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CHARACTERISATION OF COPPER SLAG IN VIEW OF METAL RECOVERY

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Abstract

In this study, a fayalitic copper slag was characterised. Copper is present as sulfidic droplets. The content and particle size distribution of the major sulfide phases (bornite, chalcopyrite and chalcocite/digenite) were quantified using analytical scanning electron microscopy (QEMSCAN). Large copper bearing particles (> 100 µm) are composed mainly of bornite and chalcocite/digenite and tend to accumulate in the lower part of the slag layer. As characterised with X-ray computed tomography (CT), around 70% of copper value is present in these large copper bearing particles.

Introduction

Metal slags generated from metallurgical processes are a group of promising recycling sources for metal. Among various slags, copper slag has drawn a lot of attention in view of metal recovery. A case study of characterisation of copper slag is performed.

For the sake of metal recovery, the particle size and mineralogy of metal phases are the key metallurgical parameters. Quantification of minerals can be performed by quantitative evaluation of minerals by scanning electron microscopy (QEMSCAN), an automated image analysis system using backscattered electron (BSE) and energy dispersive X-ray (EDX) signals from a scanning electron microscope (SEM). Another technique that was used, is X-ray computed tomography (CT), a non-destructive characterisation technology which can provide direct volumetric data acquisition and quantitative analysis in 3D with a reasonably short analysis time and limited sample preparation[1]. QEMSCAN and CT scanning are powerful tools to characterise these parameters and have been applied in many domains respectively. In this work, the distribution of copper bearing grains was studied through CT scanning. In addition, the species and distribution of copper bearing phases were characterised through QEMSCAN. Once the mineralogy and distribution of copper bearing particles are understood, the suitable slag processing techniques and conditions can be designed in view of copper recovery.

Materials and methods

A type of copper slag, a black solid material, was received as fragments with a size from around 100 µm up to 7 cm. The copper content is around 0.9 wt%[2].The mineralogical composition and microstructure of the slag was characterised with Scanning Electron Microscopy (SEM, Philips XL30 FEG). The distribution and portions of copper bearing phases was obtained through QEMSCAN. The distribution of copper bearing particles inside the slag body was characterised with Computed Tomography (CT, GE Nanotom).

Results and discussion

Figure 1 shows the microstructure of the slag. Fayalite (Fe_2SiO_4), magnetite (Fe_3O_4), copper sulfides and glassy phase can be distinguished. The copper sulfide phases exist as spherical particles with diverse particle sizes (from a few microns to several hundred microns). All the copper bearing phases observed were sulfides, having an overall Cu-Fe-S composition.

Detailed study of the distribution of copper bearing phases was carried out using a QEMSCAN system. Bornite (Cu_5FeS_4) was the most abundant copper sulfide phase, followed by chalcopyrite ($CuFeS_2$) and chalcocite/digenite (Cu_2S/Cu_9S_5). Trace concentrations of idaite (Cu_5FeS_6) were also found. Table 1 shows the abundance of various copper sulfides in the slag. The copper bearing particles, especially large particles (> 100 µm), are aggregates of various copper sulfides in most cases. Hence, a copper bearing particle can be several times larger than a copper sulfide grain. Chalcocite/digenite and bornite are the major components of large copper bearing particles and are, therefore, potentially easier to be recovered. Chalcopyrite, on the other hand, is randomly distributed in the slag samples as fine grains.

Table 1: Volume abundance of copper bearing phases in slag[4]

Mineral	Chemical formula	Abundance (vol%)
Bornite	Cu_5FeS_4	0.23
Chalcocite/Digenite	Cu_2S/Cu_9S_5	0.14
Chalcopyrite	$CuFeS_2$	0.27
Idaite	Cu_5FeS_6	0.01
Copper bearing phases in total		0.65
Other phases in slag		99.35

The particle size distribution of copper sulfide phases is studied based on the CT scanning data. As can be observed in Figure 2, around 60% of copper bearing particles accumulate in the lower (depth > 50%) part of the slag layer. The section near the bottom of slag layer (depth between 80 ~ 90%) contains more than 25% of the copper sulfides. Large particles tend to accumulate in the lower part of the slag layer.

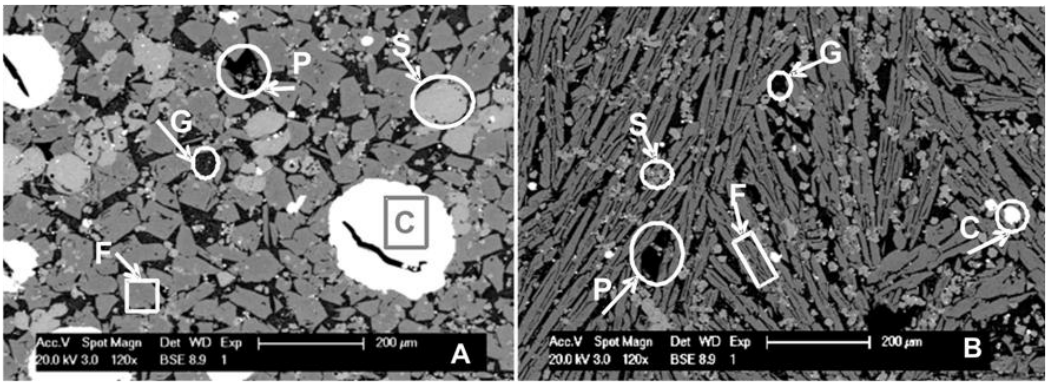

Figure 1: SEM-Backscattered Electron (BSE) image of copper slag: (F) fayalite; (S) magnetite (spinel); (G) glass; (C) copper sulfides; (P) pores[3]

The accumulative copper sulfides volume versus particle size is plotted in Figure 3. In 3D data obtained through CT scan, around 70% of the total copper sulfides appear in particles with size larger than 100 µm. Hence, the majority of the copper value accumulates in the relatively larger particles.

The data obtained from QEMSCAN shows different results. No particles larger than 300 µm were found and the amount of copper in smaller (< 100 µm) particles is significant larger (~ 68%) than that obtained through CT scanning (~ 30%). After 3D transformation, the curve fits the CT scan curve relative well below 200 µm. However, since no particle with size larger than 300 µm could be observed after the transformation, the curve deviates from the CT scan data in the large particle size range (> 200 µm). This deviation may due to the "section size" nature of the QEMSCAN data. Large particles have a larger diameter, and therefore a greater probability of intersection with the sample plane[5]. However, only the intersection across the middle plane of the ball shape particle can represent the size of the particle. The particle size deduced from other intersection

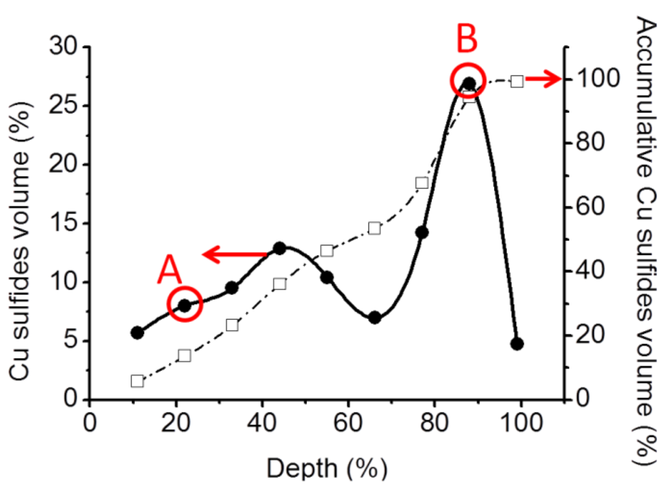

Figure 2: Copper sulfides volume distribution along depth of slag layer: (A) section near the top of slag layer; (B) section near bottom of the slag layer[4]

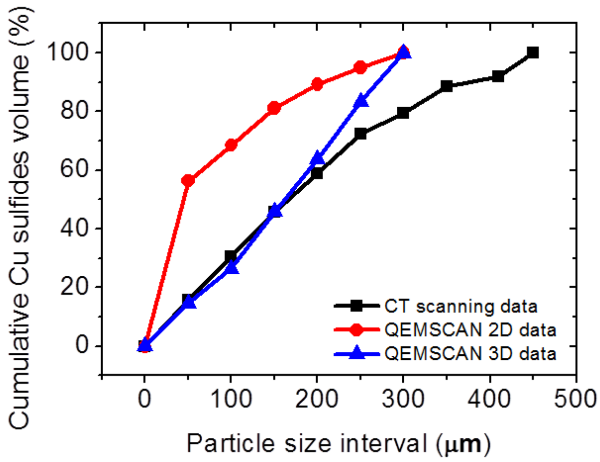

Figure 3: Cumulative copper sulfide volume versus copper bearing particle size plotted with CT scanning and QEMSCAN data before and after 3D transformation[4]

planes is smaller than the true particle size, even after stereological transformation. Hence, compared to the data from CT scanning, QEMSCAN data underestimate the volume and size of the large copper bearing particles. Acquiring data from multiple 2D cross sections may reduce the influence of "section size" and generate results more close to reality.

Conclusions

In the fayalitic slag studied in this work, copper predominantly exists in the form of bornite, chalcocite/digenite and chalcopyrite. Large copper bearing particles are aggregates of various copper sulfides, mainly bornite and chalcocite/digenite. And they tend to settle down in the bottom part of the slag layer. QEMSCAN and CT scanning can provide the mineralogy and particle size distribution respectively, which are crucial for the design of following metal recovery processes.

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