

PEEM Study of Oxidised Heterogeneous Pentlandite, Pyrrhotite and Chalcopyrite

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

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

Naturally occurring metal sulfide minerals are heterogeneous in nature to varying degrees. The presence of impurity phases in an ore can complicate processing due to interactions between different minerals, altering surface chemistry. In this study, synchrotron based Photoemission Electron Microscopy (PEEM) has been used to image naturally heterogeneous samples containing chalcopyrite (CuFeS_2), pentlandite ($(\text{Ni,Fe})_9\text{S}_8$) and monoclinic pyrrhotite (Fe_7S_8) both freshly polished and exposed to pH 9 KOH for 30 minutes. PEEM images were constructed by taking a full field image at discrete energy steps across the metal $\text{L}_{2,3}$ absorption edges and from these images it was possible to reconstruct Near Edge X-ray Absorption Fine Structure (NEXAFS) spectra from any point on the image, allowing the surface chemistry of each phase to be isolated.

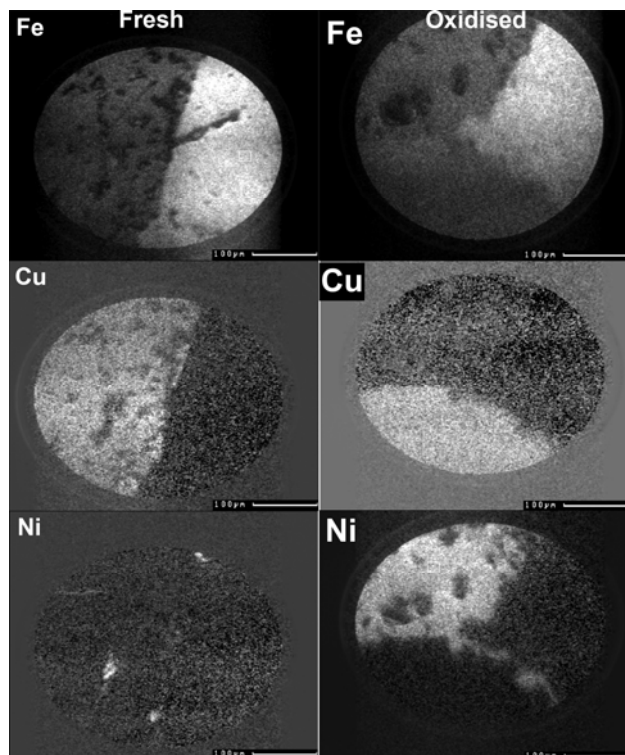


Fig. 1: Fe, Cu and Ni PEEM images from fresh polished and oxidised composite mineral samples containing chalcopyrite, pyrrhotite and pentlandite.

Iron, copper and nickel PEEM images from the fresh polished and oxidised samples, containing all three mineral phases are presented in Fig. 1. In the fresh sample, Two continuous phases are distinguishable: one with higher iron and one with higher copper. These two phases correspond to pyrrhotite and chalcopyrite and three smaller high nickel phases are visible, indicating pentlandite.

PEEM images collected from the polished sample exposed to pH 9 KOH for 30 minutes show three large

phases comprising approximately a third of the image each, one region of iron, one of copper and one of nickel, again corresponding to pyrrhotite, chalcopyrite and pentlandite respectively.

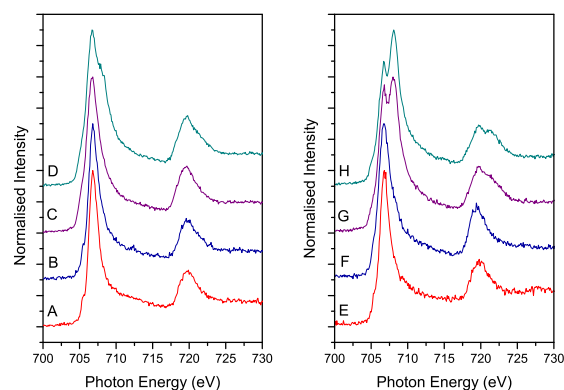


Fig. 2: Fe $\text{L}_{2,3}$ TFY NEXAFS from fresh and oxidised chalcopyrite, pentlandite and pyrrhotite phases.

Figure 2 compares the Fe $\text{L}_{2,3}$ TFY NEXAFS spectra from each region on the fresh polished and oxidised samples. Fe $\text{L}_{2,3}$ spectra from the chalcopyrite (Fig. 2A) and pentlandite (Fig. 2B) phases on the freshly polished sample show only one Fe L_3 peak at 706.8 eV from the bulk minerals^[1-4]. In addition to the peak at 706.8 eV the Fe L_3 spectra from the polished pyrrhotite phase away from any interface (Fig. 2C) and near an interface (Fig. 2D) show a shoulder on the high binding energy side of the main peak at approximately 708 eV giving a line shape resembling that published by Mikhlin and Tomashevich^[5] and Goh *et al.*^[1] for abraded pyrrhotite. After oxidation there is no change in the Fe $\text{L}_{2,3}$ spectra from chalcopyrite and pentlandite (Figs. 2 E and F) while the pyrrhotite phase, both away from an interface (Fig. 8G) and near an interface (Fig. 8H), exhibits a definite peak at 708.2 eV with greater intensity than the peak at 706.8 eV, indicating significant oxidation has occurred on this phase as expected due to the high reactivity of pyrrhotite.

The results indicate that the iron in the monoclinic pyrrhotite oxidised preferentially, while the copper, nickel and iron in the chalcopyrite and pentlandite remained relatively unchanged under the conditions studied.

- [1] S. W. Goh, A. N. Buckley, R. N. Lamb, R. A. Rosenberg, and D. Moran, *Geochim. Cosmochim. Acta* **70**, 2210 (2006).
- [2] C. I. Pearce, R. A. D. Patrick, D. J. Vaughan, C. M. B. Henderson, and G. van der Laan, *Geochim. Cosmochim. Acta* **70**, 4635 (2006).
- [3] Y. Mikhlin, Y. Tomashevich, V. Tauson, D. Vyalikh, S. Molodtsov, and R. Szargan **142**, 83 (2005).
- [4] Y. L. Mikhlin, Y. V. Tomashevich, I. P. Asanov, A. V. Okotrub, V. A. Varnek, and D. V. Vyalikh, *Appl. Surf. Sci.* **225**, 395 (2004).
- [5] Y. Mikhlin and Y. Tomashevich, *Phys. Chem. Miner.* **32**, 19 (2005).