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Influence of microwave radiation on the magnetic properties of molybdenite and arsenopyrite

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ABSTRACT

The influence of microwave radiation on the magnetic properties of molybdenite and arsenopyrite has been investigated. Pure samples of the studied minerals were subjected to microwave radiation using different power levels and different time intervals. The effect of microwave treatment was monitored through magnetic susceptibility measurement, XRD, XPS and the proportion of mineral recovered relative to magnetic fraction on a dry magnetic separator.

Microwave treatment caused significant changes in the magnetic characteristics of arsenopyrite samples. The magnetic susceptibility of this material increased from a negative value for the fresh sample to a strong, positive one after treatment at 500 W for 60 s. Additionally, the magnetic recovery was significantly increased to 98% compared to 0% for the fresh sample. In contrast with arsenopyrite, microwave-treated molybdenite showed no change in either its magnetic susceptibility or its magnetic recovery. The mineral remained nonmagnetic with 0% magnetic recovery.

XPS and XRD results showed that arsenopyrite treatment with microwaves led to the formation of ferromagnetic phases, while molybdite (MoO_3), a nonmagnetic material, was formed after molybdenite microwave treatment. The results of this work demonstrate the efficacy of magnetic separation following microwave treatment in the separation of arsenopyrite from molybdenite.

1. Introduction

Molybdenum is an important transition element. It has been used in ferroalloys and in the manufacturing of furnace parts and electrodes. Molybdenite is the main source of molybdenum. The mineral is found in trace amounts in association with other sulfide minerals such as chalcopyrite, pyrite and arsenopyrite. Upgrading molybdenite from its gangue minerals is a prerequisite for extracting molybdenum. The upgrading process is commonly conducted by physical or physicochemical separation techniques, particularly magnetic separation or flotation, respectively. Because of the similarity in the surface wettability of the mineral and its gangues, surface modifiers are essential for achieving selective separation. Sodium hydrogen sulfide and/or cyanides are widely used to depress arsenopyrite [1], and permanganates and a magnesia–ammonia mixture are used to selectively oxidize arsenopyrite to reduce its floatability [2,3]. Microbial strains such as *Thiobacillus ferrooxidans* [4] and *Leptospirillum ferrooxidans* [5] were found to oxidize the arsenopyrite surface and change its surface characteristics. Selective flotation of molybdenite from chalcopyrite mixture was successfully achieved after low temperature plasma treatment [6].

Similar to surface wettability, arsenopyrite and molybdenite have similar magnetic properties. Thermal heating of arsenopyrite renders the mineral some magnetic characteristics and makes it possible to apply magnetic separation techniques. Although heat treatment of some minerals to enhance their magnetic properties is technically feasible, it is economically prohibitive. Thus, attempts have been made to find a less-expensive and environmentally benign alternative technology. In this regard, microwave radiation was found to be a promising substitute for conventional heat treatment and can lead to valuable mechanical and/or surface changes. The microwave technique depends on the ability of materials to convert electromagnetic energy into heat. The ability of a material to absorb microwave energy depends on its dielectric constant and its loss tangent. Some materials absorb microwave energy easily, while others are transparent or reflect the energy. The difference in sensitivity of various substances to microwaves makes possible the selective heating of materials. The selective heating property of microwave radiation has been extensively implemented in the mineral processing field. Its effect was studied in the reduction of comminution power consumption [7,8], improving mineral liberation [9], reduction roasting [10], enhancing magnetic separation [11–13], ore

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sorting [14] and improving the floatability of some minerals [15,16]. Although there are numerous studies detailing microwave treatment of sulfide minerals [17–21], no significant research has been reported about the molybdenite/arsenopyrite system.

The objective of this paper is to study the effect of microwave radiation on the magnetic characteristics of molybdenite and arsenopyrite. Surface changes that occurred after microwave treatment were investigated using XRD and XPS analyses.

2. Materials and methods

2.1. Mineral samples

Pure hand-picked specimens of molybdenite and arsenopyrite were used in this study. Arsenopyrite was obtained as lumps from the Yao Gang Shan mine, Hunan, China, while foliated masses of molybdenite were supplied from the Shakanai mine, Japan. XRD and XRF analyses showed that the molybdenite sample is 98% pure, while the purity of the arsenopyrite sample is 95%. The arsenopyrite sample was ground in a mortar, whereas the molybdenite sample was cut using a pair of scissors. The ground samples were sieved to obtain a size fraction of $-12\ 5+38$ μm. Grinding and sieving were conducted inside a glove box under a nitrogen atmosphere. The ground samples were kept in sealed bags and stored in a freezer until use.

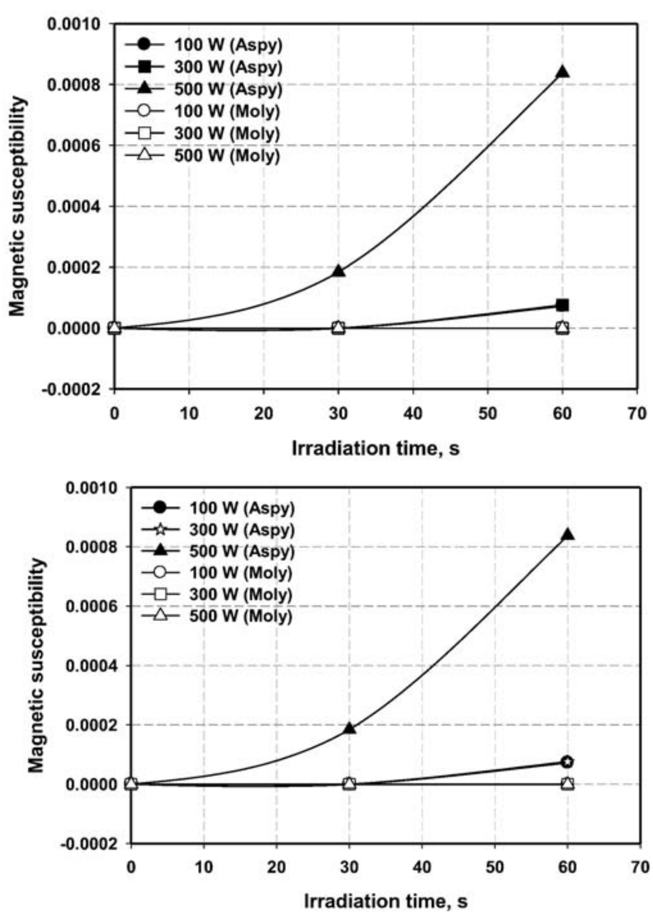

Fig. 1. Magnetic susceptibility before and after treatment (Aspy stands for arsenopyrite and Moly for molybdenite).

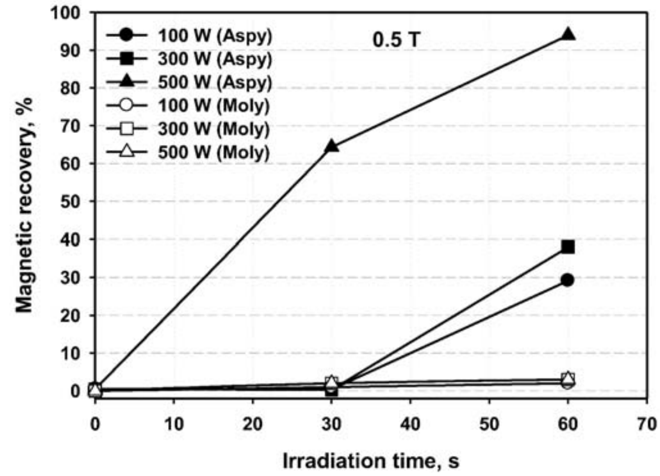

Fig. 2. Magnetic recovery of single minerals at 0.5 T before and after treatment at different power levels (Aspy stands for arsenopyrite and Moly for molybdenite).

2.2. Microwave treatment

In every experiment, about 0.5 g of a single pure mineral (particle size $-125+38$ μm) was placed in a crucible made of pure silica. The crucible was then placed in a 900 W Panasonic microwave with a maximum power output of 500 W at the desired power for a specific time. Three power levels were used; 100, 300 and 500 W. An infrared thermo sensor from the KEYENCE Company was used to measure the sample temperature after the treatment immediately; the sensor was connected to a computer where the temperature was saved automatically.

2.3. Magnetic susceptibility measurements

Magnetic susceptibility of fresh and microwave-treated samples was measured using a susceptibility meter "Bartington, UK" MS3 sensor and an MS2G meter assembly for powder samples connected to a computer for data display and saving. The samples were placed in 1-cm^3 plastic vials for measurement after calibration using a calibration sample provided by the manufacturer. The MS2G meter has a field amplitude of 500 μT and a 1.3 kHz operating frequency. Three measurements were carried out, and the average is reported in this paper. The output results are dimensionless and measured using the cgs system.

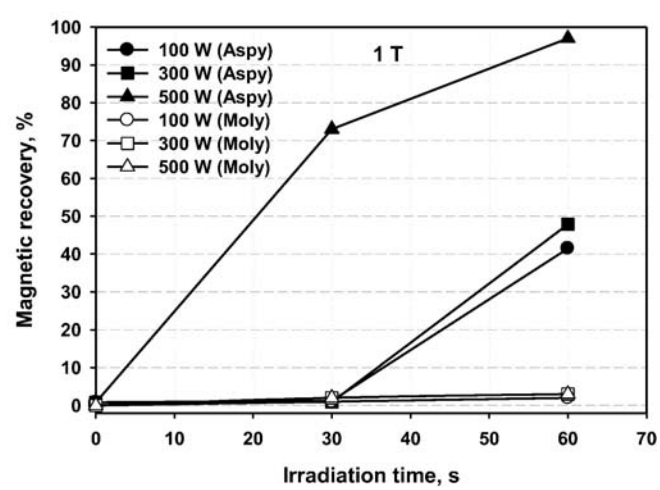

Fig. 3. Magnetic recovery of single minerals at 1 T before and after treatment (Aspy stands for arsenopyrite and Moly for molybdenite).