EFFECTS OF TEMPERATURE ON DISTRIBUTION BEHAVIORS OF MINOR ELEMENTS IN COPPER FLASH SMELTING —COMPUTER SIMULATION①

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ABSTRACT By newly-developed computer model[1, 2] of the distribution behaviors of minor elements As, Sb, Bi and accessory elements Pb, Zn in copper flash smelting, copper flash smelting process of Guixi Smelter was simulated. Results showed that the predictions by the computer model were in agreement with the known commercial data from Guixi Smelter. Using Nagamori's physical suspension index equation[3], the apparent percentages of Cu and S in the slag were calculated, and the main form of mechanically entrained copper particles in the slag was determined to be sulfide. Furthermore, the effects of smelting temperature upon the fractional pressures, activity coefficients of As, Sb, Bi, Pb, Zn, etc. and their distributions in matte, slag and gaseous phase were analyzed. According to the simulations, when smelting temperature rises, the volatilizations of As, Sb, Bi, Pb and Zn in gaseous phase increase, while their distributions in matte decrease. The increase of smelting temperature is helpful to improve the total elimination rate of above-mentioned elements in gaseous and slag phases.

Key words As Sb Bi Pb Zn simulation computer model thermodynamics

1 INTRODUCTION

The distribution behaviors of As, Sb and Bi in copper smelting process are important. Environmental contamination by minor elements associated with copper-bearing ores and concentrate of those elements in blister copper are problems of increasing severity as ore quality declines. The presence of trace quantities of minor elements in copper significantly reduces its ductility, electrical conductivity, and lowers its thermal conductivity. Embrittlement of copper also occurs due to impurity phase precipitating at copper grain boundary interfaces. Presently, many problems still need to be solved concerning the distributions of impurity elements in gaseous, slag and matte phases. So it is of great theoretical meaning and practical value to study distribution behaviors of impurity elements, such as As, Bi, Sb, Pb and Zn, in smelting process.

2 COMPUTER MODEL

The authors have already developed the computer model of the distribution behaviors of the fifth group elements in copper smelting process[1, 2]. The model can not only predict the effects of process factors such as composition of charges, volume of oxygen-enriched air, smelting temperature, volume percentage of O_2 in oxygen-enriched air, Fe/SiO_2 and matte grade upon the distribution behaviors of minor elements As, Sb, Bi and accessory elements Pb, Zn in copper smelting process, but also simulate the

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following copper smelting processes: copper flash smelting process, Noranda process, Mitsubishi continuous process, etc.

In this paper, one of the process factors of copper flash smelting process —smelting temperature was simulated by this model, and the directive function of thermodynamic analysis in the actual industrial operations was discussed.

3 COMPUTER SIMULATION OF COPPER SMELTING PROCESS

Based on the operating conditions of Guixi Smelter in China, the matte-making smelting in copper flash smelting process was computer-simulated and the calculated results were compared with the commercial data. The agreement between the computer predictions and the commercial data is excellent, so present computer model can be used to monitor and optimize the arsenic, antimony and bismuth elimination in actual industrial operations of copper flash smelting.

The following operating conditions of copper flash smelting in Guixi Smelter are the basis of the simulation: (1) The smelting temperature is 1 473 K. (2) The composition of charges is listed in Table 1. (3) Volume of oxygen-enriched air is $628\,m^3/t$ charge. (4) Fe/SiO_2 is 1.2. (5) The amount of heavy oil is 29.26 kg/t charge. (6) Volume percentage of O_2 in oxygen-enriched air is 33.5%. Table 1 shows the comparison between the results of simulation and the commercial data from Guixi Smelter. It should be pointed out that there is a little difference between the amounts of Cu and S in industrial slag and the results of simulation. This is because the theoretical calculation does not count on mechanically entrained matte particles. Thus it can be concluded that the loss of mechanically entrained matte is mainly due to part of the loss of Cu in slag. As to matte-making in copper flash smelting process, the following equations by Nagamori and Mackey[3] are applied.

$$[Cu]_{sl}^{ap} = 0.01 \times ([Cu]_{sl} \times (100 - S_{mt}^{sl}) + [Cu]_{mt} \times S_{mt}^{sl}) \quad (1)$$

$$[S]_{sl}^{ap} = 0.01 \times ([S]_{sl} \times (100 - S_{mt}^{sl}) + [S]_{mt} \times S_{mt}^{sl}) \quad (2)$$

where S_{mt}^{sl} is the estimated suspension index which indicates weight percentage of suspended matte phase in bulk slag phase; sl and mt stand for slag and matte phases, respectively; $[Cu]_{sl}^{ap}$ and $[S]_{sl}^{ap}$ stand for apparent percentages of Cu and S in commercial slag containing mechanically suspended matte, respectively.

According to Jalkanen's reports[4], S_{mt}^{sl} is 1 when matte grade is 50 in copper flash smelting. Thus total amount of the loss of copper in slag, or apparent percentage of Cu in slag is:

$$[Cu]_{sl}^{ap} = 0.01 \times (0.21 \times 99 + 51.93 \times 1) = 0.73$$

The apparent percentage of S in slag is:

$$[S]_{sl}^{ap} = 0.01 \times (0.12 \times 99 + 22.32 \times 1) = 0.34$$

The predicted results of Cu and S in the slag are 0.73% and 0.34%, respectively, and the amounts of Cu and S in the industrial slag are 0.76% and 0.32%, respectively. So the agreement between the predictions and the commercial data is good.

Table 1 The comparison between the results of simulation and the commercial data

Charge constitutents	Concentrate / %	Industrial matte/ %	Predicted matte/ %	Industrial slag/ %	Predicted slag/ %
Cu	22.30	51.94	51.93	0.76	0.21
S	28.83	22.63	22.32	0.32	0.12
Pb	0.14	0.24	0.22	0.02	0.02
Bi	0.036	0.017	0.018	< 0.005	0.004
Fe	26.59	21.24	22.63	41.99	43.58
Zn	0.33	0.26	0.14	0.23	0.21
Sb	0.087	0.05	0.03	0.11	0.10
As	0.12	0.08	0.05	0.03	0.03

Note: The commercial data were taken by the authors at Guixi Smelter in July 1993.

4 EFFECT OF SMELTING TEMPERATURE UPON DISTRIBUTION BEHAVIORS OF MINOR ELEMENTS

The industrial operation conditions of copper flash smelting at Guixi Smelter are the basis of the simulation. The smelting temperature varies from 1 400 to 1 650 K. The predicted results are shown in Figs. 1~ 3.

4.1 The effects of smelting temperature upon the activity coefficients of minor elements in matte

Fig. 1 shows the relations between smelting temperature and activity coefficients of As, Sb, Bi, PbS, ZnS and Pb in matte. When smelting temperature increases, the activity coefficients of As, Sb, Bi and Pb in matte decrease. The activity coefficient of Pb decreases the most. When smelting temperature rises from 1 473 to 1 653 K, the activity coefficient of Pb in matte decreases from 33.6 to 19.8 and that of Sb decreases from 10.98 to 8.79. The activity coefficients of As, Bi, PbS and ZnS in matte do not change significantly.

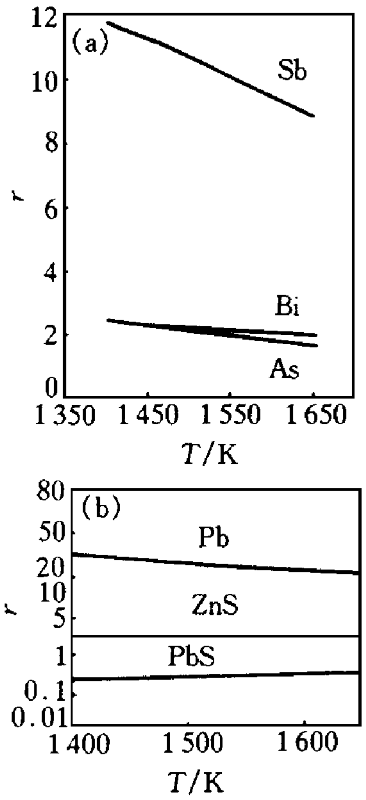

Fig. 1 Activity coefficients(r) of minor elements in matte vs smelting temperature

4.2 The effects of smelting temperature upon the volatilization of As, Sb, Bi, Pb and Zn in gaseous phase

Impurity can volatilize as metal fraction or volatile oxide and sulfide and even produce various kinds of volatile matter such as element, sulfide and oxide, etc. Some researchers have already discussed thermodynamics of copper smelting process. Nagamori and Chaubal believed that the fractional pressure of AsS in gaseous phase was larger than that of As during matte-making and copper matte converting processes, but Itagaki and Yazawa[5] concluded that the fractional pressure of As was larger, even in matte-making smelting process.

Fig. 2 shows the effect of temperature upon the volatilization of As, Sb, Bi, Pb and Zn in gaseous phase, where p stands for fractional pressure. When the smelting temperature rises, the fractional pressures of AsS, SbS, AsO and Bi increase, while those of As_2 and BiS have a trend of decrease. When the smelting temperature increases from 1450 to 1650K, $p_{AsS} > p_{As_2} > p_{AsO}$ and $p_{BiS} > p_{Bi}$ can be obtained. When the temperature is high, As exists mainly in the form of AsS, Zn in the form of Zn in gaseous

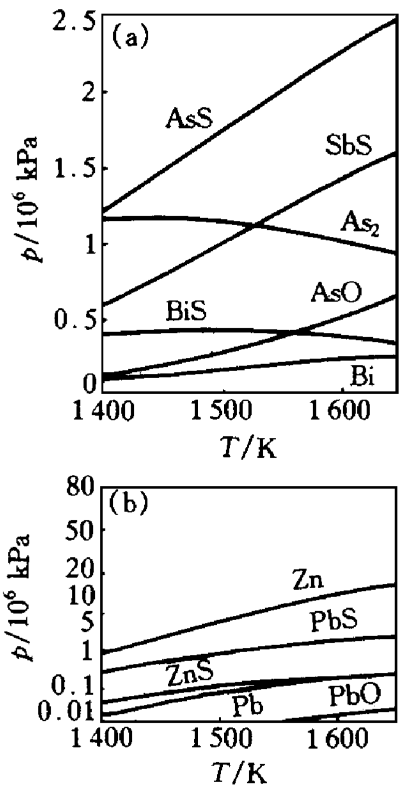

Fig. 2 Volatilization of minor elements in gaseous phase vs smelting temperature

phase, Pb in the form of PbS, and $p_{PbS} > p_{Pb} > p_{PbO}$. The amount of PbO in gaseous phase is negligible. When smelting temperature rises from 1 400 to 1 650 K, the increase amounts of p_{Zn} and p_{PbS} are rather large, especially p_{Zn} which increases almost 20 times. From the above, it is concluded that As, Sb, Bi and Pb exist mainly in the form of sulfide in gaseous phase, except Zn mainly in the form of element.

4.3 The effects of smelting temperature upon the distribution behaviors of As, Sb, Bi and Zn in copper flash smelting

The change of smelting temperature has great effects upon the distributions of Sb and Bi in the slag. Fig. 3 shows the effects of smelting temperature upon the distribution behaviors of As, Sb and Bi in copper smelting process. $(Me)_g$ stands for the distributions of As, Sb, Bi, Pb or Zn in gaseous phase, $\langle Me \rangle_{sl}$ for those in slag, and $[Me]_{mt}$ for those in matte. When the smelting temperature rises, the volatilization rates of As, Sb, Bi, Pb or Zn increase in gaseous phase while decreasing in matte. Obviously, the effects of smelting temperature upon the distributions of Sb, Pb, Zn in gaseous and matte phases are great.

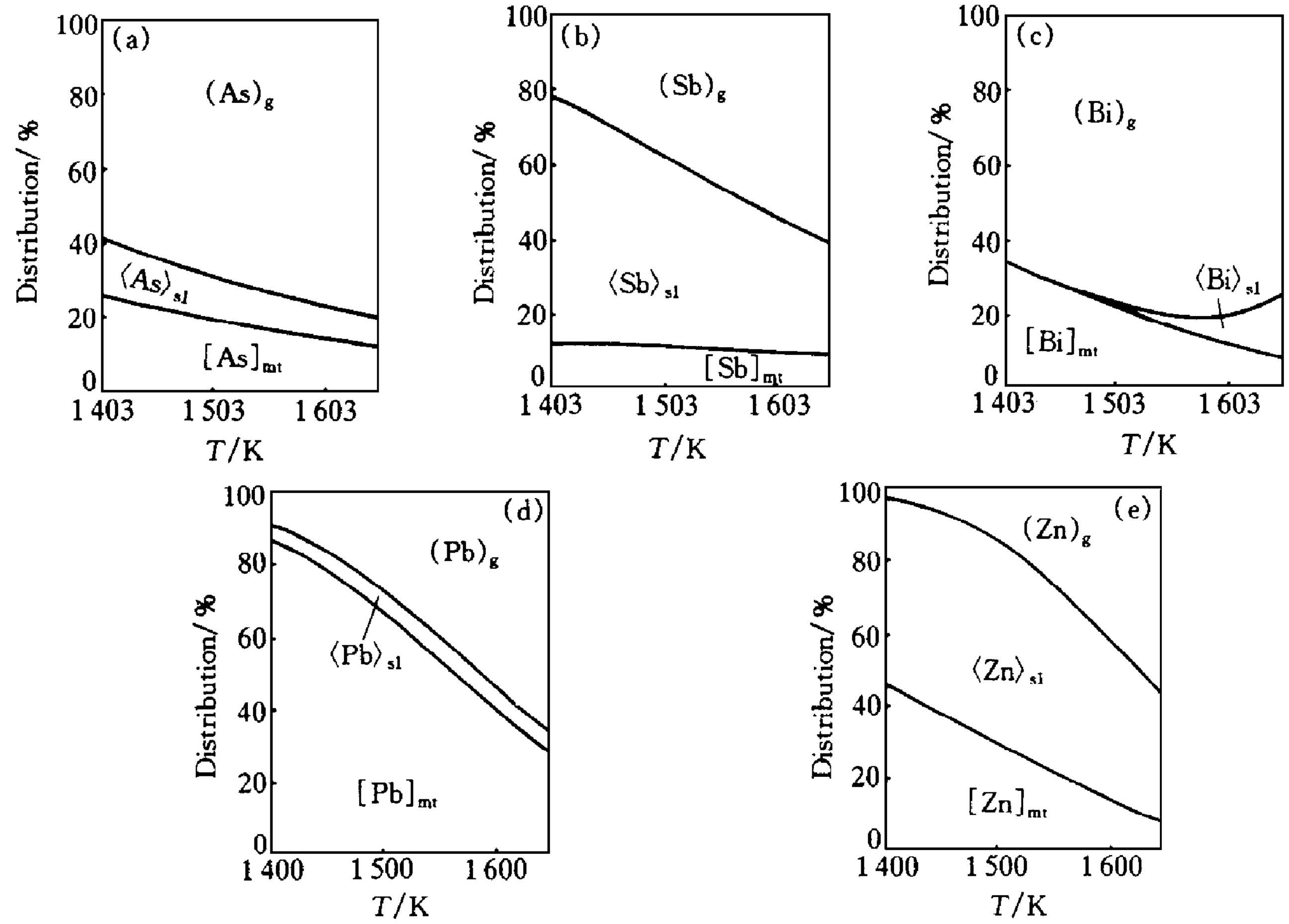

Fig. 3 Distribution of minor elements vs smelting temperature

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