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Microwave Heating Characteristics and Microwave Assisted Magnetic Enhancement of Pyrite

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ABSTRACT: In this study, microwave heating characteristics and microwave assisted magnetic enhancement of pyrite were investigated. Studies include the microwave heating of pyrite samples having size fractions of -1680+1200 urn, -1200+ 850um , -850+420um , and -420 urn in a microwave oven at 850 W, 680 W and 510 W power levels and 2.45 Ghz frequency. The microwave treated pyrite samples of -420 |im particle size, was subjected to magnetic separation process at magnetic field intensities of 0.1, 0.3 and 0.5 Tesla. It was observed that heating rate and maximum attained temperature of pyrite samples increased with increasing power levels and decreasing particle size. Of all heatings, highest attained temperature and heating rate were observed for -420|im size fraction and at 850 Watt. Temperature raised to 860°C in 495 seconds. Magnetic-separation tests showed that amount of magnetic product recovery increased with increasing temperature, and magnetic field intensity. Following the 120 seconds heating at 825 °C, 97 % of the pyrite was removed as magnetic product by magnetic separation at 0.5 Tesla.

1 INTRODUCTION

Microwave energy is nonionizing electromagnetic radiation with frequencies that range from 300 MHz to 300 GHz or wavelength that range from 1 mm to 300 mm. Microwaves can be transmitted, absorbed or reflected. Insulators are transparent to the microwaves and. thus, do not store any of energy in the form of heat. Metals with high conductivities, reflect the microwaves which provide no significant heating effects. Materials such as semiconductors, with medium conductivities, typically from 1 to 10 Sm^{-1}, can be effectively heated with microwaves. (Xia & Pickles 1997). The materials which absorb the microwave contain dipoles. When microwaves are applied to the material, the dipoles align and Hip around, as the applied field is alternating. Materials heat when the stored internal energy is lost to friction. (Kelly & Rowson 1995; Kingman et al. 1999; Haque 1999). The advantages of microwave heating are rapid and selective heating, uniform heal distribution,flexiblemoduler design, environmentally friendly application, fast switch-on and switch-off. and high efficiency. Cooking food, drying, pasteurising, curing, thawing and tempering, waste control, denaturing proteins, deinfestation are some ot the examples of microwave processing (Matthes et al. 1983: Vasilakos & Magalnaes 1984).

In recent years there has been a growing interest of microwave heating in mineral treatment and a number of potential application of microwave processing have been investigated. These include microwave assisted ore grinding, microwave assisted carbolhermic reduction of metal oxides, microwave assisted drying and anhydration, microwave assisted mineral leaching, microwave assisted roasting and smelting of sulphide concentrate, microwave assisted pretrcatment of refractory gold concentrate, microwave assisted spent carbon regeneration and microwave assisted waste management.

One of the most important possible application of microwave heating is coal desulphurization. The inorganic sulphur occurs in raw coal mainly in pyritic and sulfate form. The separation of fine pyrite from coal is difficult by conventional magnetic separation methods. The performance of magnetic separation in removing mineral pyrite from coal can be improved by increasing the pyrite's magnetic susceptibility. Several studies have shown that magnetic susceptibility of pyrite can be enhanced by heating (Ergun &Bean 1968). However, the problem of heating pyrite in coal is that energy is wasted by also heating the coal. (Fanslow et al. 1980). A selective method of heating is to use microwaves at sufficiently high energy density to heat quickly for minimum heat loss to the coal (Fanslow et al. 1980; Kellaııd et al. 1988)

2 EXPERIMENTAL

2. / *Mineral Sample*

Different size fractions of test .samples were prepared from pyrite crystals by comminution and sieving. These fractions were -1680+1200u.m, -1200+850um . -850+420um . and -420 urn. Samples were further purified through microscopic examination and cleaning.

2.2 Microwave Treatment

A variable power (maximum output 850 watt) and 2.45 GHz microwave oven was used for microwave heating. 10 grams of representative samples of different size fractions were heated at 850 W, 680 W and 510 W applied power levels. Each sample for every run was loaded into microwave transparent porcelain crucible. A stainless stcel-sheathed, K type thermocouple which was inserted through the roof of oven and hole of crucible cover was used for measuring and continuously monitoring sample temperature. The accuracy of the thermocouple data was with in + 2 °C from measurements made on boiling water. Healing was continued until the maximum temperatures was attained. Microwave treatment was also applied under inert nitrogen atmosphere. Thermocouple data were recorded during irradiation in both air and nitrogen atmosphere. To minimize the effect ot field pattern variations within the oven, the curicible was always located in the same central position.

2.3 *Magnetic Separation*

Alter determining the healing characteristics of different size fractions of pyrite samples, samples of finest fraction namely -420 *\im* were subjected to microwave irradiation for 120 seconds at attained temperatures of 325 °C, 475 °C, 625 °C, 725 °C, and 825 °C. A switch off equipment was connected to microwave oven to keep the temperatures constant during the microwave irradiation. Then, treated samples were subjected to magnetic separation by using high intensity dry test magnet, at 0.1.0.3 , and 0.5 Tesla magnetic field intensities.

3 RESULTS AND DISCUSSIONS

Microwave heating characteristics of different size Iractions of pyrite sample for different power levels arc given in Figures 1 to 6. Detailed results have been presented elsewhere (Uslu, 2002). As seen from the figures, heating rale and maximum attained temperature of pyrite samples increased with increasing power and decreasing particle size. Heating rates decreased when the temperatures approached to maximum. Of all heatings, highest attained temperature and healing rate were observed for -420 urn size fraction at 850 watt. Temperature raised to 860 ℃ in 495 seconds. The increase in heating rales with increasing microwave power results from the increase in the absorbtion of microwave energy.

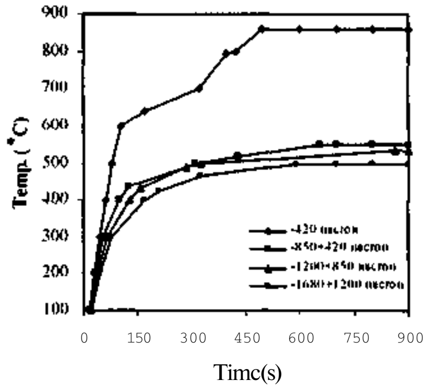

Figure I. Heat treatment of pyrite under air for different size fractions at 850 Watt

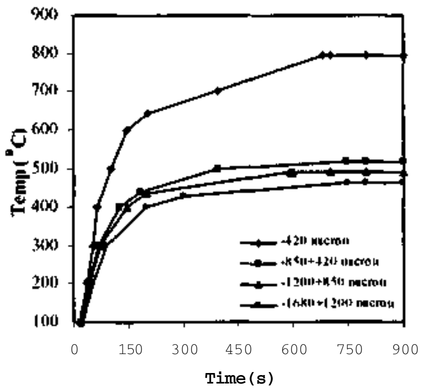

Figure 2. Heat treatment of pyrite under air for different size fractions at 680 Watt .

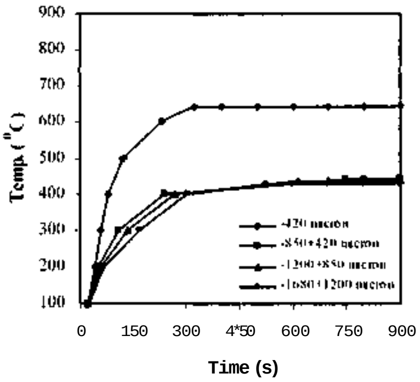

Figure 3. Heat treatment of pyrite under air for different size fractions at 510 Watt

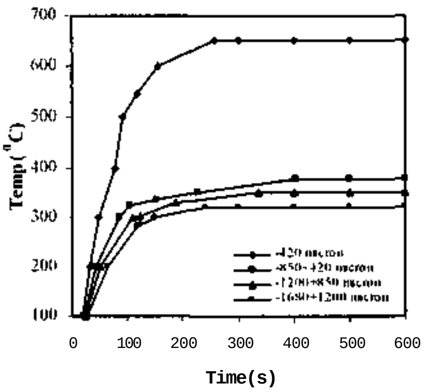

Figure 4. Heat treatment of pyrite under nitrogen for different size fractions at 850 Watt

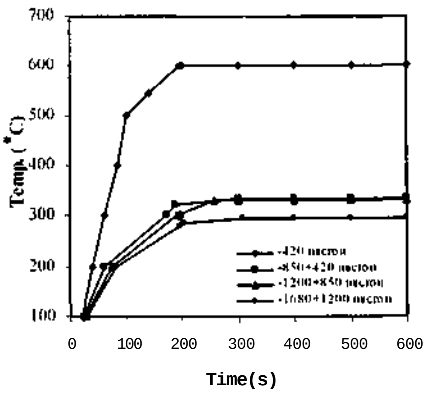

Figure 5 Heat treatment of pyrite under nitrogen for different size fractions at 680 Watt

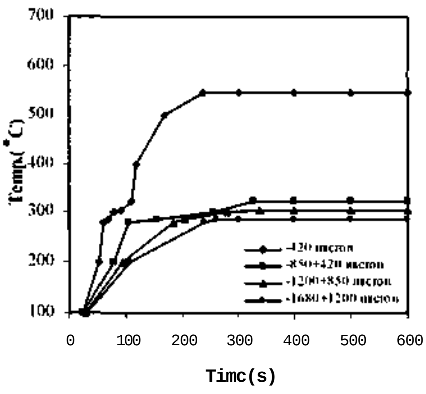

Figure 6. Heat treatment of pyrite under nitrogen for different size fractions at 510 Watt

Experimental results also demonstrated that the heating of pyrite particles is indeed influenced by particle size; the observed behaviour was rationalized from heat transfer effects. Maximum attained temperature and heating rate were lower in heatings under nitrogen. Nitrogen decreased the heating by hindering the contact of pyrite with oxygen in the air. The maximum attained temperature and heating rate under nitrogen were observed for -420 ujn size fraction at 850 watt. Temperature raised to 651 °C in 258 seconds.

Results of magnetic separation tests are given in Figures 7-8. As seen from figures, amount of magnetic product recovered increases with increased attained temperature and magnetic field intensity. Maximum magnetic product recovery was obtained for pyrite particles with maximum temperature of 825 °C in 0.5 tesla magnetic field intensity. Magnetic separation of microwave treated samples in nitrogen atmosphere resulted lower magnetic product recovery. The XRD analysis and microscopical examination of microwave treated samples showed that the pyrite (FeS_2) is converted to new phases like pyrrhotite ($Fe_{|.x}$ S, (0< x < 0.125)), troilite (FeS), a-hematite (a-Fe_20_3) and *y*-hematite (y-Fe_20_3). Due to thermodecomposition of pyrite (weakly paramagnetic) to pyrrhotite (ferromagnetic), 7- hematite (ferromagnetic) and troilite (moderately paramagnetic) magnetic separation of sample is facilated at low magnetic-field intensities. The increase in magnetic susceptibility of pyrite can be attributed to the fact that as the mineral heats up, the atoms re-align making the structure of the lattice more ordered. This alignment of atoms increases the magnetic-susceptibility of the mineral overall.

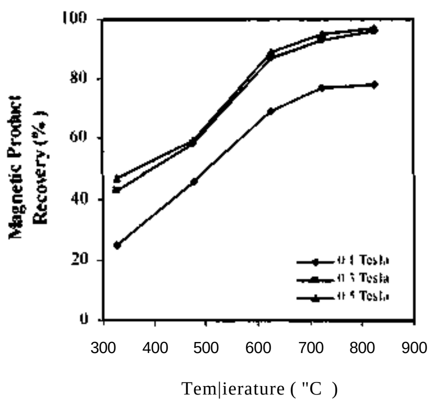

Figure 7. Magnetic separation of microwave pyrite samples heated under air

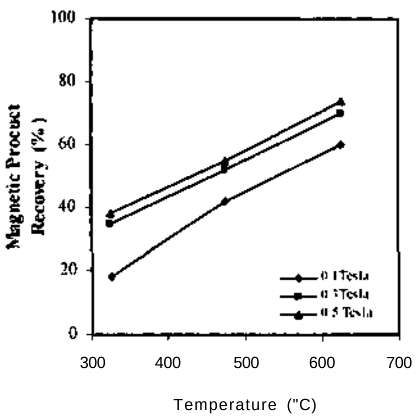

Figure 8. Magnetic separaten of pyrite samples heated under nitrogen

4 CONCLUSIONS

The results of this study show that microwave treatment has a considerable effect on the mineralogy, heating characteristics and magnetic processing of pyrite mineral. Heating rate and maximum attained temperature of pyrite samples increased with increasing power and decreasing particle size. The maximum attained temperature of 860 °C was obtained for the -420 um size pyrite particle at 850 watt in 495 seconds. It was also shown that the magnetic susceptibility of the pyrite could be increased by a considerable amount due to decomposition of pyrite to a strongly magnetic phases. Use of microwave radiation for the removal of pyritic sulphur from the coal may soon be commercial reality. Therefore, it is necessary to establish a multidisciplinary research team for the commercial development of microwave technology in mineral processing.

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