

Influence of Microwave Heating and Thermal Auxiliary on Decomposition of Siderite

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Abstract. In the present study, microwave radiation was used to decrease power inputs and roasting duration time for thermal decomposition of Deveci, Hekimhan siderite ore. The siderite was not enough to absorb adequate microwave radiation to start the decomposition or roasting reaction. Therefore, sucrose as a thermal auxiliary was added to the raw siderite ore before microwave irradiation. The effect of amount of sucrose (10 to 30 % by weight) against the duration of heating and roasting temperature of the thermal decomposition of siderite was investigated in the present study. On the contrary of the literature, the experimental results showed that the siderite was decomposed in 3 minutes with addition of 30 wt % sucrose and transformed to Fe₃O₄. The temperature, the weight loss and the magnetic susceptibility of the roasted final product were recorded as 1100 °C, 32.14 wt.% and $15410.03 \cdot 10^{-8}$ m³/kg., respectively.

1. Introduction

Iron is an important industrial metal and generally produced by pyro-metallurgical process which is a thermal treatment to get valuable metals. One of the most important iron ore is siderite (FeCO₃), having the paramagnetic property at room temperature and its mass magnetic susceptibility is $32-270 \cdot 10^{-8}$ m³/kg [1]. Magnetite and/or the maghemite and weakly magnetic hematite can be obtained from the siderite ore by roasting or calcinations process [2].

Thermal decomposition properties of siderite and calcination behaviour to obtained iron oxide (Fe₂O₃ or Fe₃O₄) have been extensively researched in the literature [3, 4]. Recently, Alkac and Atalay [5] investigated the thermal treatment of siderite by microwave heating and conventional heating. They claim that the siderite does not respond to microwave heating and the microwave is not suitable equipment for the siderite roasting process.

Contrary to common belief, microwaves cannot break any chemical bond [6]. The actual mechanism of microwave heating does involve molecular rotational energy induced by microwave. Therefore, in order to use the microwave energy, it needs at least one of the reactants which should be a microwave susceptible. In the present study, thermal decomposition of siderite ore, which was taken from Hekimhan, Malatya, was investigated under microwave irradiation. Previous study [5] and our preliminary investigation showed that the siderite was not enough to absorb adequate microwave radiation to start the decomposition or roasting reaction, so sucrose was added to the siderite as thermal auxiliaries. The sucrose was used as thermal auxiliary for heating up the siderite until it started to absorb microwave energy by itself.



2. Materials and methods

The siderite ore was taken from Deveci, Hekimhan-Malatya and brought the laboratory and the samples were crushed and ground to obtain -150 + 75-micron size siderite ore (80–85 mass % wt). Sucrose was supplied from MERCK. The chemical composition of the raw siderite ore mainly consisted of Fe₂O₃ (41.13 wt %), SiO₂ (4.63 wt %), MnO (6.12 wt %), MgO (3.04 wt %), Al₂O₃ (1.48 wt %) and CaO (1.61 wt %).

Microwave treatment of the siderite ore was carried out in a microwave oven at 0.90 kW power level and 2.45 GHz frequency. Freshly ground samples were subjected to microwave irradiation over exposure times between 1 to 5 sec. The same procedure was repeated with addition of different amount of sucrose before microwave irradiation. Then, the microwave irradiated samples were weighted. In order to compare the results, the heating procedure was also done using a conventional electrical furnace using fresh raw ore.

In order to characterize and identify the phase compositions and crystallinity of the raw siderite compounds, X-ray Powder Diffraction was used. The XRD data were collected using Rigaku Miniflex 600 X-ray Diffractometer with Cu K α (40 kV, 15 mA, λ : 1.54051 Å) radiation at room temperature. Magnetic susceptibility of the raw and thermal treated samples was determined by magnetic susceptibility balance.

3. Results and discussions

The weight loss of the conventional oven roasted siderite samples at different temperatures (465 °C, 500°C, 600°C, 700°C and 800°C) for different duration times (5, 10, 15, 30, 45, 60 min) were given in figure 1. It was seen that the weight loss increased while increasing the temperature and duration time as expected. In the present study, the raw siderite ore was irradiated with microwave home type oven. The results showed that the samples did not response to microwave and no weight loss was recorded (not given in the text). After addition of sucrose as a thermal auxiliary, the weight loss started and the sudden weight loss in a 3 minutes was obtained with addition of 30 wt % of sucrose into the raw siderite. The weight loss of the microwave treated siderite is also given in Fig. 1, indicating that the microwave treated siderite had same weight loss as the oven treated siderite at high temperature for 60 minutes, on the contrary of the literature [5]. However, the fast increasing temperature (1100 °C in a 3 minutes) might be damaged the microwave oven. In the experimental part, three home type microwave ovens were broken. Figure 2 shows the burned and broken porcelain crucible in 3 minutes by microwave irradiation. The magnetic susceptibility results are given in Table 1.

It can be seen that the magnetic susceptibilities increased with increasing the temperature. On the contrary of the literature, it was seen that the roasted product which was obtained after microwave irradiation for 3 minutes (addition of 30 wt % sucrose) had nearly same magnetic susceptibility as the high temperature roasted products.

Table 1. Magnetic susceptibility measurements of the products

Sample Code	Heating temperature [°C]	Magnetic susceptibility [m ³ /kg * 10 ⁻⁸]
1	465	1 708.16
2	500	17 690.5
3	600	19 780.03
4	700	19 530.93
5	Microwave treated	15 410.03

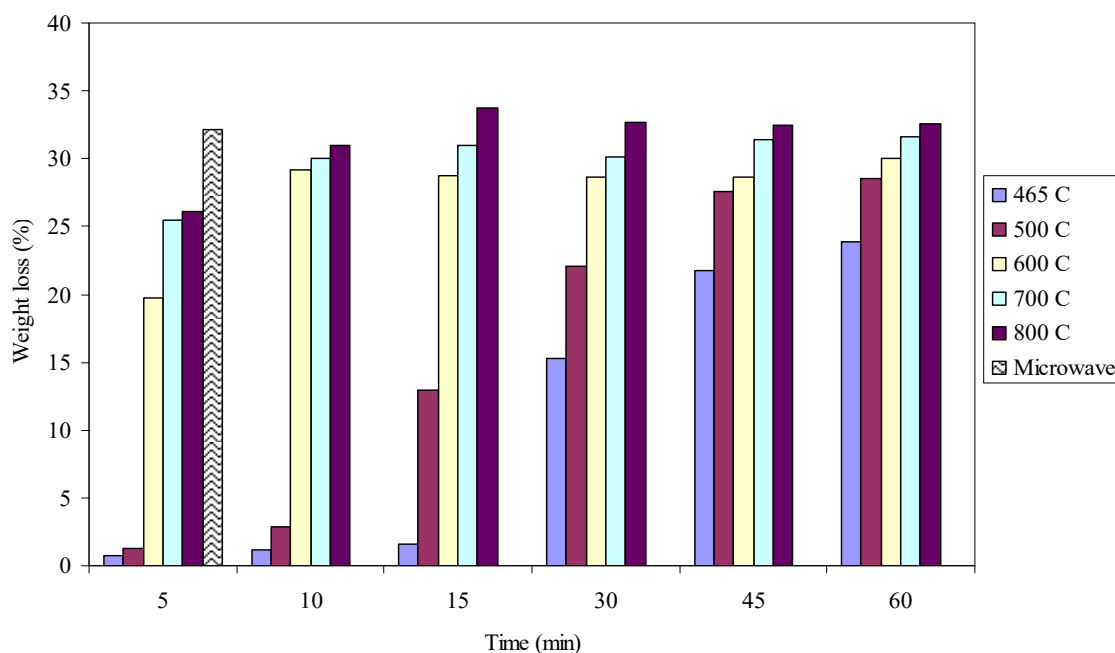


Figure 1. The weight loss of siderite heated at different temperatures for various duration times and the weight loss of the microwave treated siderite samples



Figure 2. The status of porcelain crucible after 3 minutes' microwave irradiation

The XRD patterns of the raw siderite and the oven roasted product (at 600 °C) and the microwave irradiated product (with addition of sucrose) are given in figure 3, indicating that siderite could be roasted with addition of sucrose before applying microwave and was decomposed and transformed the Fe_3O_4 .

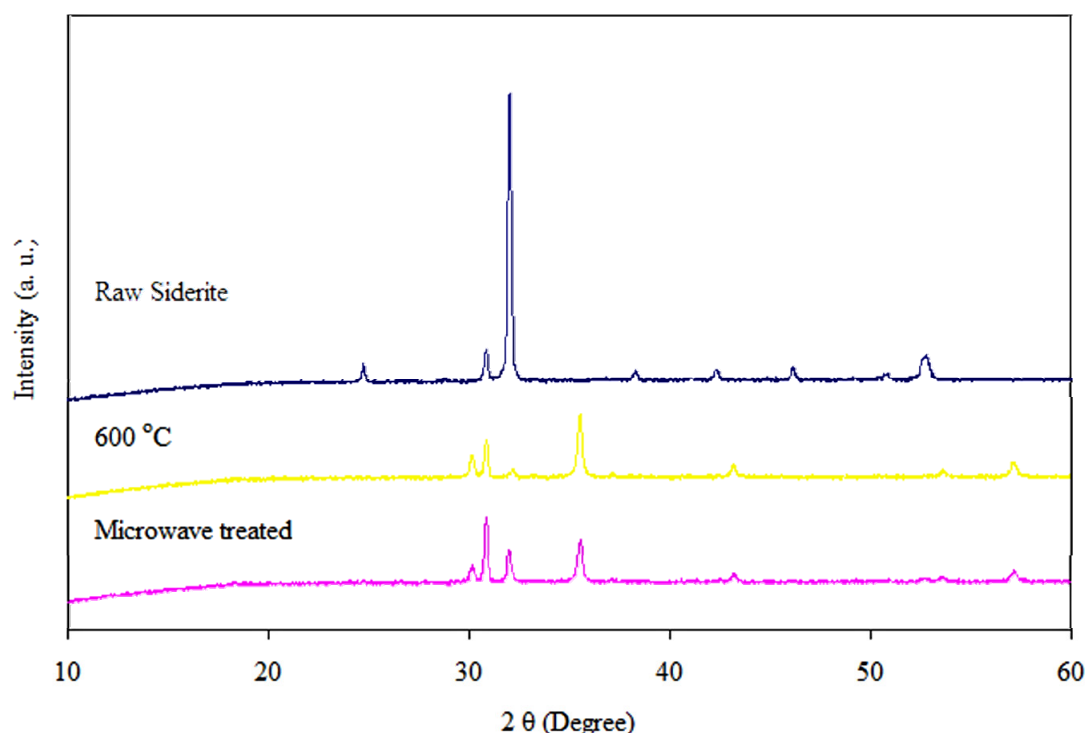


Figure 3. The XRD patterns of the raw siderite and the oven heated and microwave irradiated products

4. Conclusions

Experimental results showed that the raw siderite could not be roasted using microwave energy. However, when the sucrose was added as a thermal auxiliary into the system, the raw siderite could be successfully roasted in a very short time by microwave oven at 900-watt power level for 3 minutes' exposure time. The final product was Fe_3O_4 .

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References

- [1] C.P. Hunt, B. M. Moskowitz, and S. K. Banerjee, "Magnetic Properties of Rocks and Minerals, Rock Physics and Phase Relations"- *A Handbook of Physical Constants*. 189–203, 1995
- [2] T. Frederichs, T. von Dobeneck, U. Bleil, and M.J. Dekkers, "Towards the Identification of Siderite, Rhodochrosite, and Vivianite in Sediments by their Low-Temperature Magnetic Properties," *Phys. Chem. Earth.*, vol, 28, pp. 669–679, 2003
- [3] A. Böhm, B. Böhm, and Kogelbauer, "Selective Magnetizing Flash Roasting of Carbonaceous Iron Ores – Mineral Products for Steel Production and Environmental Protection," *Int. Miner. Proces. Cong. (IMPC)*, pp. 2423–2428, 2006
- [4] G. Atesok, and D. Hayrinnisa, "Feasibility Studies for Calcination and Sintering of Hekimhan–Deveci Siderite Ores," *I.T.U. Mining Faculty*, 2000
- [5] D. Alkac, and U. Atalay, "Kinetics of thermal decomposition of Hekimhan–Deveci siderite ore samples," *Int. J. Miner. Process.*, vol. 87, pp.120–128, 2008
- [6] A. Loupy, "Ed: In Microwaves in Organic Synthesis," *Wiley-VCH Verlag GmbH and Co Weirheim*. pp. 1-73, 2002