UPISC UNIVERSITY OF PITTSBURGH INFRASTRUCTURE SENSING COLLABORATION WORKSHOP

NATIONAL ENERGY TECHNOLOGY LABORATORY

Portable Photoluminescent Sensors for Critical Metals

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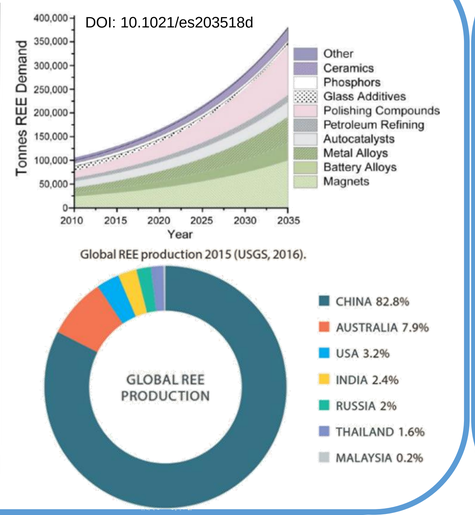
Critical Metals: Crucial for Renewable Energy

Critical metals, such as rare earth elements, cobalt, lithium, and others, are essential to advanced technologies and renewable energy. Widespread global adoption of renewable energy technologies has spurred dramatic demand increases for these metals; however, the global supply of these metals is highly monopolistic in nature. As a result, there is increasing interest in domestic production from alternative resources such as coal and its utilization byproducts. Slow and expensive characterization costs remain a significant barrier for domestic production; therefore, **portable, inexpensive sensors** are needed for metals characterization



Characterization Methods

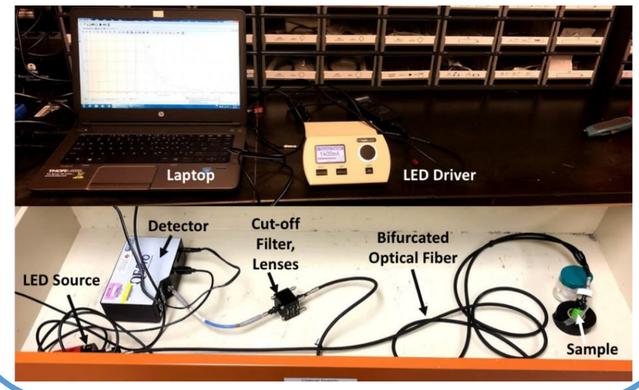
Current state-of-the-art are either too expensive, slow or insufficiently sensitive for “real-world” stream.

Technique	Instrument Cost	Detection Limit	Portable?
ICP-MS	~$180k	Part-per-trillion	No
XRF	~$13-17k	10s of part-per-million	Yes
LIBS	~$30-50k	10s of part-per-million	Yes
Luminescence Spectroscopy	~$18-35k	10s of part-per-billion	Yes

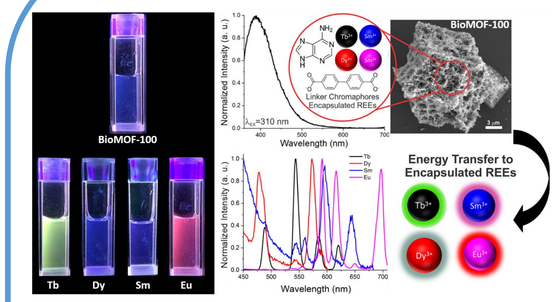
ICP-MS: Inductively-coupled plasma mass spectrometry
XRF: X-ray fluorescence spectroscopy
LIBS: Laser-Induced Breakdown Spectroscopy

Portable Fiber Optic Sensor

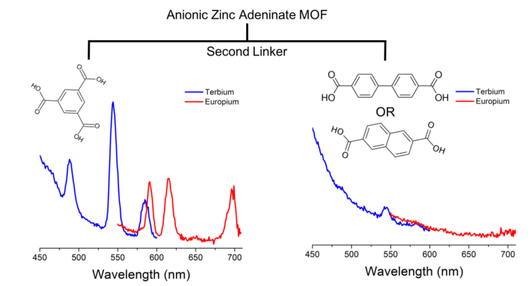
Compact, portable system comprised of a deep-UV LED light source, bifurcated optical fiber cable, and commercial detector for sensitive detection.



MOF-Based Detection of Rare Earth Elements (REE)



Metal-organic frameworks (MOFs) are inherently porous with tunable pore properties. Here, a series of anionic zinc-adeninate MOFs are used, which transfer luminescent energy to encapsulated REEs, enabling **part-per-billion** (ppb) limits of detection. The MOF structure significantly impacts sensor performance in complex matrices such as acid mine drainage.



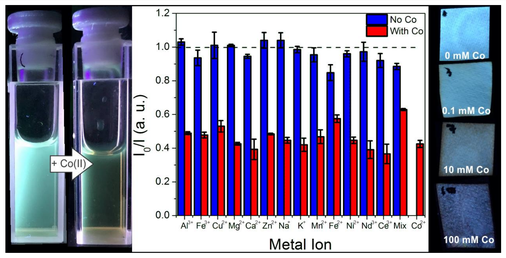
Emission in Acid Mine Drainage Matrix: 3.3 pH, [Ca] = 59 ppm, [Mn] = 29 ppm, [Al] = 10 ppm

REE Sensitized	Limit of Detection (ppb)	Limit of Quantification (ppb)
Tb	5.7 ± 0.6	18 ± 2
Dy	170 ± 10	550 ± 30
Sm	184 ± 6	600 ± 100
Eu	18 ± 4	60 ± 10
Yb	260 ± 6	900 ± 20
Nd	100 ± 2	340 ± 7

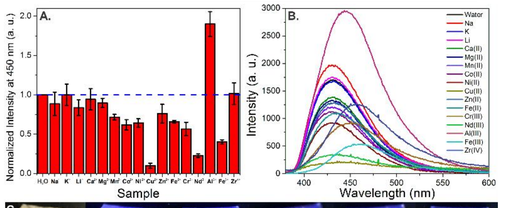
Crawford, Ellis, Ohodnicki, Baltrus, *ACS Applied Materials & Interfaces* **2021**, *13*, 6 7268
Crawford, Gan, Lemaire, Millstone, Baltrus, Ohodnicki, *ACS Sensors* **2019**, *4*, 1986
Crawford, Ohodnicki, Baltrus, *J. Mater. Chem. C*, **2020**, 8, 7975-8006

Extension to Other Critical Metals

Cobalt, widely used in electric vehicles, fuel cells, and super alloys



Aluminum, used in nearly all economic sectors



Summary and Applications

- Integration of sensing material and custom-built portable spectrometers enables technologies that are:
  - **Low cost** (<$20,000 or less)
  - **Sensitive** (down to tens of ppb levels)
  - **Versatile** (applied to multiple metal targets)
  - **Rapid** (analysis time typically 1 minute or less)
  - Potential for **real-time monitoring** and **recyclability**

Applications: Process monitoring, metals prospecting, water quality monitoring

Disclaimer

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