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November 1999 – October 2000

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ECOLOGICAL CLEAN PROCESS OF CRUDE COPPER PRODUCTION

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(Israel)

Institute of Metallurgy and Ore Benefication (IMiO)
Ministry of education and science
(Kazakhstan)

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by cooperative Grant of USAID _ TA-MOU-98-CA17-017

"ECOLOGICAL CLEAN PROCESS OF CRUDE COPPER PRODUCTION"

for the first year (November 1999 - Oktober 2000)

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2000

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SUMMARY

The aim of this work is an integrated investigation for the development of a continuous process of crude copper production based on autogeneous melting of sulphide raw materials in Vanyukov's furnace and deep impoverishment of slags in this furnace by a coke filter.

Samples of slags and mattes selected in November 1999 at the Balkhash copper melting plant (Kazakhstan) were investigated at the Technion - Israel Institute of Technology. Composition and microstructure were characterized by Scanning Electron Microscopy (SEM) and Energy Dispersive Spectroscopy (EDS). Conclusions were drawn about the character of metal slag losses (Cu, Zn, Pb). Selected properties (viscosity, density and surface tension) of liquid slag and matte were determined in the temperature range 1350-1550 ^{0}C.

Kinetic investigations of the oxidation processes in sulphide melts based on copper and iron, and of the reduction of slags by solid carbon were made in IMiO (Kazakhtan). The mechanism of copper oxide reduction by solid carbon was analyzed by continuous thermo-gravimetry.

A laboratory installation for the study of liquid slag reduction by solid carbon was assembled and samples of slag for the second year of research have been taken from the Balkhash plant.

Two scientific articles based on these results have been jointly prepared and submitted for publication.. One patent application is being prepared for the innovative installation designed and constructed to investigate the process of slag reduction in a furnace fitted with a coke filter.

To endure efficient scientific cooperation Professor S.E.Vaisburd spent one week at IMiO (Almaty) in November 1999, where he coordinated project plans. Professor S.M.Kozhakhmetov also spent one week at the Technion, in April 2000, where he met with the Technion team and participated in the preparation of the semi-annual report. Professor S.E.Vaisburd spent a further two weeks in Almaty, in October 2000, where he prepared the annual report with colleagues from Kazakhstan. A graduate student from IMiO Elnar Kenzhaliev spent 5 months at Technion, from February till July 2000, where he mastered characterization methods based on SEM and EDS, as well as the method used to measure the physical properties of the melts. The close cooperation of the partners allowed samples collected in Kazakhstan to be investigated using the unique facilities available in Israel, while obtained both in both Kazakhstan and Israel were analyzed jointly and in person by co-workers from both countries.

The goals of the 1st year have been fully achieved.

A. INTRODUCTION

This research is an integrated scientific investigation for the development of a continuous process of crude copper production based on autogenous melting of sulphide raw materials in Vanyukov's furnace and deep impoverishment of slags in a furnace fitted with a coke filter.

The two branches of the proposed technology are currently in different locations. Vanyukov's furnace is in operation at the Balkhash copper melting plant (in Kazakhstan) and is able to supply industrial samples produced by this process. The furnace fitted with a coke filter is still to be constructed, so this investigation must include both the case of slag reduction by solid carbon and a model for the coke filter furnace.

This report therefor describes:

1. The charcterization of matte and slag from Vanyukov's furnace using SEM/EDS.
2. The measurement of physico-chemical properties (viscosity, density and surface tension) of these melts.
3. The influence of some factors on the oxidation of copper sulphide melts.
4. The mechanism of copper oxide reduction by solid carbon, and:
5. The construction of a laboratory model of a furnace with coke filter.

B. RESEARCH ACCOMPLISHMENTS

1. MICROSTRUCTURE AND COMPOSITION OF SAMPLES FROM VANYUKOV'S FURNACE

Method

Phase and elemental analyses were performed by scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS). The phase composition of the samples was determined by X-ray diffraction (XRD) analysis.

Sample preparation

Samples of slag and matte were obtained from Vanyukov\s furnace in the Balkhash copper melting plant (Kazakhstan). The chemical analysis of the samples was done in IMiO (Almaty, Kazakhstan), and the composition of the samples was presented in the 1st Half-year Report [1].

Specimens for SEM/EDS measurements were cut from the samples, diamond polished and carbon coated. All sample preparation and all measurements were performed at Technion (Israel).

Results

Representative results of SEM/EDS investigation are presented in figs.1 and 2. Fig.1 shows a complicated phase composition in the cooled matte. Most phases are sulphides but of very diverse chemical composition: copper-iron sulphides, zinc-iron sulphides and copper-iron sulphides containing lead are all present, as well as lead - zinc compositions. Small amounts metal phases (copper and copper alloys) and magnetite were also detected. This

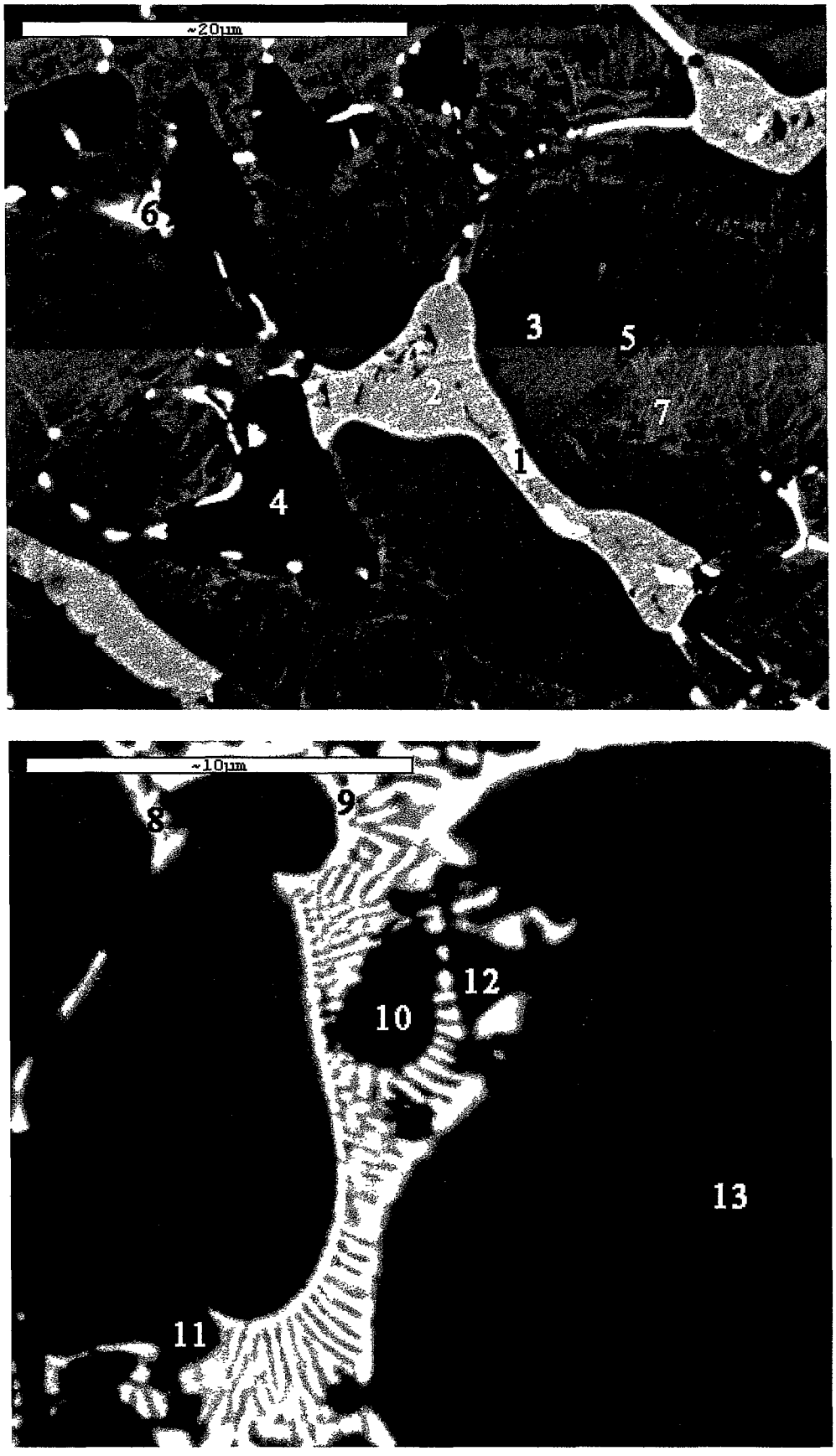
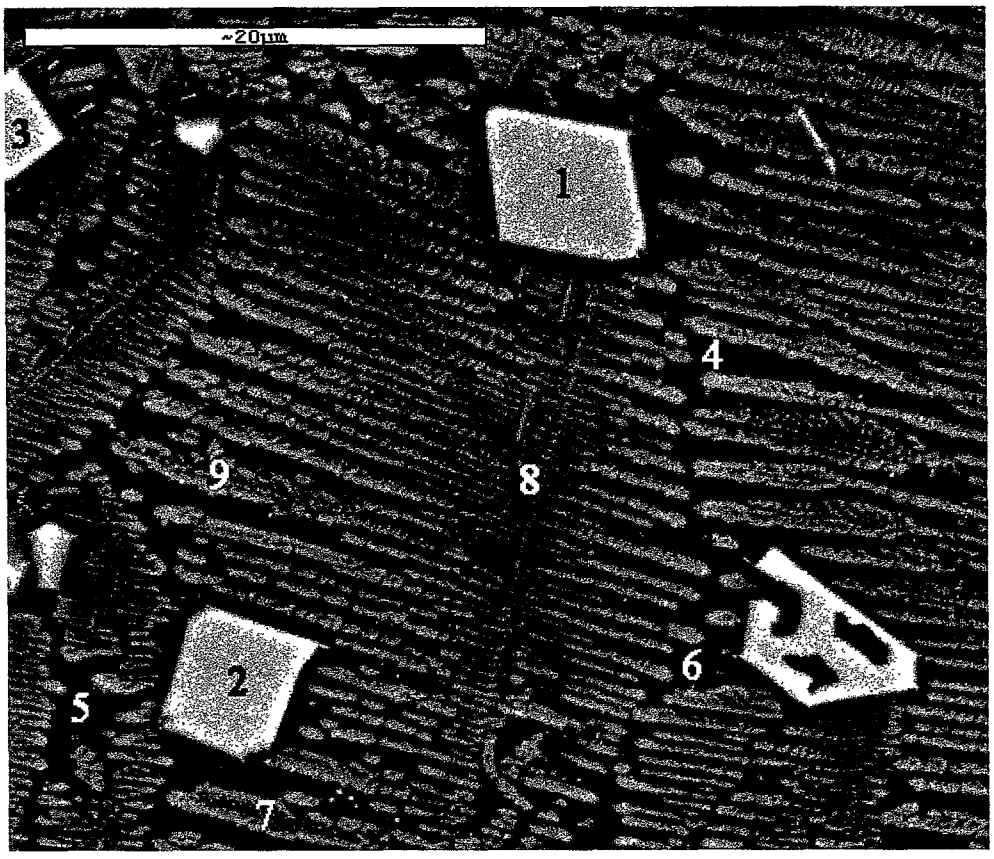


Fig.1. SEM micrographs from the sample N1 (matte). Back scattered electrons.
1, 2 - Metal alloys; 3, 4, 6-10, 13 - Sulfides;
5, 11, 12 - Magnetite.



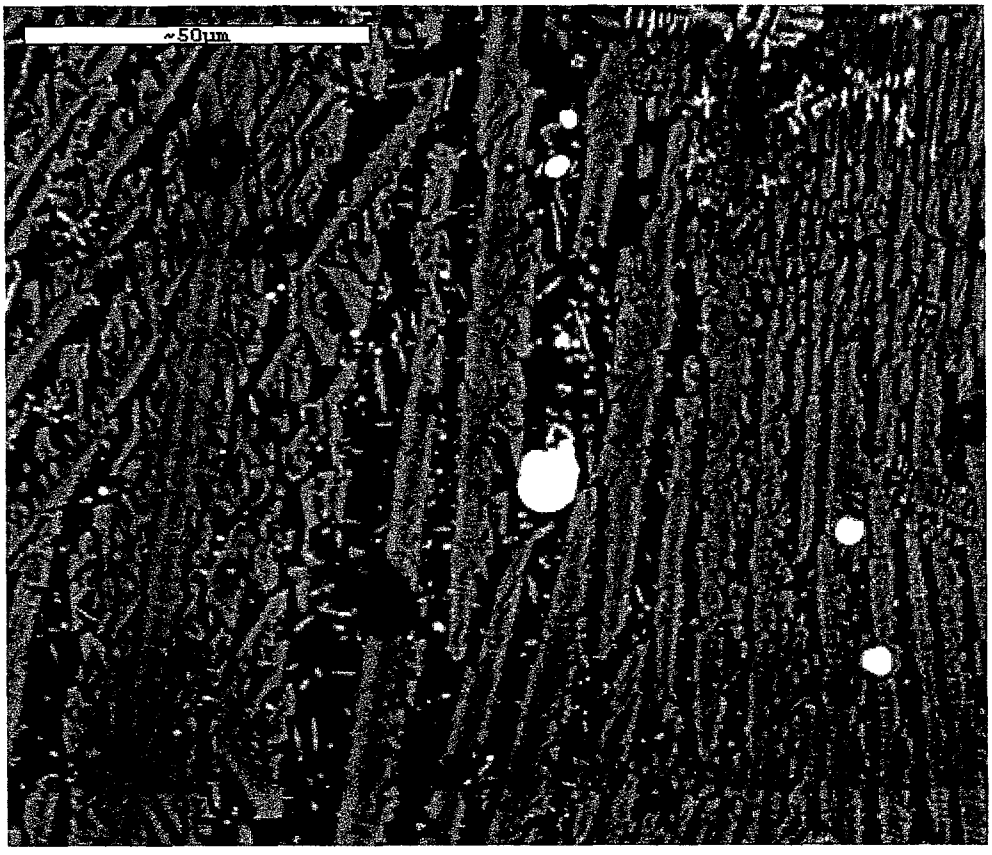


Fig.2. SEM micrographs from the sample N2 (slag). Back scattered electrons.
1-3 Magnetite, 4-9 Fayalite, 24-26 Coarse sulfides, 27-28 Fine sulfides.

complex variety of phases is a result of liquation during cooling of the homogeneous matte melt. The matte also contains a few slag inclusions.

Fig.2 shows two types of matte inclusions in a continuous field of silicates: regulae of 5-10 μm (positions 24 - 26), together with regulae of about 0.2 μm (positions 27 and 28).

The chemical composition of these regulae varies. The cooled slag also includes magnetite as a separate phase resulting from liquation.

Discussion

The chemical and SEM/EDS data allow analysis of the homogeneous liquid matte and slag compositions, while a thermodynamic calculation of the equilibrium between matte and slag was also carried out. The results make clear some fundamental principles related to the problem of metal losses with the waste slag.

The combined analysis of all the data yields the quantitative partition of metals (copper, lead, zinc, cobalt) associated with mechanical, physical and chemical losses in the ferrous silicate slag. This result determines the slag impoverishment process in the coke filter furnace.

Both the experimental data and a detailed discussion are given in an article to be submitted to Metallurgical Transactions (USA) and which is attached to this report.

2. PHYSICO-CHEMICAL PROPERTIES OF MELTS FROM VANYUKOV'S FURNACE

Method

The density and surface tension of liquid slag and matte were measured by the maximum bubble pressure method, while the viscosity of the slag was measured by the rotational method. All measurements were performed in the experimental unit developed by the Faculty of Materials Engineering of the Technion (Haifa) [2]. The high temperature viscometer was calibrated before making the measurements [1].

Samples preparation

The matte and slag samples were the same as those studied in the previous section, taken from Vanyukov's furnace in the Balkhash copper melting plant. The industrial slag-containing matte inclusions must behave as a Newtonian liquid for the viscosity measurements to be valid. Preliminary melting of the slag enabled flotation of matte regulae by SO_2 gas and their remuval as a foam. The same procedure removed slag inclusions from the industrial matte samples.

Results

Measurements were performed in the temperature range 1350 – 1550 ^{o}C and extrapolated to a temperature of 1300 ^{o}C. Fig.. 3 shows an example of the data obtained. The temperature of the dynamic viscosity is exponential dependence. The density and surface tension data demonstrate also show a classical temperature dependence, which is linear for these properties [3].

The matte viscosity cannot be measured by the rotational method used for slag measurements because of the high fluidity of the matte, and for matte and metal melts the torsion oscillation method has to be used [4]. The kinematic viscosity values for the liquid matte were therefor calculated from reference data [4].

Discussion

The matte and slag melts investigated here are very complex liquids. Therefore the measured data cannot be compared directly with known reference data for either matte [4] or slags [5]. However, the measured data are in the range of values expected for liquid slags and mattes found in traditional metallurgical processes [6-8].

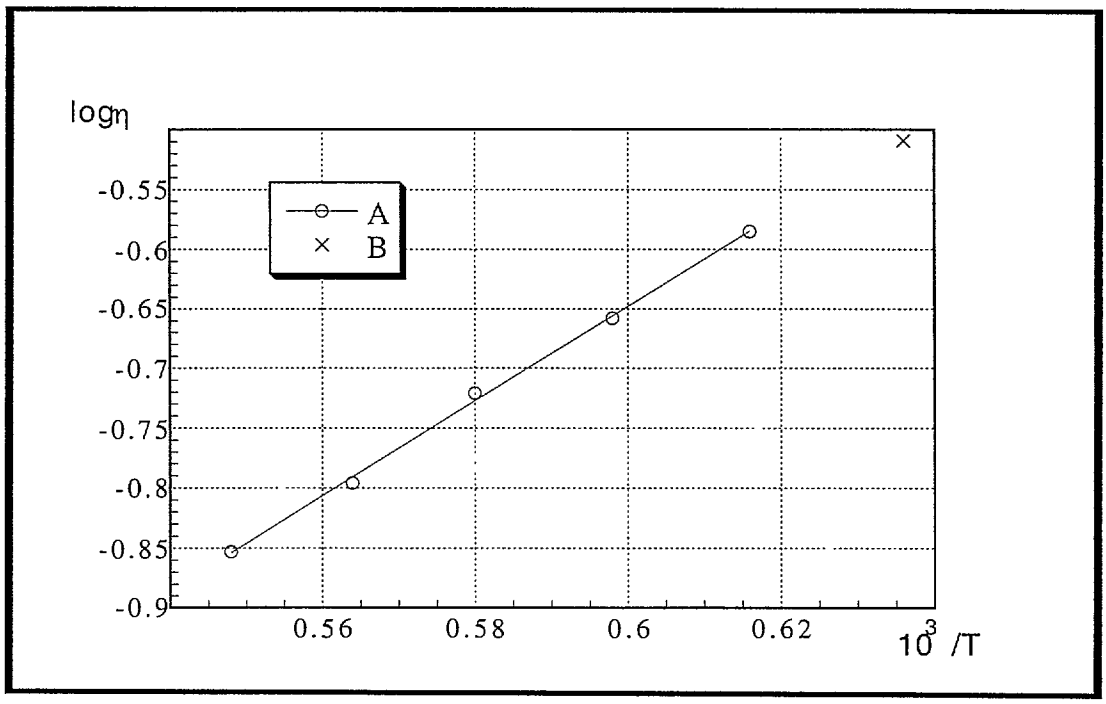


Fig.3.
Viscosity (η) of the waste slag.
A – experimental data, B – data extrapolated to 1300 °C.

The analysis of the present data leads to the conclusion that the properties of the melt satisfy the requirements of the process, and that the viscosity of the slag and matte is sufficiently low to ensure that the melts flow easily from the furnace. In addition to the low slag viscosity, the slag density is sufficiently less than the slag density to ensure that separation of matte regulae in the slag is effective. The surface properties of the melts (interfacial energies) also favour effective coalescention of matte regulae in the slag.

Full for Vanyucov's process and a more detailed discussion of these data are to be given in the paper which is to be submitted to Metallurgical Transactions (USA) and is attached to this report.

3. INFLUENCE OF VARIOUS FACTORS ON THE MATTE OXIDATION PROCESS

Method

The influence of the degree of matte metallization, of additions of metallic copper and iron, of slag-forming oxides and of carbon on the rate and mechanism of liquid copper-rich matte oxidation was studied by continuous SO_2 analysis in the gas phase, by continuous conduction measurements, and also by chemical and physico-chemical analysis of the oxidized products.

Samples for investigation

Experiments were performed on a synthetic copper matte with varying ratios of copper and iron in the melt. The melt was a stochiometric mixture of sulphides: Cu_2S and FeS.

Results

Experimental data for the temperature interval 1200-1400 ^{0}C were interpreted by planning a complete, three-phase experiment. The results of the study correlated well with the results of earlier work at the Institute of Metallurgy and Ore Benefication [9,10].

The new experiments concentrated on the oxidation of melt compositions of the system FeS - Cu_2S in the presence of carbon, since the conditions of Vanyukov's furnace include additions of coal in the sulphide burden.

The following equation for the maximum rate of oxidation in this series of experiments was found for the case of equal accessibility of oxygen to both the sulphide and carbon:

$$V_{max}= -0{,}0609+0{,}0434X_1+0{,}2466X_2-0{,}00113X_3-0{,}01334X_1\cdot X_2+0{,}007167X_2\cdot X_3+ +0{,}005683X_1\cdot X_3-0{,}007733X_1\cdot X_2\cdot X_3,$$

where: V_{max} is the maximum rate of oxidation of an iron - copper sulphide melt in mg/(cm^2·sec); X_1 is the molar fraction of FeS in the melt; X_2 is the pressure in atmospheres; and X_3 is the quantity of carbon in the sample.

Changes in the degree of oxidation for FeS - Cu_2S melts from the initial composition with additions addition of 20 wt% of carbon in the sample are shown in figs. 1 and 2 (points on the curve are taken randomly from a continuous curve). As expected, the degree of oxidation increases with the iron content in the melt and decreases when carbon is added.

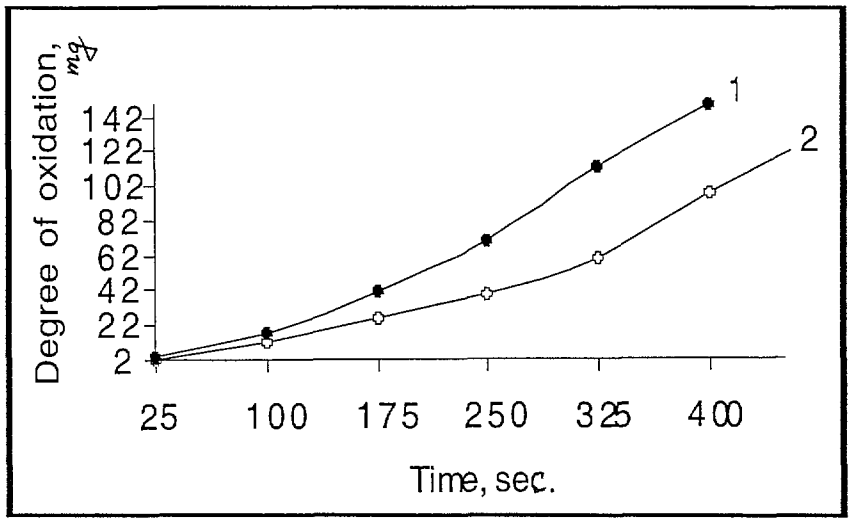


Fig. 4.
Degree of FeS - Cu_2S melt oxidation by air oxygen at 1200 ^{0}C.
1 – $3FeS{\cdot}Cu_2S$; 2 – $FeS{\cdot}Cu_2S$

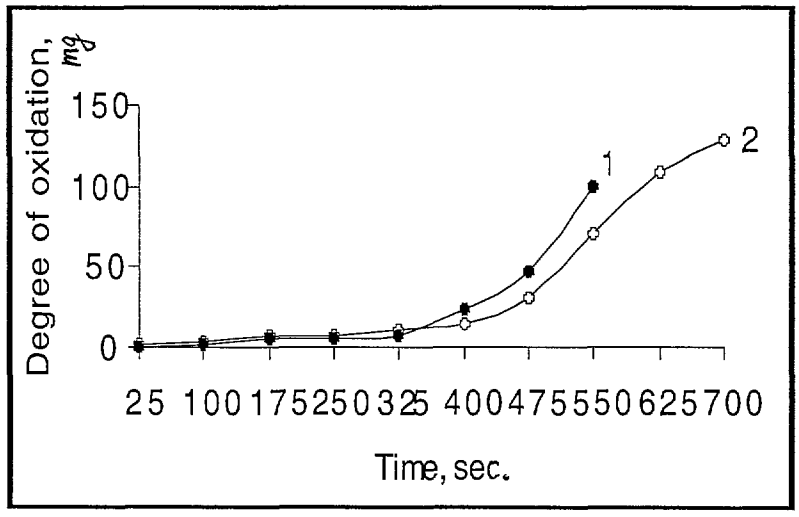


Fig. 5.
Degree of oxidation of FeS-- Cu_2S melts by air oxygen at 1200 ^{0}C
with additions of 20 wt% carbon.
1 – $3FeS{\cdot}Cu_2S$; 2 – $FeS{\cdot}Cu_2S$

Discussion

This systematic investigation of the liquid-phase oxidation of Cu_2S - FeS melts, enriched by copper, (kinetics and mechanism of oxidation as a function of the matte composition and other factors, together with the phase composition study of oxidized products suggest the possibility of oxysulphide formation [9,10]), The physico-chemical properties and structure were investigated in detail in [11,12]. An important point is that magnetite separates from these oxysulphides during cooling, and is distributed between the slag and the matte, increasing the loss of copper and other metals to the slag.

On the whole, and under the conditions obtaining in Vanyukov's process, especially during the production of copper rich mattes and white matte, the gaseous phase is characterized by a very high oxidizing potential, and the matte-slag melt reaches a high temperature (of the order of 1400-1500 ^{0}C), especially in the region of tuyeres. These peculiarities of Vanyukov's process, together with a high rate of mass-exchange during active 'barbotage' of the liquid bath of matte-slag melt above the tuyeres, strongly suggests that the oxidation rate of the sulphide burden will not limit the productivity of the installation. Detailed investigations of the kinetics and mechanism of liquid-phase oxidation, both for monosulphide melts of iron and copper and for mixed melt compositions, confirm this conclusion, which is also corroborated in the industrial exploitation of Vanyukov's furnace at the Balkhash copper-melting plant in Kazakhstan.

Based on the above considerations, itb is important to extend these studies of matte melt oxidation, planned for the second year.

Concurrently we consider it necessary to devote manpower and resources available through this grant to a more detailed and complete investigation of the process of deep reduction of copper-rich industrial slags from the Balkhash copper-melting plant.

4. KINETICS AND MECHANISM OF OXIDE REDUCTION BY OF SOLID CARBON

Method

Contactless reduction of an oxide by solid carbon both allows the study of the process kinetics and reveals the reaction mechanism. The experimental unit at IMiO [1] was used to investigate the chemical processes taking place on the surface of the oxide and at the interface with the reducing agent during reduction of the copper oxides.

Some of the experiments were performed using the «Setaram» equipment [1] to define the mechanism of copper (II) oxide reduction. In these experiments both solid carbon and metallic titanium were used as reducing agents.

An experimental circulation unit [1] was used to study the influence of additional factors on the reduction of a liquid slag containing copper (I) oxide.

Samples for investigation

Solid copper oxides CuO and Cu_2O were used. The liquid samples were prepared by dissolving Cu_2O in synthetic slags. The compositions of these slags are given in table 1.

Table 1. Composition of synthetic slags

Slag type	Contents, %				Ratio	
	FeO	SiO_2	CaO	Al_2O_3	SiO_2/CaO	FeO/SiO_2
I	54.77	33.10	5.80	6.00	5.71	1.65
II	33.17	42.10	15.00	9.10	2.81	0.79
III	13.63	50.30	24.20	11.30	2.08	0.27

All samples prepared for these measurements contained 10% Cu_2O.

Results

The results of these experiments are shown in figs. 6 and 7. The different experimental conditions correspond to different gas pressures. Fig. 6 shows results for the «CuO+C» reaction in vacuum, while fig. 7 is for the same reaction at atmospheric pressure in helium. Although the final values for the degree of copper oxide reduction after exposure for three hours are the same for both conditions, the initial degree of reduction in vacuum (between 15 minutes and 1 hour) is considerably higher, especially at 800 ^{0}C.

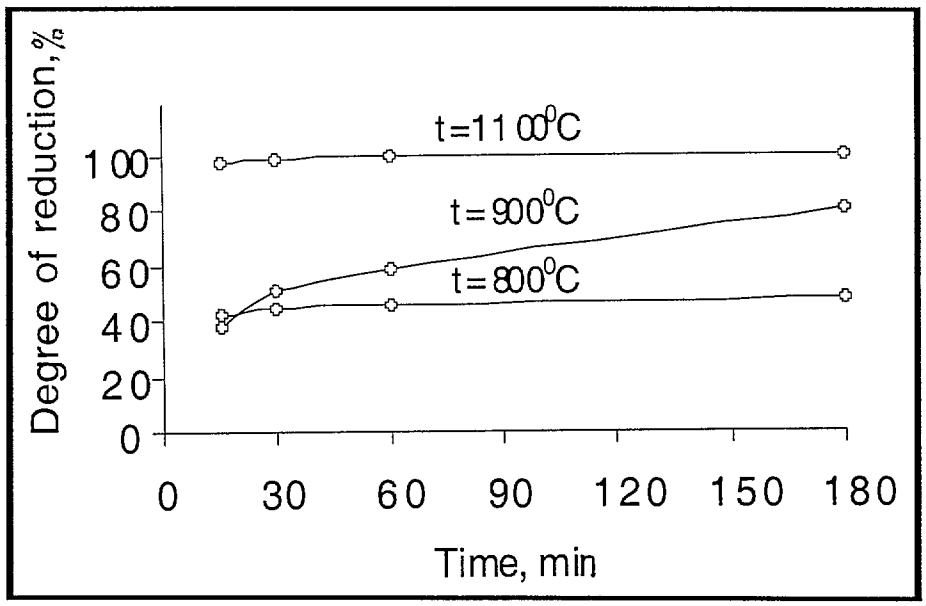


Fig. 6.
Degree of CuO reduction by charcoal in vacuum (10^{-3} Pa).

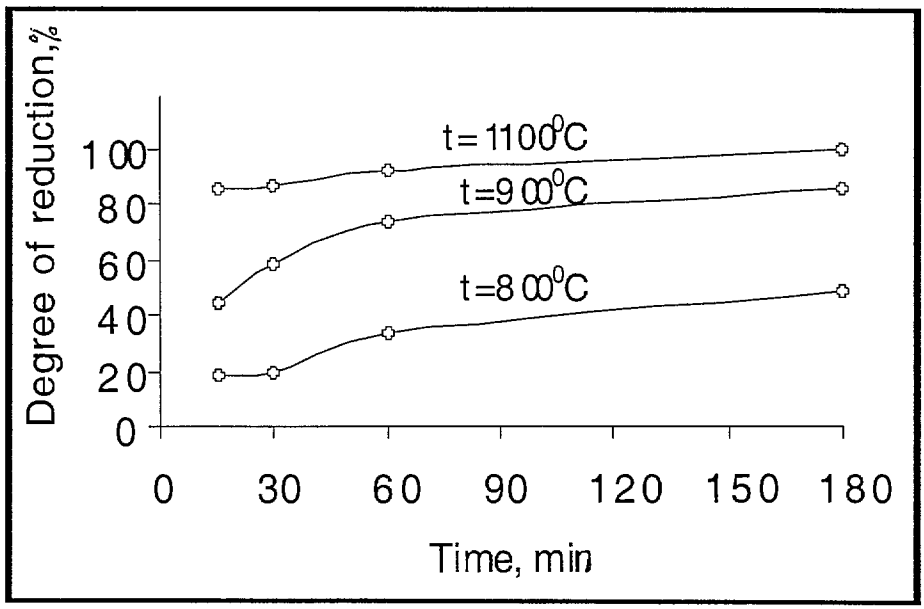


Fig. 7.
Degree of CuO reduction in helium at 1 atmosphere.

Discussion

The effect of low gas pressure could be explained by a decrease of diffusional resistance for the possible reduction reactions:

$$CuO + CO \rightarrow Cu + CO_2 \quad (1)$$

$$CO_2 + C \rightarrow 2\ CO \quad (2)$$

$$2CuO \rightarrow 2\ Cu + O_2 \quad (3)$$

$$O_2 + 2\ C \rightarrow 2\ CO \quad (4)$$

Reactions (1) and (2) represent adsorption reduction mechanisms, while reactions (3) and (4) represent dissociation mechanisms. At 800 ^{0}C reaction (2) is minimal, so that at this temperature the adsorptive mechanism is unlikely. On the other hand, at 800 ^{0}C, and especially in vacuum, reactions (3) and (4) can proceed rapidly, since one of the products is a gas, and gas phase diffusion of oxygen from oxide to solid carbon is facilitated.

The adsorption mechanisms appear increasingly likely with increasing temperature in the range 900 to 1100 ^{0}C, since reaction (2) is rapid at these temperatures. Indeed, all four reactions could contribute, especially in vacuum. The contribution from reaction (4) should decrease at atmospheric pressure in the gaseous medium, which contains as much as 90% CO, because in this case oxygen formed by copper oxide dissociation will first react either with CO in the gas phase near the oxide surface or with adsorbed CO molecules on the copper oxide surface.

For this temperature range it is therefore possible to unify the two reduction models discussed above into one integrated adsorption-dissociation mechanism for copper oxide reduction.

Results derived from the «Setaram» equipment provide additional data.

Two peaks are present on the DTG-curve for continuous heating rates. The first peak, at 800 ^{0}C, presumably corresponds to the maximum rate for the reaction:

$$CuO + \text{reducer} \rightarrow Cu_2O + \text{reduced oxide.} \quad (5)$$

As the Cu_2O concentration increases, the rate of this reaction falls, and the partial pressure of oxygen drops because of its interaction with reducer. The second peak appears at 900 ^{0}C, and corresponds to the reaction

$$Cu_2O + \text{reducer} \rightarrow Cu + \text{reduced oxide.} \quad (6)$$

A similar picture emerges both when metallic titanium is used as reducer, and in the case of copper oxide reduction by carbon in one atmosphere of inert gas and a relatively low partial pressure of carbon oxide (-10^2 Pa).

To summarize, the results of all the experiments discussed earlier confirm the feasibility of CuO reduction by a dissociation mechanism using solid carbon (coke fines) as the reducing agent.

In accordance with the original program of investigation, SEM analysis of Cu_2O reduction by charcoal in mixtures with three samples of synthetic slag, (table 1) were made.

The influence of the slag-forming components and some low-melting oxides (Na_2O and B_2O_3) on Cu_2O reduction from the three types of slags by solid carbon, using the contactless method, was studied on circulation equipment. However these systems proved too complex to derive any general conclusions. We therefore concentrated on the development of a model laboratory furnace with a coke filter, in order to study the reduction of real slag from Vanyukov's furnace and their conversion for copper production by direct contact with coke fines.

5. A LABORATORY MODEL FURNACE WITH A COKE FILTER

The laboratory model furnace with a coke filter was designed to study the deep impoverishment of slags and metal reduction from oxide melts (fig. 8).

The model consists of a vertical high-temperature furnace (1) and a low-temperature furnace with coke filter (3). The construction is mounted on a rigid frame. The vertical high-temperature furnace is placed on guide cylinders and can be moved vertically for loading and unloading coke from the coke filter furnace.

A crucible (2) is fitted with a needle valve from which molten slag from the high temperature furnace can be poured into the lower part of the assembly. The furnace shaft has a cross-section of 100×100 mm and a height of 300 mm. Two opposing walls of the furnace shaft are assembled from graphitic blocks, through which the electric current is passed. Two other walls and the furnace bottom are lined by firebrick. An asbestos lining is placed between the brick lining and the steel body, and shaft of the furnace is filled with coke fines. The steel water-cooled current supplies are isolated from the body of the furnace by stoppers and asbestos. The electrical current to the coke bed is supplied from a transformer, TDFG-2000, and temperature measurements are made using a Pt-PtRh thermocouple.

During an experiment molten slag flows through the coke filter, where the reduction processes take place. The impoverished slag exits through a drain (6) into a settler.

Preliminary tests of this model laboratory furnace have been made and the basic working principles have been demonstrated. Samples of real slag from Vanyukov's furnace and slags from the end of the first conversion stage at the Balkhash copper melting plant will be used for experiments in the second year of this investigation.

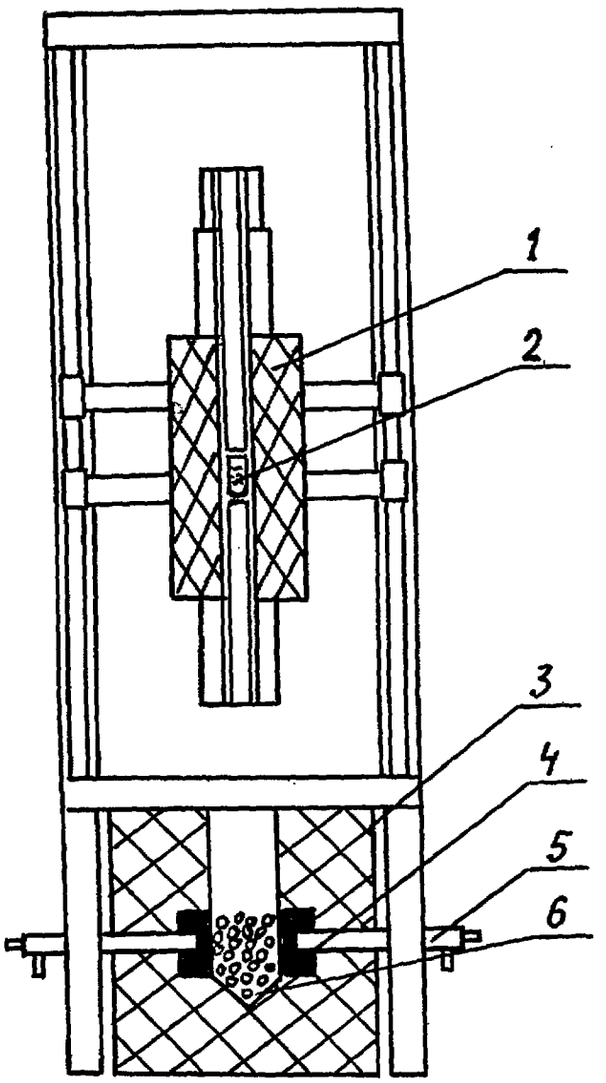


Fig. 8.
Scheme of the model laboratory furnace with a coke filter
1 – high-temperature vertical furnace; 2 – crucible; 3 – lower furnace with coke filter; 4 – graphite; 5 – current supplies; 6 – pouring opening.

REFERENCES

1. D.G.Brandon, S.M.Kozhahmetov et al. – Ecological clean process of crude copper production. Management (half-year) report. Grant number TA-MOU-98-CA17-017. Haifa (Israel) – Almaty (Kazakhstan). April 2000.

2. S.Vaisburd and D.G.Brandon. - A combined unit for viscosity, surface tension and density measurements in oxide melts. - Meas. Sci. Technol., **8**, 822-826 (1997).

3. E.A.Moelwyn-Hughes. - Physical chemistry. // London - New York – Paris, 1961.

4. S.E.Vaisburd. - Physico-chemical properties and specific features of the structure of sulfide melts. // Moscow, "Metallurgy", 1996 (russ.).

5. Slag Atlas. // Verlag Stahleisen GmbH, Dusseldorf, 1995.

6. A.V.Vanyukov and V.Ya.Zaytsev. – Slags and Mattes of Non-Ferrous Metallurgy". // Moscow, "Metallurgiya", 1969. (russ.)

7. A.V.Vanyukukov and V.Ya.Zaytsev. - Theory of Pyrometallurgical Processes. // Moscow, "Metallurgiya", 1973. (russ.)

8. Smelting in Matte-Slag Liquid Emulsidon. - Ediited by A.V.Vanyukov. // Moscow, "Metallurgiya", 1988. (russ.)

9. E.A.Dzhantureeva, S.M.Kozhakhmetov and oth. - Studies of oxysulphide alloy $2FeO{\cdot}Cu_2S$. // Abstracts of the 5-th International Conference in chemistry and technology of chalcogens. Karaganda, 1995, p. 214 (russ.).

10. E.A.Dzhantureeva - Study of the mechanism of sulphur oxidation in sulphide melts of copper and iron. // Author's abstract of candidate dissertation. Almaty, 1995. (russ.).

11. S.E.Vaisburd, A.G.Ryabko, Yu.V.Fisher and I.N.Zedina. - Physico-chemical properties of oxysulphide melts on the base of iron and nickel. // Rasplavy, 1987, **1**, No.1, 38-47 (russ.).

12. S.E.Vaisburd, A.G.Ryabko, A.V.Taberko and M.M.Marshak. - Physico-chemical properties of oxysulphide melts on the base of iron and copper. // Rasplavy, 1990, **4**, No.2, 90-96 (russ.).

C. SCIENTIFIC IMPACT OF COLLABORATION

Professor S.E.Vaisburd visited IMiO (Almaty, Kazakhstan) in November 1999 for one week, where he coordinated the working plan for this joint project. Professor S.M.Kozhakhmetov spent one week in April 2000 at the Technion – Israel Institute of Technology (Haifa, Israel) where he met with colleagues from Israel and participated in the preparation of the semi-annual report. Professor S.E.Vaisburd spent a further two weeks in Almaty in October 2000 where, together with colleagues from Kazakhstan, he prepared the annual report. A post-graduate from ImiO, Kenzhaliev E.B., worked at the Technion from February till July 2000 (during 5 months), where he played a very active role in the joint work supported by this grant.

The close cooperation of the partners in this project enabled well-characterized samples from Kazakhstan to be investigated in depth in Israel, while the results obtained, both in Kazakhstan and in Israel, have been discussed, analyzed and reported by all the co-workers in the two countries.

D. DESCRIPTION OF PROJECT IMPACT

The results of the 1st year of work include the origin of metal losses, the properties of the melts (slag viscosity at high temperature, the mechanisms of copper and iron oxide reduction) and especially the model furnace with a coke filter. These results are a solid base for the work to be performed during the 2nd year of this grant.

E. STRENGTHENING OF DEVELOPING COUNTRY INSTITUTIONS

Part of the available funding was used by IMiO (Kazakhstan) to purchase equipment (computer, FAX, scanner, printer, xerox). Consumable materials were also covered by the grant (alumina tubes, graphite electrodes, pipes of stainless steel, refractory blocks). These all represent essential medium- and short-term investments in the infrastructure of ImiO.

Most important is the long-term investment represented by the extended stay of a post-graduate from ImiO, E.B.Kenzhaliev, at Technion from February until July 2000 (5 months). During this time Elnar Kenzhaliev was able to master SEM/EDS methods of microstructural analysis of morphology and microchemistry, as well as methods for measuring the physical properties of melts (viscosity, density and surface tension). Taken together with the visits by Prof. Vaisburd to Kazhakstan and Prof. Kozhakhmetov to Israel, this investment in human resources is expected to be of long-lasting significance.

F. FUTURE WORK

During the 2nd year basic attention will be paid to the study of the deep impoverishment of slags from Vanyukov's furnace using the laboratory installat

ion to simulate the operation of a furnace fitted with a coke filter (IMiO, Almaty). Characterization of samples obtained from these experiments, using SEM/EDS methods and XRD analysis, will be the principle task of the Israeli partners (Technion, Haifa), and we expect a further extended (one semester) stay at Technion by Elnar Kenzhaliev, together with further visits to the two institutes by Professor S.E.Vaisburd (to ImiO, Almaty, Kazakhstan) and Professor S.M.Kozhakhmetov to the Technion (Haifa, Israel).