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A New Approach to Microns-Resolution Trace Element and Mineralogy Mapping at PPM Sensitivity for Digital Rock and Geological Research

Sylvia JY Lewis[1], SH Lau[1], Wenbing Yun[1], Benjamin Stripe[1], Alan Lyon[1], David Reynolds[1], Sharon Chen[1], Richard Ian Spink[1]

[1.] Sigray, Inc. Concord, CA USA

Analysis of geological materials has advanced substantially in the past decade, with the introduction of automated scanning electron microscope (SEM) based solutions such as QEMSCAN and MLA for mineralogy mapping and the development of the use of microCT systems for Digital Rock and mining applications. However, critical gaps in geological microanalysis still exist. For one, trace elements or minor elements within a mineral of similar chemistries (e.g. below 3% weight of gold in pyrite) are challenging to detect in the SEM-based mineralogy approaches [1], which is problematic for finding rare earth elements and for exploration of "invisible gold". For microCT approaches, resolution limitations can prevent accurate determination of composition – as grayscale levels of regions of interest are influenced by both mineralogy and the presence of porosity [2].

We have developed a patented laboratory x-ray analytical microscope that provides both high resolution and high sensitivity needed for substantial improvements in geological microanalysis of mineralogy and composition. The performance attributes of the system include: <5-8 µm spot on the sample (with 1 µm targeted), large working distances of >2 cm, narrow spectral bandwidth, and large x-ray flux. The outstanding performance is enabled by: (1) a revolutionary new type of high flux x-ray source designed to be >10X brighter than the brightest rotating anode x-ray source available; (2) an axially symmetric x-ray mirror lens with large solid angle collection and high focusing efficiency; and (3) a detector configuration that enables the collection of 10X more x-rays than current micro x-ray fluorescence (microXRF) designs. The sensitivity reaches around and below ppm-scale, far surpassing charged particle analysis (e.g. EPMA and SEM-EDS), and >1000X throughput over the leading microXRFs.

Despite the introduction of a number of laboratory microXRF systems in the past decade, the state-of-the-art has been limited primarily by low resolution (~30 µm) and low throughput. This is attributable to a combination of low x-ray source brightness and poor performance x-ray optics. We present our initial results in removing the x-ray source bottleneck, in which we use a novel x-ray source using Fine Anode Array Source Technology (Sigray FAAST™). When coupled with our proprietary high efficiency x-ray mirror lens, the throughput achieved is comparable to that of many synchrotron microXRF beamlines.

Applications of the x-ray analytical microscope include high throughput mapping of mineralogy at high resolution, including trace elements, such as rare earth metals, and deposits (e.g. siderite, clays), with ppm sensitivity, providing diagenetic historical insight and information for properties such as permeability and elastic/mechanical properties. Additional applications include using the system as a complement to existing techniques, such as an identification tool prior to LA-ICP-MS analysis or as a compositional analysis tool that can be used to interpret grayscale values from microCT results for Digital Rock modeling.

[1] D Pirrie et al. *Geology Today* (2011) p.232
[2] A Fogden et al, SCA Proceedings (2014) p.7
[3] The authors acknowledge funding from the NSF, Division of Industrial Innovation & Partnerships for the development of x-ray mirror lens (IIP-1448727) and the NIH, National Institute of General Medicine Science for the development of the microstructured source target (GRANT11545218).

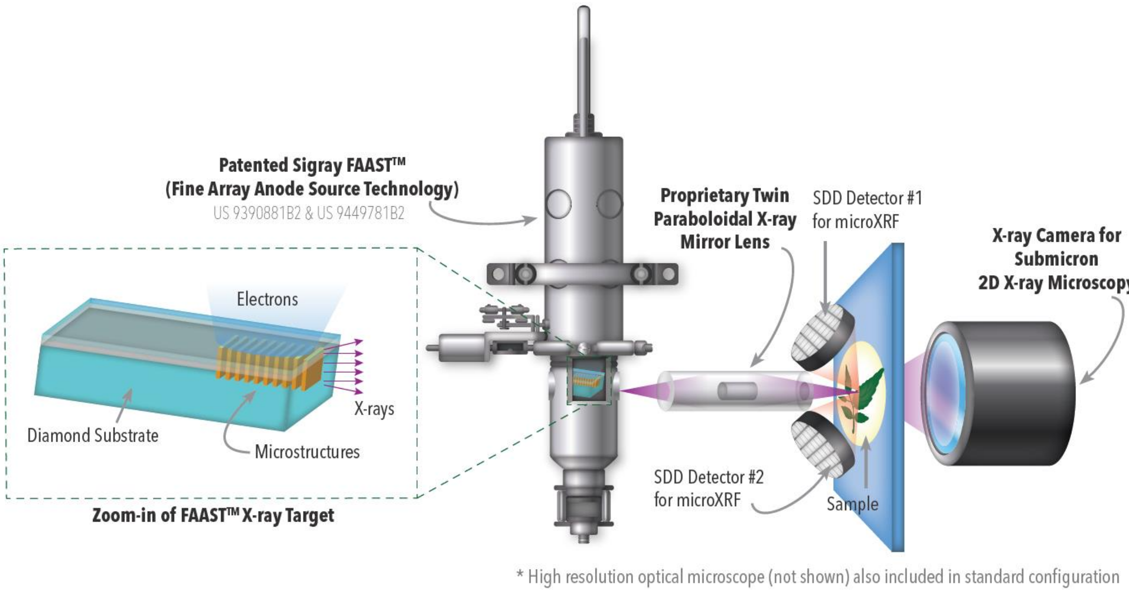

Figure 1. Patented system and its key components

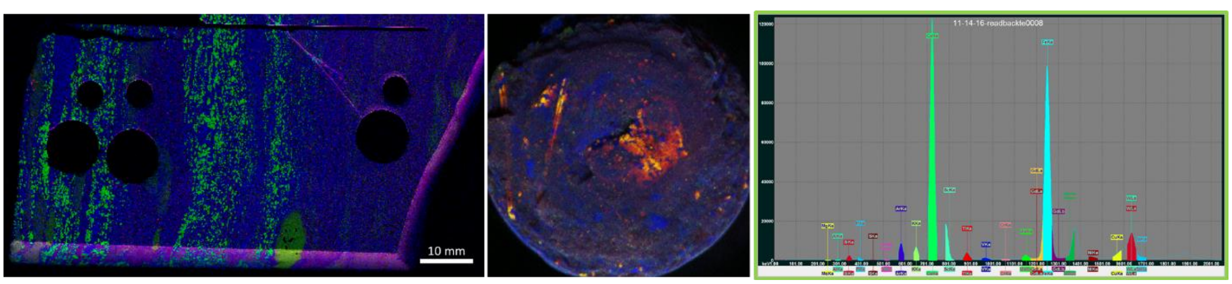

Figure 2. Exemplary results of the x-ray analytical microscope applied to geological samples

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