SPEM Investigation of Heterogeneous Sulfide Minerals Containing Chalcopyrite and Bornite

Robert G. Acres, Sarah L. Harmer, and David A. Beattie

Ian Wark Research Institute, University of South Australia, Adelaide, Australia

The surface chemistry of sulfide minerals is critical to their separation and processing by flotation and acid leaching. Physical and chemical differences including impurity type and concentraiton have shown to effect the separation and leach rates of chalcopyrite. The capability of mapping surface chemistry allows us to directly determine the effect of impurities on the surface chemistry of the sulfide minerals. In this study the application of SPEM to the study of heterogeneous sulfide minerals is evaluated. SPEM has been used to study the surface of a freshly fractured heterogeneous sample of chalcopyrite ($CuFeS_2$) and bornite (Cu_5FeS_4) subjected to oxidation by air exposure. 500 x 500 µm maps of sulfur, iron and copper are presented in Fig. 1. Iron and copper images have had their contrast slightly increased for clarity. The clearest differences are observed in the sulfur image as the S *2p* peak is much stronger than the Cu and Fe 3p peaks available at the 380 eV photon energy used. Differences in the Cu and Fe images are subtle, but there appears to be a correlation between higher sulfur and higher copper and between lower sulfur and higher iron.

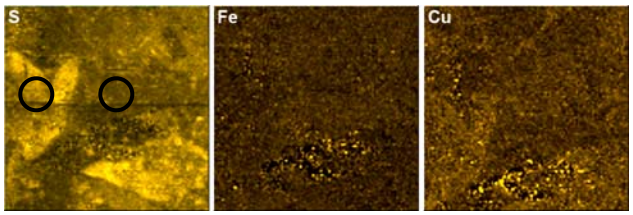

Fig. 1: 500 x 500 µm Sulfur, Iron and Copper SPEM Maps from Heterogeneous Chalcopyrite with Bornite

Regions on high sulfur and low sulfur indicated by circles in Fig. 1 were selected for high resolution point spectra. S *2p* spectra from these points are shown in Fig. 2. Also shown are comparison spectra from vacuum fractured homogeneous chalcopyrite collected at 1486.6 eV on conventional XPS (Chalcopyrite from Harmer *et al.* 2004, Bornite from Harmer *et al.* 2005) and chalcopyrite on heterogeneous chalcopyrite with bornite fractured in N_2 (380 eV from Acres *et al 2009*).

Spectra from the lower sulfur region indicated in Fig. 1 indicate this region to be chalcopyrite. The S *2p* spectrum from this region is given as Fig. 2A. Comparing this air oxidised chalcopyrite to the vacuum fractured (Fig. 2B) and N_2 fractured (Fig. 2C) samples shows that the contribution from oxidation products, disulfides at 161.7 eV and polysulfides at 163.2 eV are larger on the air oxidised surface, whereas the bulk monosulfide peak at 161.1 eV dominates the other two spectra.

Spectra from the higher sulfur region on the left of the images in Fig. 1 indicate this region is bornite. The S *2p* spectrum from this region shows more oxidation than the chalcopyrite region, consistent with bornite having a higher oxidation rate than chalcopyrite (Buckley and Woods 1984). The vacuum fractured spectrum highlights that the peaks at higher binding energy in the air oxidised case are indeed surface oxidation products.

These results indicate that distinguishing between chalcopyrite and bornite on a slightly oxidised sample is possible using SPEM. The differences between the regions on the iron and copper images are quite subtle and difficult to discern owing to the poor signal from the copper and iron 3p photoemission peaks. It is possible that with further oxidation it would become harder to distinguish between the two regions, as bornite will become more like chalcopyrite as iron migrates to its surface and near-surface layers.

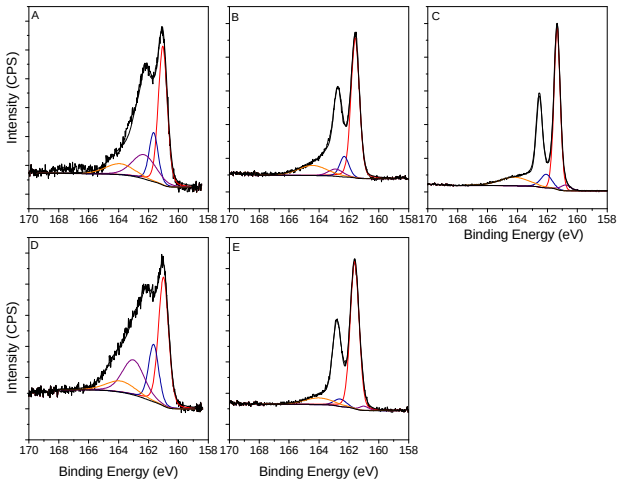

Fig. 2: S *2p* SXPS spectra from A) Chalcopyrite in Air Exposed Heterogeneous Chalcopyrite / Bornite (380 eV), B) Chalcopyrite in N_2 Fractured Heterogeneous Chalcopyrite / Bornite (380 eV), C) Vacuum Fractured Chalcopyrite (1486.6 eV), D) Bornite in Air Exposed Heterogeneous Chalcopyrite / Bornite (380 eV), E) Vacuum Fractured Bornite. (1486.6 eV)

References

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