doi:10.1017/S1431927615001634 Paper No. 0084 Microsc. Microanal. 21 (Suppl 3), 2015

Setup and Practical Applications of a pnCCD Based XRF System

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Micro-focused X-ray fluorescence (µXRF) analysis has proven very useful as a complementary X-ray imaging technique [1]. The technique requires a focused X-ray beam, a stage capable of moving in a raster pattern, and an X-ray spectrometer (normally a silicon drift detector, SDD). Unfortunately, images are built pixel-by-pixel, using the stages to bring the sample under the stationary beam. This means that the time required to create an image is limited by the speed of the stage, not the detector. High speed stages tend to have poor position reproducibility, and accurate stages tend to be slower and more expensive. To eliminate this limitation, a new method of X-ray imaging must be established. In optical experiments, the incoming light is focused with an optic onto an imaging device. This device records all of the information simultaneously, greatly improving the speed with which an image is produced. It preserves both the position and the energy information of each incoming photon, making it an ideal imaging device. Unfortunately, these imagers are not normally sensitive to X-rays. However, a new type of CCD, known as the pnCCD is capable of detecting both the position and energy of each X-ray event.

The pnCCD was originally designed for use in X-ray telescopes [2]. More recently, these large, position sensitive, energy dispersive detectors have been used for experiments at various synchrotrons and free electron lasers [3]. Finally, the device has been applied to µXRF imaging, showcasing fast, large area imaging [4]. The pnCCD is capable of recording energy dispersive X-ray data at every pixel in a 264 x 264 pixel array. Each pixel in the array has a size of 48 µm, but sub-pixel resolution is possible down to a resolution of 10 µm. Much like in optical imaging, the optic is placed in front of the pnCCD, rather than in front of the X-ray source. As a spectrometer, the X-ray energy resolution at each pixel is equivalent to 150 eV at Mn K-alpha, and the pnCCD can count X-rays at a rate of over 200 000 counts/s. Ultimately, these properties reduce the time required to create X-ray images. Yet the question remains: How does one build an XRF based on a pnCCD spectrometer? The goal of this project was to create a laboratory scale µXRF using the pnCCD as the spectrometer. Figure 1 shows the setup of our system, which uses a 50 W X-ray source and two stepper motor stages. The X-ray source is aligned at grazing incidence, allowing for quasi-total reflection imaging.

Once the hardware is setup, one must also process the data coming from the pnCCD. Although the pnCCD is perfectly capable of producing an X-ray Spectrum Image (XSI), the software and algorithms used to create it are different from the software used with an SDD based system. Due to the speed of the system, the pnCCD will produce data at a rate of 10 GB/min or more. These raw data are processed to create the XSI through a series of programs. Through these programs, phase analysis, quantitative analysis, noise reduction and sub-pixel resolution are all possible. An example X-ray image is shown as Figure 2, which demonstrates the high resolution imaging capabilities of the detector. The pnCCD µXRF system presents both hardware and software challenges, but the solution to these problems represents a significant improvement in µXRF technology. This work will discuss the challenges and opportunities of a pnCCD based µXRF system along with the practical applications of the system.

References:

[1] Davis, J.M., Newbury, D.E., Ritchie, N.W.M., *et al*, Bridging the micro to macro map: A new application for milli-probe X-ray fluorescence, Microscopy and Microanalysis **17** (2011), p. 410-417.
[2] Strüder, L., Briel, U., Dennerl, K., *et al*, The European photon imaging camera on XMM-Newton: The pn-CCD camera, Astronomy and Astrophysics, **365** (2001) L18
[3] Wiesemann, U., Thieme, J., Guttmann, P., *et al*, The new scanning transmission X-ray microscope at BESSY II, Proc. 6th International Conf. on X-ray Microscopy, American Institute of Physics, (2000)
[4] Scharf, O., Ihle, S., Ordavo, I., *et al*, Compact pnCCD-based X-ray camera with high spatial and energy resolution: A color X-ray camera, Analytical Chemistry, **83** (2011), p. 2532:2538.

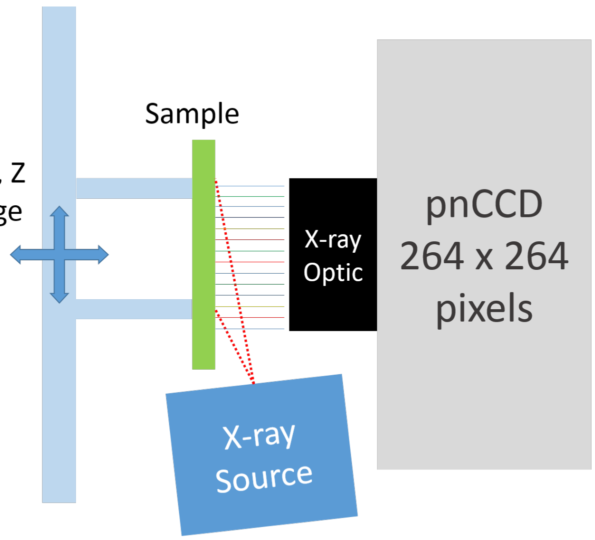

Figure 1: A schematic drawing of the setup for a pnCCD based μXRF system. The X-ray source is unfocused and polychromatic, but the fluoresced X-rays from the sample are focused using a parallel beam, polycapillary optic. A stage allows for fine adjustment of the area imaged, but it is not used to create the images.

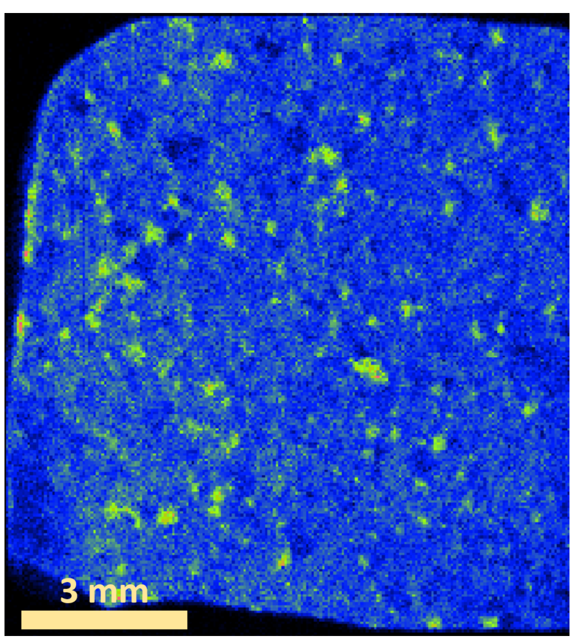

Figure 2: An Fe X-ray intensity image produced using the pnCCD based μXRF system. The sample is an ordinary Fe-Ni meteorite measuring approximately 2 cm in length and 1.3 cm in height. The scale bar on the lower left portion of the image represents 3 mm.