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Application News

EPMA-8050G Electron Probe Microanalyzer

Analysis of Sintered Ore for Steel Making

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User Benefits

- The mineral structure of sintered ore can be investigated by quantitative mapping of Al, Mg, Si, Ca, and Fe.
- Useful in research on the composition of the calcium ferrite phase.
- Useful in research on effective utilization of high phosphorus iron ores by quantitative analysis of trace P.

■ Introduction

Reduction of carbon dioxide (CO_2) emissions is being promoted with the aim of achieving carbon neutrality by 2050. Hydrogen reduction ironmaking is a method in which iron ore is reduced by using hydrogen in place of coke (carbon). Research on technologies for reducing CO_2 emissions from the steel making process is also underway, for example, by hydrogen reduction technology that utilizes hydrogen in the blast furnace (COURSE50). Recently, low grade iron ores with high contents of silica (SiO_2), alumina (Al_2O_3), phosphorus (P), and other impurities have been used in large amounts in response to the depletion of high grade ores. In the future, the increase in impurities is expected to become remarkable, making it even more difficult to secure the quality of sintered ore, which is the main iron source in blast furnaces.

This article introduces an example of analysis of sintered ore before hydrogen reduction, in which an EPMA™ (EPMA-8050G) electron probe microanalyzer was used.

■ Structure of Sintered Ore

Sintered ore consists of hematite, magnetite, calcium ferrite, and slag. The OM-image in Fig. 1 is an optical microscope image of sintered ore, in which hematite (Fe_2O_3) is observed as a high-brightness structure at the upper left, calcium ferrite appears as an acicular (needle-like) or columnar structure at the upper right, and a mixed structure of magnetite (Fe_3O_4) and calcium ferrite is observed around the center.

The elemental distribution images in Fig. 1 are the results of a mapping analysis of the region indicated by the red square in the OM-image in Fig. 1 and conversion of each element to the wt% concentration of the simple oxide (in the case of iron, Fe_2O_3). The CaO/SiO_2 image in Fig. 1 shows basicity.

It can be understood that the region of bright contrast in the COMPO image is iron oxide. Calcium oxide (CaO), which is the basic component of calcium ferrite, shows a correlation with SiO_2, while the basic component magnesium oxide (MgO) shows an inverse relationship with SiO_2. Furthermore, iron oxide decreases as the Al_2O_3 content in the calcium ferrite phase increases. The structure that includes slight amounts of phosphorus (P), sulfur (S), potassium (K), and titanium (Ti) is slag, in which multiple mineral components and other substances have melted and bonded.

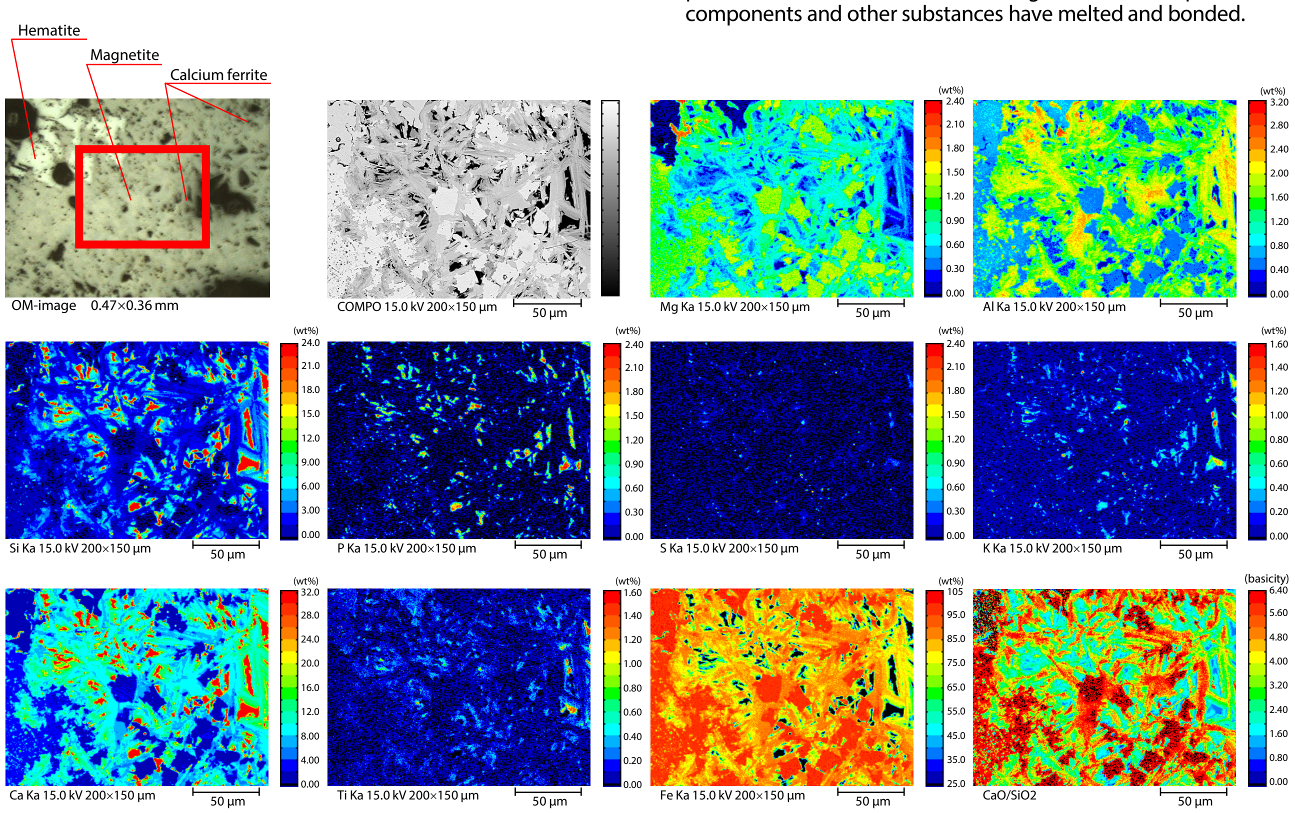

Fig. 1 Mapping of Sintered Ore

■ Iron Oxides in Sintered Ore

Sintered ore contains hematite and magnetite, which are iron oxides. In order to identify the difference in the oxidation valence of these oxides, Fig. 2 shows oxygen (O) and iron (Fe) by the wt% concentration of the simple elements.

Fig. 3 is a Fe-O scatter diagram expressing the positions of the compounds by the theoretical iron oxide concentration. In this figure, clusters can be observed in the regions representing the compounds of hematite and magnetite. Fig. 4 is a phase diagram when a filter was set by the Fe-O scatter diagram in Fig. 3, where the purple region is hematite, the red region is magnetite, the yellow and blue regions are calcium ferrite, and the green region is slag.

The matrix display in Fig. 5 shows scatter diagrams in which the combinations of the various elements (Mg, Al, Si, Ca, Fe) are expressed by the phase colors in Fig. 3. Since the correlations of the elements can be seen, it can be understood that the Si and Ca of calcium ferrite increase while Mg decreases as the Fe of the iron oxide decreases. The scatter diagram of Si-Fe-Ca in Fig. 6 shows that the composition ratio of Si and Ca to the Fe content is substantially the same because the cluster has a linear shape.

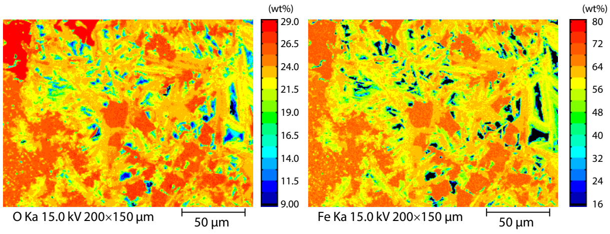

Fig. 2 Mapping of O and Fe in Sintered Ore

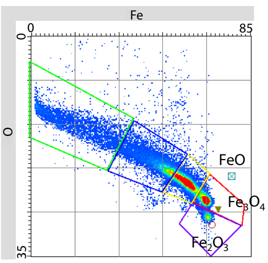

Fig. 3 Fe-O Scatter Diagram

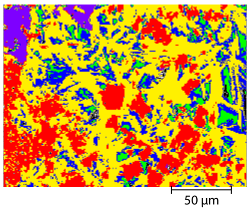

Fig. 4 Phase Diagram of Sintered Ore

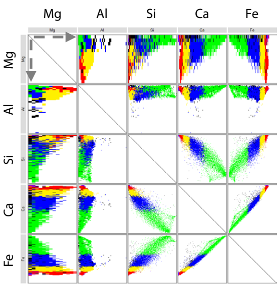

Fig. 5 Matrix Display

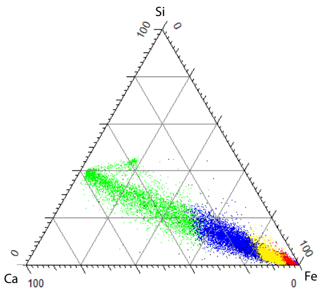

Fig. 6 Scatter Diagram of Si-Fe-Ca

■ Calcium Ferrite in Sintered Ore

Fig. 7 shows the scatter diagram of SiO_2-Fe_2O_3-CaO expressed in mol% changed to the compositions of the simple oxides (for Fe, Fe_2O_3). Fig. 8 is almost similar to Fig. 4, showing the phase diagram when a filter was set for the mol% of Fe_2O_3 in the scatter diagram in Fig. 7 as ≥ 98 mol%: Fe_2O_3 (purple), 85-98 mol%: Fe_3O_4 (red), 60-85 mol%: Ca-ferrite-1 (yellow), 40-60 mol%: Ca-ferrite-2 (blue), and <40 mol%: slag (green). Fig. 9 and Fig. 10 show the correlations of the composition ratios of MgO and Al_2O_3 in Fig. 7, respectively.

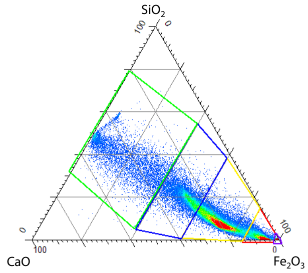

Fig. 7 Scatter Diagram of SiO_2-Fe_2O_3-CaO

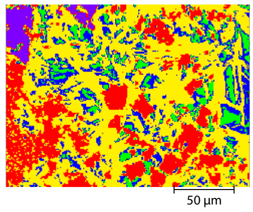

Fig. 8 Phase Diagram of Sintered Ore

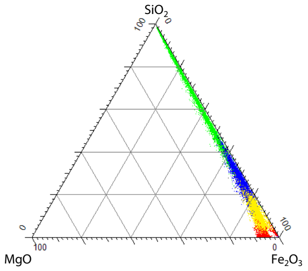

Fig. 9 Scatter Diagram of SiO_2-Fe_2O_3-MgO

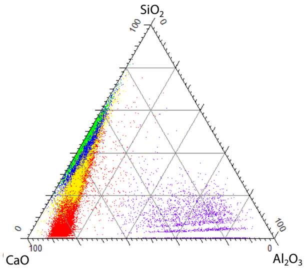

Fig. 10 Scatter Diagram of SiO_2-Al_2O_3-CaO

■ Quantitative Analysis of Sintered Ore Structure

Table 1 shows the results of a quantitative analysis of the sintered ore structure for components other than hematite, which was shown in the phase diagram in Fig. 8. Table 2 shows the results expressed in terms of the mol% of the simple oxides. Based on the mol concentration ratio of CaO and SiO_2, the slag is considered to be a $2CaO$-SiO_2 system. Phosphorus was detected only in the slag, indicating that P is concentrated in the slag during sintered ore production.

Table 1 Quantitative Analysis of Sintered Ore Structure (wt%)

	O	Mg	Al	Si	P	S	K	Ca	Ti	Mn	Fe	Total
Magnetite	27.53	1.01	0.29	0.03	0.00	0.00	0.00	1.24	0.03	0.28	70.61	101.01
Ca-ferrite-1	28.09	0.61	1.30	0.95	0.00	0.00	0.00	6.10	0.03	0.17	61.96	99.23
Ca-ferrite-2	29.28	0.31	1.23	3.32	0.00	0.01	0.00	9.90	0.12	0.11	54.29	98.57
Slag	31.49	0.10	0.37	13.19	1.80	0.18	0.53	34.59	0.13	0.04	7.88	90.29

Table 2 Quantitative Analysis of Sintered Ore Structure (mol%)

	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	MnO	Fe_2O_3
Magnetite	5.47	0.72	0.14	0.01	0.00	0.01	4.21	0.07	0.70	88.68
Ca-ferrite-1	3.02	2.91	4.10	0.00	0.01	0.01	18.86	0.09	0.39	70.62
Ca-ferrite-2	1.38	2.46	12.85	0.01	0.05	0.00	27.40	0.27	0.22	55.37
Slag	0.29	0.48	31.95	2.02	0.38	0.46	59.05	0.20	0.05	5.12

■ Conclusion

Since it is possible to identify iron oxides, calcium ferrite, and slag by a quantitative mapping analysis and phase analysis of sintered ore, this technique is utilized in analyses of the sintered ore structure and research and development related to ore reduction. In addition, progress in evaluation of sintered ore from various angles is expected by determination of the trace contents of other elements such as P, S, Mn, and Ti.

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<References>

1) Zhi Quan Wang, Yasushi Sasaki, Yoshiaki Kashiwaya and Kuniyoshi Ishii: Tetsu-to-Haganė, Volume. 86 (2000), No. 6, 370

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