal and associated byproducts, offering an environmentally friendly alternative to conventional extraction techniques. These findings contribute to the development of sustainable strategies for critical mineral recovery from unconventional resources.