TA003
MATERIALS PROCESSING – GLASS AND MINERALS

THE INFLUENCE OF MICROWAVES ON THE LEACHING KINETICS OF SULPHIDE MINERALS

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ABSTRACT

The influence of microwave heating on the leaching kinetics of chalcopyrite and sphalerite has been investigated. Chalcopyrite is inert to many leaching agents, especially ferric ion media. This mineral is considered to be one of the largest sources of copper, in terms of the scale of availability, and copper is usually extracted by pyrometallurgical processes. However, there has recently been a growing interest in extracting copper from chalcopyrite hydrometallurgically, in order to minimize SO_2 emissions during smelting operations. Some problems may arise during hydrometallurgical operations. These include: low recovery of extracted metal; difficulties in solid-liquid separation; and the effect of impurities on the complexity of the purification process. The greatest difficulty associated with hydrometallurgical operations is probably the time-scale of the leaching process required to achieve high metal recovery, since it is carried out at relatively low temperatures and hence rates compared with pyrometallurgical processes.

Microwave-assisted leaching has been investigated in an attempt to improve the yields of extracted metal and reduce processing time. This is especially pertinent in view of the increased demands for more environmentally-friendly processes. The unique nature of the microwave-heating characteristics of metallic ores is the main driver for the practical implementation of microwave heating in metal extraction.

It has been reported in the literature that application of microwave energy can accelerate the reaction rate of metal leaching. However, no clear and unambiguous conclusion has yet been reached on the actual effect of microwaves on the reaction systems. Many researchers explain the tremendous acceleration in reaction rates by the existence of a non-thermal microwave effect. The microwave effect is said to originate in the lowering of the Gibbs energy of activation of the reactions, either through storage of microwave energy in the vibrational energy modes of the molecules (i.e. an enthalpy effect) or by alignment of molecules (i.e. an entropy effect; (Fini and Breccia, 1999; Galema, 1997). On the other hand, many others suggest that the effect of microwaves is purely thermal. A recent paper by Al-Harahsheh and Kingman (2004) gives a detailed review of microwaves-assisted leaching.

The aim of this work is to investigate the influence of microwaves on the dissolution kinetics of chalcopyrite and sphalerite in ferric ion media. The choice of sphalerite and chalcopyrite is dictated as follows. Chalcopyrite is a good microwave absorber; it is thus expected to manifest a positive temperature difference between the particle and the liquid. Hence the higher surface temperatures

would then yield a higher leaching recovery. On the other hand, sphalerite is a poor microwave absorber; therefore microwaves will mainly heat the liquid, with a negative or zero temperature gradient at the reaction interface. This results in similar heating conditions to those in conventional heating.

Pure chalcopyrite and sphalerite crystal samples were utilized in this study. Standard leaching experiments were carried out in a 500 ml reaction vessel. The starting volume of leaching solution was 250 ml. Leaching solution consisted of 0.5 M H_2SO_4 or HCl and 0.5M of Fe^{3+}. Leaching experiments were carried out at various temperatures and particle sizes. The reaction vessel was immersed in a thermostatic water bath, which controlled the temperature in the vessel to within ±0.5ºC. One gram of chalcopyrite was added to the leaching solution, after the leaching temperature had been reached. Agitation of the mixture was achieved by stirring at a desired speed. Small volumes of sample were removed periodically for chemical analysis. The residue was then collected on filter paper; sulphur extraction from the residue into toluene was carried out using a soxhlet apparatus.

(MARS X) apparatus at 2.45GHz. All the experiments were carried out in the Teflon controlling vessel, where temperature and pressure were monitored and temperature controlled within ±1ºC. The power level was chosen in order to keep the temperature constant, with a minimum of switching on and off required during the experiment, and to allow a maximum time of available power. Therefore, for every temperature, one power level was chosen. 50 ml of leaching solution were first heated to the desired temperature. The vessel was then removed temporarily to add 0.2 or 0.4g of chalcopyrite or sphalerite. The vessel was replaced in the cavity, and the desired temperature program was chosen for a fixed time interval. Stirring was effected during the experiment by means of a magnetic bar. The vessel was then removed quickly and liquid separated from solids by vacuum filtration. The sampling procedure for standard leaching was applied in exactly the same way. The reaction rate of chalcopyrite leaching in ferric ion media is slightly higher when microwave energy is used as a heating source compared with that when conventional heating is applied. The data in both microwave and standard leaching is best fit by a model of diffusion through the growing product layer, according to the shrinking core model. The activation energy calculated for microwave leaching is slightly lower than that for standard leaching. However, the difference lies within the limits of experimental error. One can therefore suggest that the reaction interface has a temperature higher than that of the bulk solution, leading to a higher reaction rate. Microwave leaching of chalcopyrite at different particle sizes shows a critical size for which the dependence on surface area is no longer observed, in contrast with conventional leaching. This further suggests that the thermal effect of microwaves and the increase in copper recovery is due to the preferential heating of chalcopyrite particles over the leaching liquid. However, for identical temperatures, the zinc recovery from sphalerite is similar for conventional and microwave conditions. This is probably due to the poor heating characteristics of sphalerite by microwaves. This latter fact was confirmed by measuring the dielectric properties of solids and liquids involved in the reaction.

It is suggested that the effect of microwaves on the leaching rate is purely thermal. Further work is required to determine the optimum conditions for the application of microwave heating in hydrometallurgy.