TEMPERATURE AND COMPOSITION DEPENDENCES OF VISCOSITY FOR FeO_x–SiO_2 SLAG MELTS UNDER MAGNETITE FORMATION CONTROL

Hiromichi TAKEBE, Sei KUZUMAKI

Ehime University, Graduate School of Science and Engineering, 790-8577 Matsuyama, Japan

hiromichi.takebe.mk@ehime-u.ac.jp

Introduction

Minimisation of copper loss into slag melt is an important issue for a sustainable copper smelting process. The viscosity[1-3] of the slag melt affects the phase separation process in Cu-Fe-S matte/FeO_x–SiO_2 slag melts. Viscosity measurements of the slag melts under the conditions of magnetite formation control are desirable as basic data for the smelting process.

In this study viscosities of synthesised FeO_x–SiO_2 slag melts with various Fe/SiO_2 mass ratios and Al_2O_3 concentrations and a copper slag melt were measured with the control of their oxygen potentials at 1200–1300°C.

Experimental

The batch compositions of synthesised slags were binary FeO–SiO_2 with various total Fe/SiO_2 mass ratios. To understand the effect of Al_2O_3 addition on melt viscosity, alumina powder with 5 and 10 mol% was also added to the FeO–SiO_2 mixture with a batched Fe/SiO_2 mass ratio. A commercial copper slag was also used for viscosity measurements.

The oxygen potential (OP) of the slag melts was controlled by adding 1.0 g carbon powder into 100 g slag samples. The OP was measured by a handmade zirconia oxygen sensor with the cell structure of Fe, FeO/ZrO_2+9 mol%MgO/$\underline{O}$ in slag melt, where $\underline{O}$ is the oxygen partial pressure of the measured electrode. Figure 1 (a) shows the schematic of the zirconia sensor. The measured OP for the copper slag at 1250°C in Ar flow was 4.0×10^{-10} atm. We postulated that the OP was almost independent of the slag composition and the temperature of the viscosity measurements. The concentrations of FeO and Fe_2O_3 were calculated by the thermodynamic software package FactSage7.1 using FToxid and FactPS databases, the measured OP value and the slag composition evaluated by X-ray fluorescence analysis after viscosity measurements.

The rotating cylinder method was used for viscosity measurements using handmade high-purity alumina crucible and Pt–30%Rh spindle in Ar. Figure 1b shows the schematic of the viscosity measurement apparatus under the OP control. The mixture of raw materials was pre-melted at 1250°C for 30 min in Ar and cooled to room temperature. The cullet was initially melted at 1300°C for 30 min in Ar and then the viscosity was measured at 1300, 1250 and 1200°C with decreasing the temperature.

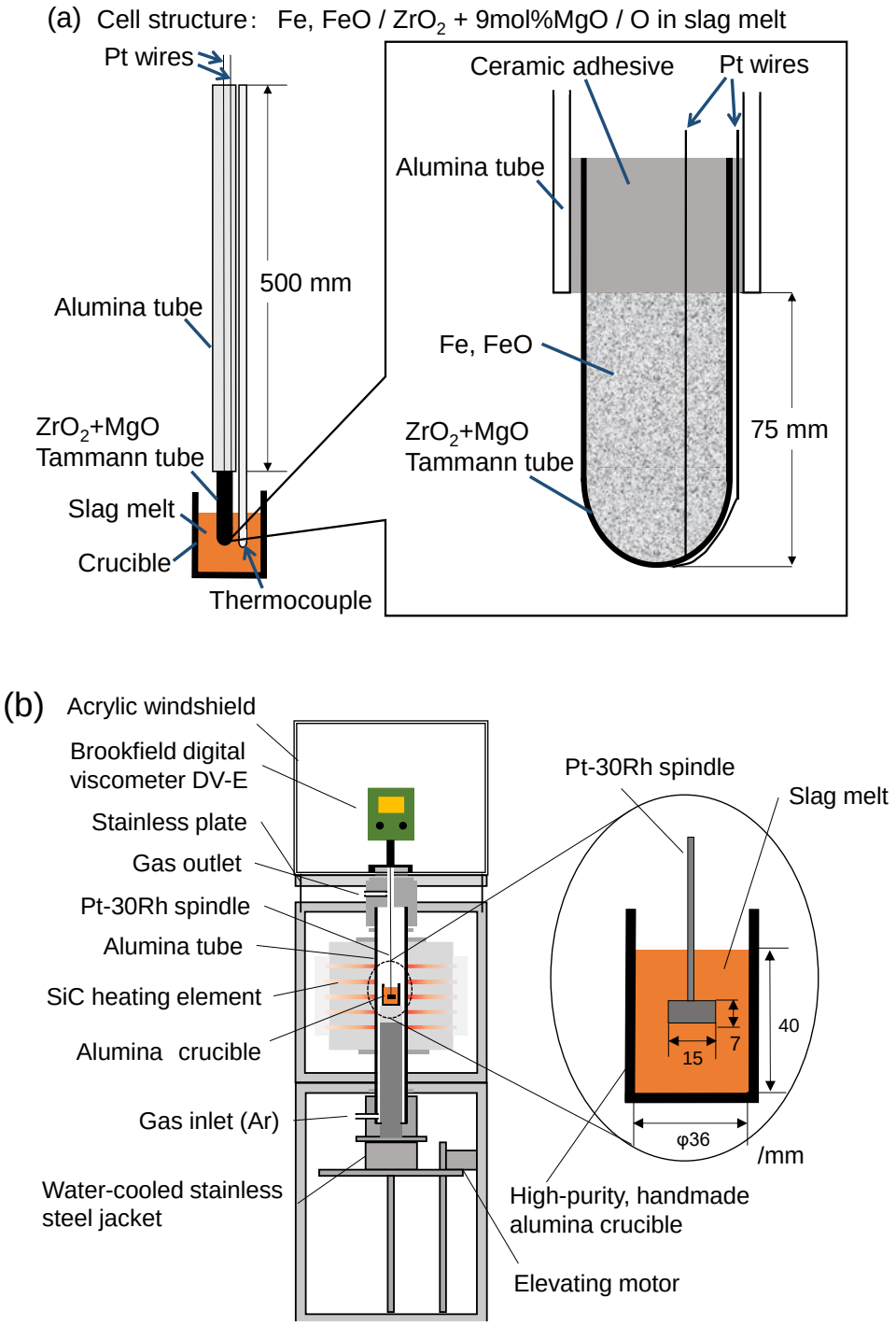

Figure 1: Schematics of (a) zirconia oxygen sensor and (b) viscosity measurement apparatus

Results and Discussion

Table 1 shows the analysed and estimated compositions of the slag samples for viscosity measurements at 1300°C as an example. Under the OP of 4.0×10^{-10} atm, the estimated Fe_2O_3 concentration was less than *ca.* 3 wt%. 5 and 10 wt% Al_2O_3 was added to the batches for FS3 and FS4, respectively. Al_2O_3 from the crucible was dissolved into all slag melts during viscosity measurement processes.

Table 1: Analysed and estimated compositions of slag samples for viscosity measurements at 1300°C; The concentrations are denoted by wt%

Slag sample	FeO	Fe_2O_3	SiO_2	Al_2O_3	Others	Total Fe/SiO_2 ratio
FS1	58.4	2.1	38.5	1.1	-	1.2
FS2	58.9	3.0	31.5	6.8	-	1.5
FS3	58.6	3.3	30.6	7.6	-	1.5
FS4	56.0	2.9	30.5	10.6	-	1.5
Copper slag	43.4	0.7	38.1	5.9	11.9	0.9

Figure 2 shows the temperature dependences of viscosity for the FeO_x (FeO/Fe_2O_3)–SiO_2–Al_2O_3 slag melts, where x = 1–1.5. The viscosity increases gradually with decreasing both temperature and Fe/SiO_2 ratio for the slag melts. A similar dependence of Fe/SiO_2 ratio on viscosity at 1400°C had been obtained for FeO_x–SiO_2–Al_2O_3 slag melts in a previous study.[2]

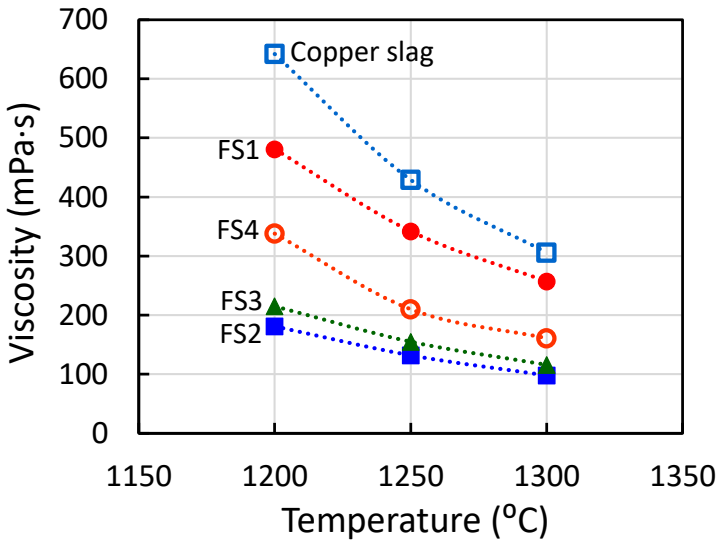

Figure 2: Temperature dependences of viscosity for FeO_x–SiO_2–Al_2O_3 and copper slag melts

Figure 3 shows variations of melt viscosity as a function of Al_2O_3 concentration for the slag melts with a Fe/SiO_2 mass ratio of 1.5. The viscosity increases monotonically with increasing Al_2O_3 concentration in the slag melts containing *ca.* 6–10 wt% Al_2O_3.

The results indicate that the viscosity depends on the free volume between the constituents[4] and the polymerisation degree of the SiO_4 and AlO_4 tetrahedral networks[5]. The constituent of FeO also has both roles of modifier and charge compensator for network breaking to form non-bridging oxygens between SiO_4 and/or AlO_4 tetrahedra and for network forming of AlO_4 tetrahedra, respectively.

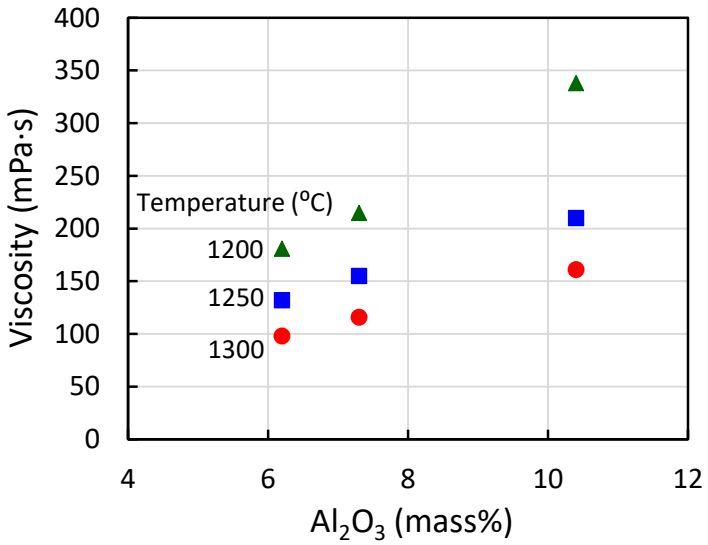

Figure 3: Variations of viscosity as a function of Al_2O_3 concentration for FeO_x–SiO_2–Al_2O_3 synthesised slag melts with an analysed Fe/SiO_2 mass ratio of 1.5

Conclusions

The viscosity of FeO_x–SiO_2–Al_2O_3 slag melts could be evaluated in Ar flow under the oxygen potential control by adding carbon powder in the temperature range of 1200 and 1300°C. The viscosity increases gradually with decreasing both temperature and Fe/SiO_2 mass ratio for the slag melts. The viscosity increases monotonically with increasing Al_2O_3 concentration in the slag melts containing *ca.* 6–10 wt% Al_2O_3.

References

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