HYPERFLUORESCENCE FOR REAL-TIME MINERAL & MATERIAL IDENTIFICATION: UPDATE

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Introduction: The discovery, assessment and utilization of Space Resources from off-Earth bodies will require a sequence of essential activities: resource discovery, deposit evaluation and viability assessment, extraction via mining and mineral processing, then subsequent utilization via sensor-controlled manufacturing for product creation. Each stage must be successfully achieved for successful production of useful materials from space resources.

However *in situ* resource extraction (ISRU) will be conducted in future in off-Earth environments, the complex and inhomogeneous nature of geology demands constant monitoring of mineral feeds to ensure processing plants perform optimally, ideally receiving only expected feeds they are designed to work with [1].

This can be achieved by a selective mining approach, in which both target and penalty minerals are detected, identified and quantified before sorting into a feedstock stream to create a known targeted composition feed from complex ore body geology. Through such control of the input mineral feed a resource can be processed with consistent and high yields with lowered equipment maintenance and downtime - highly important considerations when working remotely, off-Earth.

Analysis of minerals at a rapid enough rate to enable practical feedstock monitoring and selective mining requires non-contact spectroscopic techniques [2]. While various potentially applicable techniques do exist, such as laser induced breakdown spectroscopy (LIBS), x-ray fluorescence (XRF), Raman spectroscopy, gamma-ray fluorescence and hyperspectral reflectance analysis, each technique has its own advantages and disadvantages, with current systems mostly designed for laboratory assessments and not well suited for field deployment for rapid evaluation of bulk materials. Others are sensitive to sample pose or provide elemental information only and not identification of the mineral or chemical species present or lack the ability to undertake detailed analysis of material on a moving conveyor system, or over a several meter area, without significant loss of resolution or very long measurement times.

HyperFluorescence (HF) is a new materials analysis technique, pioneered by the University of Adelaide and capable of rapid, non-contact mineral identification and quantification, and scalable for application from microanalysis to ore sorting over a useful detection area. This is achieved by using the minerals intrinsic "novel fluorescence" signature in combination with an imaging sensor. "Novel fluorescence" is our umbrella term for fluorescence observed from materials under excitation and detections conditions not conventionally used for fluorescence materials identification: regimes of "novel fluorescence" include multi-photon excitation (Upconversion [3]), IR fluorescence detection, and cryogenic temperatures typical of Space environments.

HF utilizes similar apparatus to the existing absorption/reflectance technologies of hyperspectral analysis, and the integration of the NF approaches with hyperspectral sensing enables targeted identification using fluorescence and the collection of context information using absorption/reflectance on the same apparatus. The HF technique is capable of near-real-time material detection, identification and quantification, including of very small proportions of target minerals in complex matrices, such as the spodumene inclusions imaged in their own NF in a polished section of lithium-bearing ore (Fig. 1).

HyperFluorescence technology shows tremendous promise for resource assessment for Space application as well as terrestrial applications, where real-time monitoring and assessment of minerals is increasingly sought-after. This presentation will consider selected mineral sensing projects currently underway in our program, aiming at development of this new technology for both terrestrial and off-Earth applications.

Asbestos Sensing

Asbestos is a significant health hazard with no robust field detection technique. Although our asbestos sensor project is motivated by the terrestrial requirement for a rapid non-contact asbestos sensor, we note that serpentine asbestos (Chrysotile) is a significant water-bearing mineral and which along with other serpentine minerals are present on the Martian moons, and are therefore of great interest as potential Space water sources.

Apatite Sensing

Apatite minerals are of high significance due to their contents of phosphates, rare earths and potentially uranium, and also as indicator minerals in terrestrial mineral exploration. Our study of apatite (fluorapatite) is motivated by it being a major host of fluorine in coal: fluorine is a penalty element that heavily reduces the coal sale value. NF has been discovered from fluorapatite, which has enabled us to construct prototypes of both a cross-belt sensor and a handheld scanner/core-logger system. We are developing these real-time technologies for field detection of fluorapatite to enable diversion away from the coal product, but this technology is dual-use: apatite, being present on the Lunar surface and a potential source of water within the regolith, appears an important mineral to identify off-world.

Lithium Ore Sensing

Spodumene, the major hard rock lithium-bearing ore mineral, requires a significant quantity of energy in a carefully controlled calcining process to be extracted effectively. Through an industry partner lithium miner, we are developing real-time spodumene sensing for improving the efficiency of this process via monitoring of the input mineral feed. The detection of spodumene is presented as an example of the capability for NF detection and quantification of small proportions of high-value minerals in complex matrices, with the NF data in Fig. 1 being collected in near real-time.

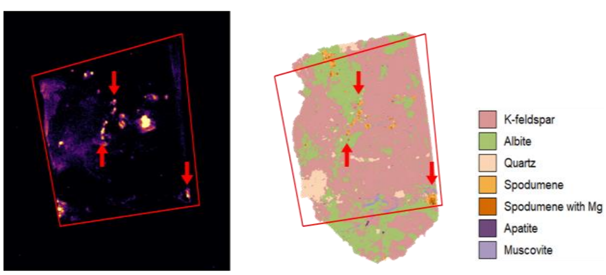

Figure 1 - An image of a polished section of lithium ore (RHS) showing mineral constituents mapped using MLA. The LHS shows the same section illuminated under the specific conditions for detection of “novel fluorescence” from spodumene in near real-time: the correlation coefficient for NF detection of spodumene is > 0.9.

Feldspar

A significant proportion of the Earth’s and the Moon’s surface are composed of feldspar minerals, which we demonstrate emit species-specific novel fluorescence that enables real-time compositional analysis. Currently we are analyzing representative feldspar samples from all the species on the feldspar ternary diagram. As a bulk part of the lunar regolith, determining the local composition of the feldspar minerals present could inform civil and structural engineering decisions on how the regolith is utilized, and which species are present for assessing potential for processing.

Fig. 2 shows an example of pebble-sized feldspar minerals (plagioclase axis) emitting fluorescence under species-specific conditions.

Figure 2 - An image of the “novel” fluorescence from pebbles of feldspar, a dominant mineral family on the Moon, under excitation from an LED.

Conclusion: Research into “Novel Fluorescence” signals and technological development of “HyperFluorescence” is underway with the goal of creating a new suite of sensors capable of filling the critical gap for real-time non-contact materials identification for Space Resource Assessment and subsequent utilization. We have presented representative results here showing examples of species-specific identification of minerals of significance. The NF/HF technique is scalable, non-contact, requires no sample preparation, and can detect very small concentrations of target materials in complex rocks and mineral mixtures such as regolith.

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