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Characterization of Rare Earth Element Ores with High Spatial Resolution Scannhing Electron Microscopy

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Rare earth elements (RREs) include the fifteen lanthanides plus scandium and yttrium [1]. Because of their prevalence in renewable energy devices and high-end electronics, REEs become increasingly significant for the advancement of technology and energy saving devices [2]. The goal of this project is to estimate the economical values of rare earth elements and to find the optimal extraction process through charactering composition and morphology of REEs-bearing minerals. Typically, the quantitative evaluation is achieved by automated scanning electron microscope and mineral liberation analyzer, but the results are limited by the low spatial resolution and global chemical analysis of these methods. High spatial resolution imaging and x-ray microanalysis are needed to correctly characterize the REEs-bearing minerals.

Field-emission scanning electron microscope and microanalysis at low accelerating voltage could resolve these problems [3]. However, the standard x-ray detector geometry does not allow x-ray microanalysis and high-resolution imaging. The imaging and x-ray microanalysis cannot achieve the best special resolution without the smallest probe size because of the long working distance. The annular Silicon drift detector (SDD) system solves this problem: a short working distance is obtained since this detector is inserted below the pole piece. Such position leads to a high solid angle up to 1.2 sr, with a working distance used for high spatial resolution imaging [4]. Besides, more counts will be acquired in a short time because the count rate can reach as high as 2,000,000 cps, which lead to the lower detection limit of elements and smaller minimum size of different phase features. Figure 1 shows a comparison between a conventional SDD and an annular SDD under the same acquisition conditions. With the higher count rate of 116 kcps of the annular SDD, the x-ray maps of Zr and Si have smaller noise and more detailed phase boundaries. Figure 2 shows the high quality x-ray maps at low accelerating voltage using an annular SDD. The small probe diameter, the small interaction volume and the large solid angle contribute to the detailed maps: even very small phases could be observed.

The annular SDD with larger solid angle allows quantitative micrograph with simultaneous high resolution imaging for a complete characterization of the rare earth element ores.

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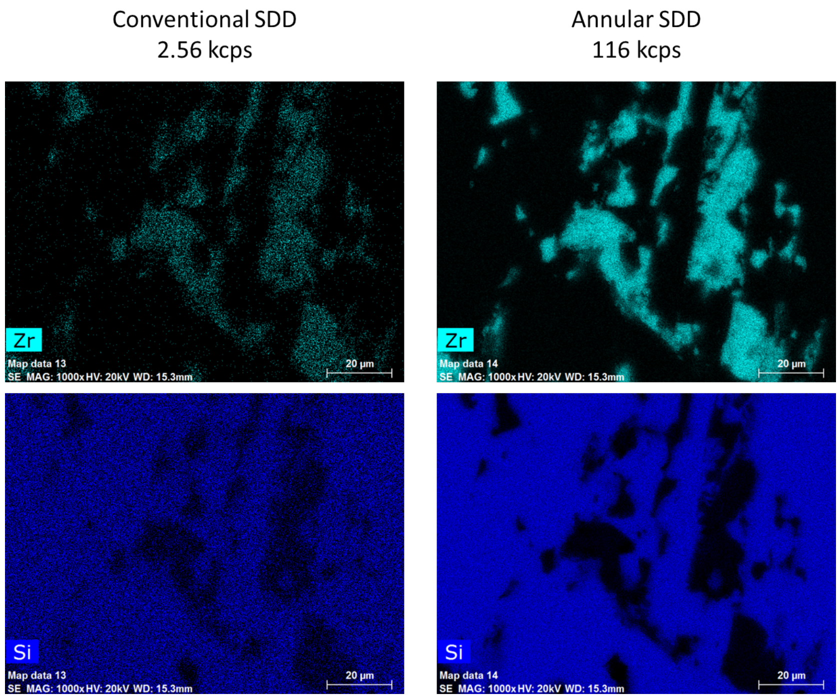

Figure 1. Comparison between a conventional Silicon drift detector (SDD) (left) and an annular SDD (right). The same acquisition time of 250 seconds and SEM parameters were used.

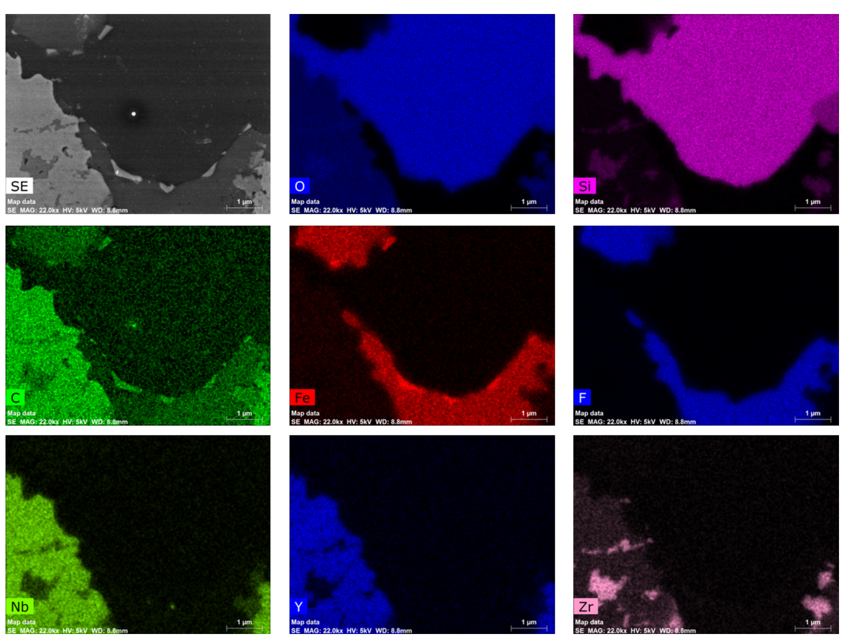

Figure 2. Example of high spatial resolution x-ray map with the annular SDD obtained from a rare earth element ore at low accelerating voltage of 5 kV.

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