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COMPOSITION OF FERRO-NICKEL PRODUCED FROM SILICATE AND MAGNESITE ORES BY SEGREGATION PROCESS

The composition of ferro-nickel grains from the silicate and low-grade magnesite ore produced by segregation process has been presented. From the magnesite ore, containing 0.223% NiO, metallic grains with 85-93 % Ni were obtained. Under similar process conditions the silicate ore containing 1.158% NiO provided metallic grains having from 26 to 46% Ni. A high content of nickel in the ferro-nickel grains obtained from the low-grade magnesite ore was explained by a high CO_2/CO ratio in the process atmosphere.

1. INTRODUCTION

The segregation process of nickel oxide ores was studied intensively in the seventies by: Adzuma et al. (1973, 1974), Hoover et al. (1975), Iwasaki et al. (1966, 1971, 1972), Nagano (1970), Rey (1980), Ser and Stojsic (1968), Takahashi et al. (1970), Wright (1973), Canterford (1975), Okamoto et al. (1970), Suzuki et al. (1970), Oswaldo Grande Ibarra (1975), Hudyma (1980, 1984). To obtain metallic nickel, the ore which is mixed with chloridizing and reducing agents is roasted. In these works the influence of the roasting temperature, retention time, content of chloridizing and reducing agents, and inert gas flow intensity on the metal recovery was investigated. When garnierite or laterite ore is heated, both nickel and iron oxides are reduced and grains of ferro-nickel are formed. The formation of iron during the segregation treatment of nickel ores has not been studied extensively except by Hoover et al. (1975), Iwasaki et al. (1966), Nagano et al. (1970). Also, information about the chemical composition of the reaction atmosphere does not appear frequently in the literature (Adzuma, Suzuki, 1973; Ser and Stojsic, 1968; Oswaldo Grande Ibarra, 1975).

The aim of this paper was to determine the parameters of the segregation process responsible for the formation of metallic grains having different content of nickel as well as for the degree of reduction of iron oxides.

2. MATERIALS, METHODS, APPARATUS

Two nickel ores were used for the experiments:

1. Silicate ore, from Szklary (Lower Silesia),containing 1.158% NiO, 34.44% SiO_2, 31.70% Fe_2O_3, 1.10% Cr_2O_3, 0.175 % MnO, 1.61% CaO, 8.59% MgO, 0.01% ZnO, 0.10% Na_2O, 0.79% K_2O, 0,02% CoO, 0.09% CuO, 10.16% H_2O, and 5.36% CO_2.

2. Magnesite ore, from Konstanty mine in Braszowice (Lower Silesia), containing 0,223% NiO, 32.68% SiO_2, 13,75 % Al_2O_3, 14.01 % Fe_2O_3, 0.28 % Cr_2O_3, 0.51 % CaO, 17.39 % MgO, 19.01% MgO 0.001% ZnO, 0.01% Na_2O, 0.079% K_2O, 0.02 % CoO, and 0.01% CuO.

The segregation process was carried out on a large laboratory scale (Hudyma 1993). Samples for roasting were prepared by mixing the ore with $CaCl_2xH_2O$ and coal. For investigation, a

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spinning stainless retort of 1800 cm^3 in capacity and 116 mm in diameter was used. The retort was heated in an electric furnace. Powdered samples (either 300 or 600 grams) were heated from 30 to 60 minutes in their own atmosphere. The gas samples were analysed at three temperatures: between 200 and 300 K below the roasting temperature, at the beginning, and at the end of the retention time. The content of CO, CO_2 and H_2 was determined by Orsat's method and verified by means of chromatography (Hudyma 1993). Kraft's thiocyanate extraction method was applied for analysis of iron and nickel reduced in the segregation process (Kraft 1965).

2. RESULTS AND DISCUSSION

The samples prepared either from the silicate or magnesite ores were mixed with 3% calcium chloride and 3% coal (Hudyma, 1993).The amount of the reduced nickel and iron in the metallic grainswasanalysed and presented as nickel-to-iron ratio. Fig. 1 shows the relationship between roasting temperature and nickel-to-iron ratio in the metallic grains formed in the segregation process. After roasting of the silicate ore between 1173 K to 1293 K, the metallic grains contained both nickel and iron and their ratio, according to Fig.1,were from 0,675 to 0,252 (curve 1) and from 5,82 to 0,07 (curve 2). These numbers according to our previous work (Hudyma, 1993) correspond to 26-46% of nickel in the metallic particles. In the case of magnesite ore which was 5-fold leaner than the silicate ore, metallic grains containing from 85% to 93% were obtained provided that the temperature of retention time was between 1173 and 1273 K. Below 1273 K the metallic grains formed in the segregation process contained from 5% to 10% of nickel (Fig.1, curve 2) (Hudyma, 1993).

When nickel chloride is reduced by hydrogen, the amount of the reduced iron depends clearly on the CO_2/CO ratio as is shown in Fig. 2 in the Simons diagram (Carson and Simons, 1961; Simons, 1971) representing the area of coexistence of iron and nickel and their oxides as a

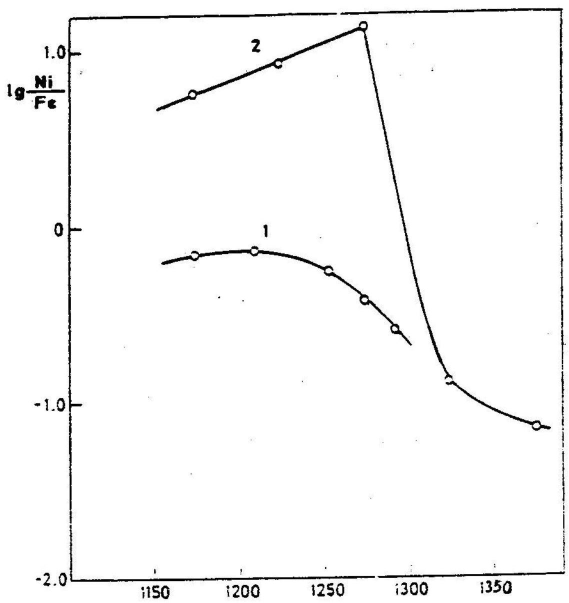

Fig 1. Chemical composition of ferro-nickel grains produced by segregation process:
1 - silicate ore : 1.158% NiO, size fraction -0.316 mm,
2 - magnetite ore : 0,223% NiO, size fraction -0.075 mm.
The term lg Ni/Fe represents the nickel-to-iron content ratio in metallic grains

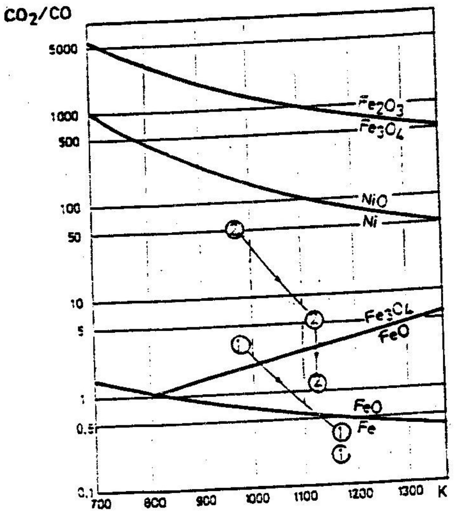

Fig. 2. Coexistence of the iron and nickel and their oxides depending on CO_2/CO ratio and temperatures. Thin lines with arrows show changes of CO_2/CO ratio during theramal treatment of the silicate (line 1) and magnesite (line 2) ores

function of temperature and CO_2/CO ratio in the process atmosphere. The CO_2/CO ratio calculated from the analyses of reaction gases (Hudyma, 1993) for the silicate and magnesite ores is illustrated by points 1 and 2 on the curves in Fig. 2. During roasting of the silicate ore, the ratio CO_2/CO varies from 5 at the beginning of the process to about 0.1. These conditions favour initially the formation of FeO and later metallic Fe. The low CO_2/CO ratio is responsible for the elevated amount of iron in the metallic particles formed at 1173 K.

A different composition of the reaction atmosphere was observed during the roasting of magnesite ore containing 36% of $MgCO_3$. At 973 K the CO_2/CO ratio was between 50 and 20 (Hudyma, 1993) pointing to coexistence of the metallic nickel and magnetite. At the end of the segregation, when the temperature is 1123 K (Fig.1, curve 2), magnetite is reduced to wustite and mainly nickel accumulates in the metallic grains.

4. CONCLUSION

When the segregation process is properly performed, it is possible to convert from 93 to 97% of nickel oxides into metallic nickel. The reduction of iron oxides to metallic iron, which leads to the formation of the ferro-nickel grains, depends on the concentration of CO_2 and CO in reaction gases. When the CO_2/CO ratio is above 0.6 after the retention time, ferro-nickel with a high nickel content is obtained. Such conditions are fulfilled when a low-grade magnesite ore is used in the segregation process.

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Przedstawiono skład chemiczny ziaren żelazoniklowych, otrzymanych w procesie segregacji dwóch tlenkowych rud niklu: rudy krzemianowej, zawierającej 1,158% NiO i ubogiej rudy magnezytowej, zawierającej 0,223% NiO. W identycznych warunkach procesu segregacji, w temperaturach pomiędzy 1173 a 1273 K, otrzymano z rudy krzemianowej ziarna metaliczne zawierajace od 26-46,% czystego niklu, a z rudy magnezytowej ziarna zawierające od 85-93 % niklu. Wykazano, że ilość żelaza zredukowanego, wchodzącego w skład ziaren metalicznych zależy od stosunku CO_2/CO w atmosferze procesu segregacji. Otrzymanie wysokoprocentowych ziaren niklowych jest możliwe jedynie przy zatrzymaniu redukcji Fe_2O_3 do FeO.