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A Combination BSE and CL Detector using Silicon Photomultipliers

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Considerable advancement in the performance of solid state photomultipliers (SiPMs) has been driven by the need to replace photomultiplier tubes (PMTs) for use in combination MRI/PET medical instrumentation due to the sensitivity of PMTs to magnetic fields [1]. The application of SiPM technology to Backscattered Electron imaging (BSE) in electron microscopes was introduced by Barbi et al [2]. In this case, scintillators are bonded to SiPMs to create compact Scintillator-on-Multiplier (SoM) electron sensors. The multiplicity of possible scintillator materials coupled with the rapid and continual improvement in SiPMs encouraged the development of a laboratory testing methodology which can yield a Figure of Merit for any combination of scintillator and SiPM [3]. The SiPMs are separated into two broad categories: those sensitive primarily to visible light (RGB SiPMs) and those with improved sensitivity to near ultraviolet (NUV SiPMs). One of the interesting corollaries of SiPM electron detector technology is that hybrid BSEDs can be constructed using different scintillators within a single detector, an implementation which will become more useful as scintillators with improved sensitivity to low energy electrons are developed. A different type of hybrid detector, discussed here, comprises SoMs optimized for BSEs and bare or filtered SiPMs for Cathodoluminescence (CL).

All of the data shown herein were acquired using 25kV accelerating voltage and between 200 and 800 pA of specimen current at 10-15 mm working distance. Figure 1 (left) shows a schematic of a detector comprising both BSE and Light sensors. Figure 1 (right) is the actual PCB (unpopulated). Each sensor is 4X4 mm^2 in area. The prototype PCB, with which the present data were collected, was populated with only 4 sensors rather than 8, specifically two BSE sensors (YAG/SiPM SoMs) and two light sensors (bare SiPMs). The CL images shown were collected using only a single sensor. Figure 2a is the combined image (all four sensors contributing) from a mineral sample. EDS showed the bright particles in the CL image (Figure 2c) to be predominantly calcium and fluorine. Figure 2b is the combined image overlaying the F and Ca X-ray maps. Interestingly, the F is strong in only part of the region showing the bright light, while the entire region is shown to be Ca rich. It should be noted that bare SiPMs also produce an electron image, although faint, which is useful for locating the light emitting particles in the context of the electron image.

Figure 3 shows a light image from a CaF_2 microprobe standard. The red oval highlights a strong CL signal which stands out from the already strong CL emission from the matrix material. No chemical composition difference was found in the regions showing enhanced CL emission. Although low level impurities may in fact be the cause of the enhanced emission, it is also possible it is strain-induced.

To further investigate the utility of combined BSE-CL imaging, we are constructing an 8-sensor device incorporating four BSE sensors on the inner diameter and four light sensors on the outer. The BSE sensors will be YAG/RGB SiPM SoMs; one of the light sensors will be a bare RGB SiPM, while the other three SiPMs will have custom designed filters bonded to their active surface. The wavelength ranges of best sensitivity of the four light sensors will be: bare SiPM: 350-700 nm; Filter 1 ("Blue"): 350-500 nm; Filter 2 ("Green"): 500-600 nm; Filter 3: ("Red"): 600-700 nm. The net result will be a hybrid BSE-CL detector with improved efficiency and with the ability to discriminate the CL signal into broad RGB categories.

References:

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[3] M. Tzolov et al, M&M 2016

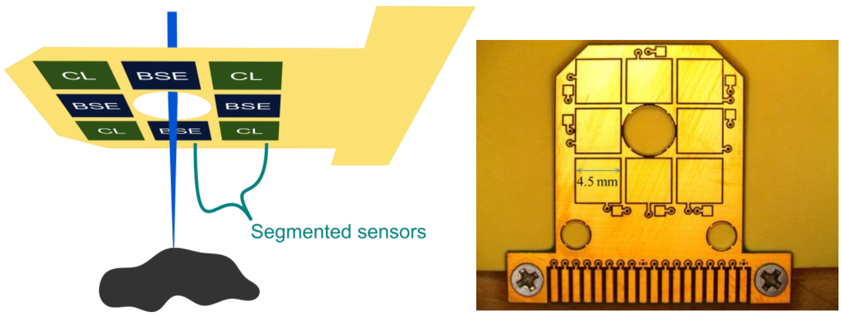

Figure 1. left: schematic of hybrid BSE/CL detector; right: actual (unpopulated) PCB

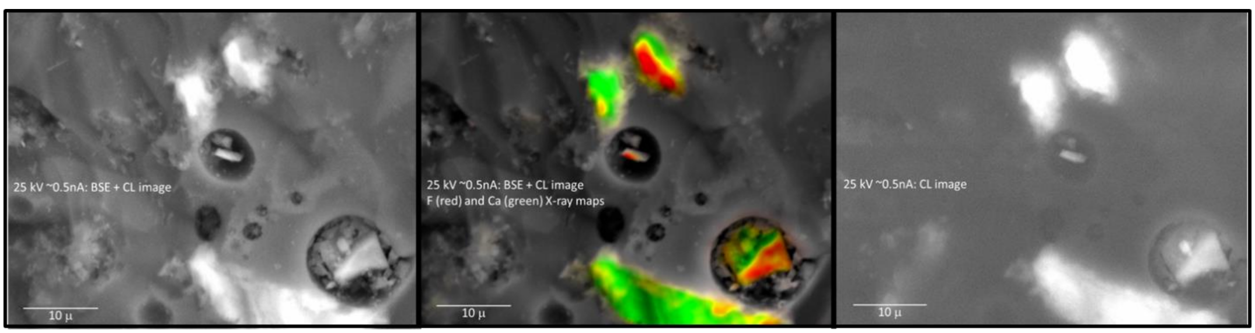

Figure 2. Typical region of mineral particle- Left to right: combined image, overlay of F and Ca X-ray maps with combined image, CL image

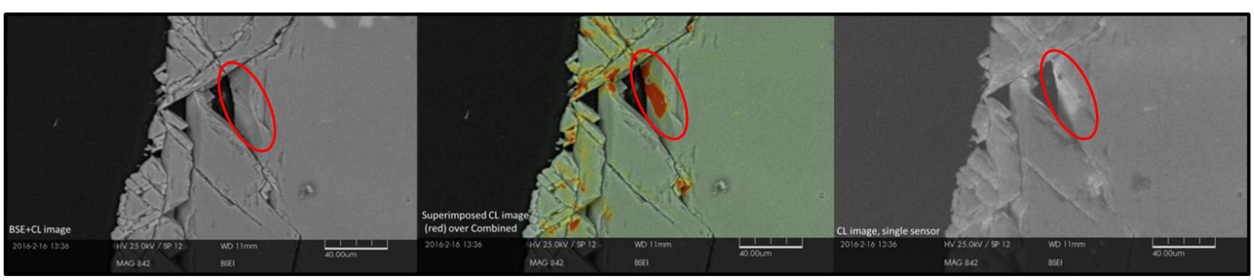

Figure 3. CaF_2 - Left to right: combined image, overlaid image (using false color), CL image

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