

SOLUBILITY OF COPPER IN AUTOGENOUS SMELTING SLAG

A. V. Tarasov

State Research Center of Russian Federation -
State Research Institute of Non-ferrous Metals "Gintsvetmet"
Moscow, Russia

ABSTRACT

The effect of Al_2O_3 on solubility of copper in slag containing 20 to 40% SiO_2 with the copper content of matte varying from 40 to 80% has been investigated. Regression equations have been obtained which establish a relation between copper and Fe(III) contents of slag with the composition of matte and slag. A comparison of actual solubility of copper in commercial slags with a computed value has indicated that copper losses due to copper dissolved in slag can be reliably predicted for matte smelting processes.

INTRODUCTION

The copper content of slag is determined as a sum of soluble loss and loss in the form of sulfide suspension. The soluble loss can be determined by investigating the thermodynamic equilibrium of the matte-slag-gas phase system. The proportion of sulfide suspension in slag is assessed by a comparison of the total copper content of slag with soluble loss. It is dependent on the design of the smelting unit and the specific smelting conditions.

AIM OF STADY

The copper solubility has been studied in the process of an investigation of equilibrium in systems copper/matte/iron-silicate slag/gas phase [1, 2] and matte/iron-silicate slag/gas phase [3, 4] with controlled sulfur dioxide gas pressure. Slags generated in industrial processes contain up to 10% Al_2O_3 and other constituents [5].

The solubility of copper in multi-component slags has not been studied to a sufficient extent. Only in [6], equilibrium in the system matte/slag/gas phase (containing SO_2) has been investigated for iron-silicate slags saturated with Al_2O_3 .

In [7, 8] it was proposed to predict the copper content of slag in the process of matte smelting and blister copper smelting based on the data obtained under equilibrium conditions. This computation was based on regression equations relating reactivity coefficients of $\text{CuO}_{0.5}$ and $\text{CuS}_{0.5}$ to the slag composition, with oxidizing and sulfidizing potential of the respective system and the smelting process temperature. In [9] examples are presented of the use of the model offered in [7, 8] for various commercial processes. The equilibrium in the matte/slag/gas phase system was investigated using two different methods: circulating method similar to [10] and flow-through method [6].

MATERIALS AND METHODS

To prevent dispersion of matte in slag, they were melted separately at opposite ends of an alundum or quartz boat places with a slight slope in a quartz ampoule. Slag after melting flowed into the lower part of the boat and no suspension was formed.

Using the circulation technique, a boat with a weighed sample of slag and matte was placed in a quartz reactor connected to a close circulation system from which air was evacuated to a residual vacuum of about ~ 1 Pa (10^{-5} atm). Then the system was filled with a gas mixture of $\text{CO}_2 + \text{CO}$. The reactor was placed in a furnace heated to the test temperature. Gas samples were periodically collected through a measuring valve and analyzed with the aid of a chromatograph.

In the case of the flow-through test method, slag and matte were brought to an equilibrium with a gas mixture of $\text{Ar} + \text{SO}_2$. The ratio of components in the gas phase was maintained at a level ensuring certain oxidizing and sulfidizing potentials to produce slag with pre-determined ferric iron and sulfur contents. The ferric iron content of the equilibrium slag was varied from 3 to 10% by weight, that of sulfur from 0.05 to 1.5% by weight, which corresponds to their respective concentrations in commercial slags.

The feed matte was a mixture of synthetic sulfides, Cu_2S and FeS ; the copper content varied from 30% to 80%. The feed slag was prepared by fusion of ferrous iron oxalate and quartz in iron crucibles in an argon stream. The SiO_2 and Al_2O_3 content varied from 22% to 40% and from 0 to 18%, respectively.

The loss of non-ferrous metals with slag is strongly dependent on the ratio of modifier cations and lattice-forming cations, i.e. the basicity of the slag [5, 11]. In the metallurgical practice various alternatives are common for comparison of slags using their basicity [11].

It was selected to use the ratio (by weight) of $(\text{FeO}) / (\text{SiO}_2 + \text{Al}_2\text{O}_3)$ which was varied in the tests from 0.7 to 1.6, which corresponds to the basicity of common commercial slags generated in advanced autogenous copper smelting processes used in Russia, i.e., Vanyukov smelting process (PV) and oxygen-flame smelting (KFP). The temperature of the tests was maintained at two levels: 1523 K and 1573 K.

Preliminary tests had indicated that the equilibrium was reached after about 3 hours, which is in good agreement with the data presented in [10]. In our tests this retention time was 4 hours.

In [6], in the process the research of the equilibrium of matte/slag/gas phase system for $\text{FeO}-\text{Fe}_2\text{O}_3-\text{SiO}_2+\text{Al}_2\text{O}_3$ slags saturated with Al_2O_3 at 1573 K, the effect of the matte composition, SiO_2 and ferric iron contents on the copper solubility in slag was determined. It was demonstrated that an increase in the copper content of matte above >50% resulted in a substantial increase in copper solubility in slag. An increase in the SiO_2 content of slag negatively affected the copper solubility within the entire range of matte compositions.

The present study was carried out to investigate the effect of Al_2O_3 on the copper solubility at 1523 K for slags saturated with silica and containing 5-8% ferric iron with variations in copper content of matte from 40% to 80% (Figure). For mattes containing <50% Cu, the copper solubility decreased only slightly with an increase in the Al_2O_3 content of slag, whereas for higher grades of matte the effect of Al_2O_3 becomes stronger.

RESULTS

Copper solubility was studied in slags containing, %: 23-28 SiO₂, 5-10 ferric iron, and 15-17 Al₂O₃ with mattes containing 55-80% Cu. As a result of statistical processing of the experimental data obtained in this study and in [6], a regression equation was elaborated which relates the copper solubility in slag with matte and slag compositions:

$$(Cu) = A - 9.73 \cdot 10^{-3}[Cu] + 1.65 \cdot 10^{-4}[Cu]^2 + 9.92 \cdot 10^{-2}(Fe) - 2.17 \cdot 10^{-2}(SiO_2) - 8.15 \cdot 10^{-4}(Al_2O_3), \quad (1)$$

where (Cu) is the content of soluble copper in slag, % by weight; [Cu] is the copper content of matte, % by weight; (Fe), (SiO₂), (Al₂O₃) are ferric iron, SiO₂, Al₂O₃ contents of slag, % by weight; $A=9.63 \cdot 10^{-1}$ (at 1523 K) and $8.63 \cdot 10^{-1}$ (at 1573 K).

The coefficient of multiple correlation for Equation (1) is equal to 0.986; the coefficient of variation is 8.55%. The matrix for paired correlation coefficients for the parameters investigated has the following form (number of experimental points = 90; tabular correlation coefficient for the significance level of 0.05 - 0.207 and for the significance level of 0.01 - 0.270):

	(Cu)	[Cu]	(Fe)	(SiO ₂)
[Cu] ...	0.68			
(Fe) ...	0.61	0.34		
(SiO ₂) ...	-0.43	-0.17	-0.06	
(Al ₂ O ₃) ...	-0.06	-0.12	-0.03	-0.35

The solubility of copper in slags from the PV and KFP processes as determined by the electron-probe analysis (see the Table below) was compared with the solubility computed by Equation (1).

The content of oxide iron (ferric) in slags generated in commercial smelting processes is dependent on the degree of oxidation of the system, i.e., the matte composition and the acidity of slag.

A comparison of actual and computed values of copper solubility in slag has indicated that there is satisfactory agreement between two sets of data. The average deviation of computed values from the actual data was about 8% (rel.) which is comparable with the error of determination of copper in slags by the atomic-absorption method with the aid of a Perkin Elmer spectrophotometer.

Since the proportion of soluble loss of copper in slags from the KFP and PV processes is about 80% of the total copper content of slags [9], computations using Equation (1) make it possible to estimate the total copper losses with slags of the above processes. Equation (1) was used for plotting thermodynamic and smelting models [12].

CONCLUSIONS

1. A regression equation was developed which correlates the copper solubility and ferric iron content in slag with the matte and slag compositions.
2. A comparison of actual copper solubility in commercial slags with computed values has indicated that soluble copper losses with slag from matte smelting may be reliably predicted.

REFERENCES

1. Eguchi M, Yazawa A.// Trans. Japan. Inst. Metals.- 1977.- Vol. 18.- N 4.- P.353-360.
2. Geveci A., Rosenqvist T.// Trans. Inst. Min. Met.- 1973.- N 805C.- P.193-201.
3. Jalkanen H.// Scand. J. Metallurgy.- 1981.- N 10.- P. 177-184.
4. Sehnalek F., Imris I. Advances in extractive metallurgy. London: Inst. Min. and Met., 1972.- P.39-62.
5. Vanyukov A.V., Zaitsev V.Ya. Slags and mattes in non-ferrous metallurgy. Moscow, Metallurgia, 1969.- 408 p.
6. Kaplan V.A., Vaskevich A.D., Zaitsev V.Ya., Rabicheva L.M.// Izv. AN SSSR, Metally.- 1982.- N 2.- P.31-34.
7. Vaskevich A.D., Sorokin M.L.// Tsvetnye Metally.- 1982.- N 7.- P. 25-27.
8. Vaskevich A.D., Sorokin M.L., Kaplan V.A.// Tsvetnye Metally.- 1982.- N 10.- P.22-26.
9. Sorokin M.L., Vaskevich A.D., Vanyukov A.V.// Tsvetnye Metally.- 1983.- N 9.- P.14-16.
10. Zaitsev V.Ya., Tsesarsky V.S., Vaskevich A.D., et al. Investigation of processes for production of heavy non-ferrous metals. Transactions of Moscow Institute of Steel and Alloys. Moscow, Metallurgia, 1976.- N 91.- P.17-28.
11. Yesin O.A., Geld P.V. Physical chemistry of pyrometallurgical processes. Moscow, Metallurgia, 1966.- Part 2.- 704 p.
12. Author's Certificate No 936625, USSR, C 22 B 5/02. Method for processing of sulfide materials containing heavy non-ferrous metals/ Zaitsev V.Ya., Tarasov A.V., Kaplan V.A. et.al.

Table

Comparison of actual copper solubility in PV and KFP slags with values computed by Equation (1)

Cu content of matte	Cu content of sulfide suspension	Slag composition			Soluble Cu in slag	
		Fe (ferric)	SiO ₂	Al ₂ O ₃	Actual	Computed
Vanyukov Smelting Process (PV)						
56.0	56	3.6	22.8	2.2	0.58	0.69
56.0	56	2.7	23.5	2.1	0.56	0.61
56.0	56	2.6	29.9	2.2	0.50	0.55
70.3	70	6.2	29.7	1.8	0.84	0.86
70.3	70	4.3	29.5	1.8	0.60	0.69
70.3	70	2.6	28.2	1.8	0.55	0.61
78.1	78	8.7	29.7	2.0	1.39	1.38
78.1	78	5.2	31.8	2.0	1.11	1.04
78.1	78	3.2	29.7	2.0	0.79	0.84
69.2	69	7.3	31.5	1.9	0.93	1.03
69.2	69	3.3	30.4	1.9	0.65	0.69
69.2	69	2.2	30.5	2.0	0.57	0.63
74.9	75	4.7	30.0	2.3	0.72	0.85
74.9	75	2.9	30.4	2.3	0.58	0.69
78.4	78	9.4	27.8	2.1	1.55	1.51
78.4	78	8.5	28.2	2.1	1.45	1.41
Oxygen-Flame Smelting Process (KFP)						
42.1	56	7.5	30.6	6.9	0.87	0.89
38.9	52	6.8	33.7	7.0	0.77	0.76
42.0	56	7.4	28.5	6.9	0.89	0.91
40.5	54	5.5	32.4	7.3	0.57	0.66
55.0	70	10.6	35.4	6.9	1.36	1.28
38.5	52	6.6	31.6	7.3	0.65	0.76
47.9	65	6.9	32.8	4.2	0.82	0.89

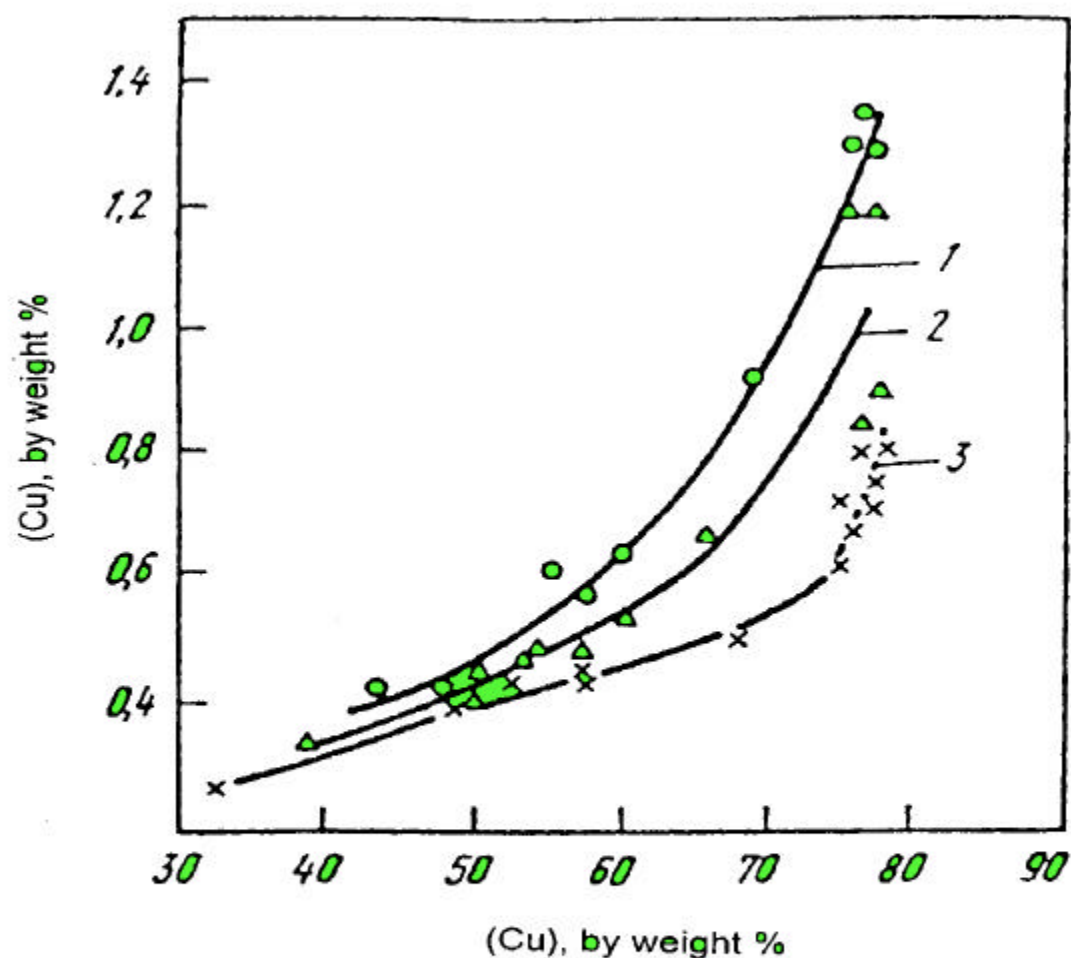


Figure - Solubility of copper in slag with the different Al_2O_3 , content, %:
 1 - 4,5-5,5; 2 - 9,0-10,5; 3 - 14,0-15,5