# Micro-spectroscopic Investigation of the Plasma-surface Interaction in the Microwave Carbothermic Reduction of the Powdered Magnetite

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The microwave-heating technology accumulated through the nuclear fusion research has contributed to the field of industrial microwave processing. One of those technologies is microwave iron making [1]. The fundamental chemical equation for iron carbothermic reduction is $Fe_3O_4 + 2C \rightarrow 3Fe + 2CO_2 - 317$ kJ/mol. In the conventional blast furnaces the reduction energy (317 kJ/mol) has been supplied by combustion of carbon of which amount is comparable to that needed in the reduction. The equivalent energy can be supplied by electrical energy in the microwave iron making; thus, the microwave method allows reducing the $CO_2$ emission to half the amount in the blast furnaces, if the electric power for the microwave is generated by carbon-free energy, such as solar, hydro and nuclear power.

A feature in the reduction process during the microwave heating is a sudden rise in material temperature from ~700 °C to ~1000 °C accompanied by light emission of atmospheric plasma [2]. The emission light consists of line spectra of iron atom. This indicates that there is strong interaction between plasma and material. We have investigated experimentally the role of the interaction on the reduction process by means of spectroscopic method. Here, we present the spatially resolved microscopic spectral image covering the boundary region of the raw material made of magnetite and graphite powder composite.

Fig. 1 shows a typical set of images (visible and spectral) for the reduction dominated period. These images were obtained by the spectroscopic system called Integrated Microscopic Imaging System (IMIS) at NIFS, when the specimen was heated by E-field of microwave (cw 2.450 GHz around 120 W) in the $TE_{103}$-single mode cavity. It is seen that the bright emission with the jet appears above the surface of material [see Fig. 1(a)], and iron atomic spectra are superimposed on the strong continuous spectrum above the material [see Figs. 1(b) and 1(c)]. These images suggest the existence of the mixture of plasma-powder, which can be formed in such a way that the powder is blown into the plasma by $CO/CO_2$ gas flow resulting from the reduction reaction. The property and effect of plasma-powder mixture will be considered.

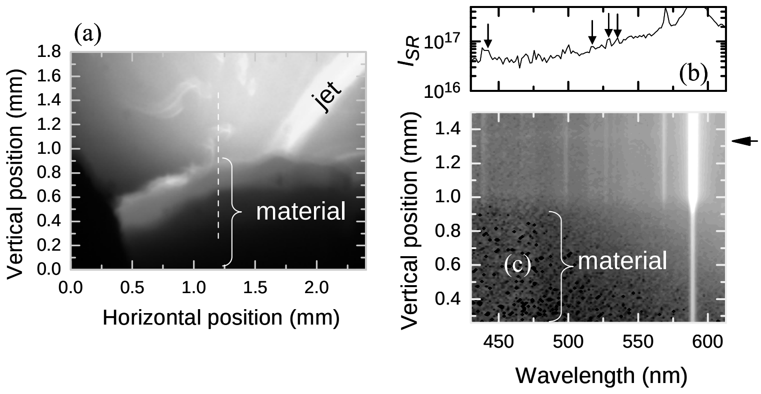


Fig. 1. The visible (a) and spectral (c) images of specimen captured at the reduction dominated period. The dashed line in (a) shows the image of the slit of spectrometer (the position of the detection of the spectral image). The emission spectrum in (b) is for the vertical position of 1.33 mm indicated by the arrow in (c). Arrows in (b) shows spectra assigned as Fe I. The strong lines at 569 nm and 590 nm are Na I.

[1] Ishizaki K., and Nagata K.: ISIJ Intern. 46 (2006) 1403.
[2] Matsubara A., et al.: PFR 3 (2008) S1085.