

## Effect the Lead, Silicon and Aluminium on the Properties of Liquid Copper

<sup>1</sup>M.S. Hamani, <sup>1</sup>D.E. Hamoudi and <sup>2</sup>A.Hafsaoui

<sup>1</sup>Foundry Laboratory, Department of Metallurgy and Genius of Materials, Algeria

<sup>2</sup>Department of mines, University of Annaba, 23000 Algeria

**Abstract:** At the liquid state, on the diagrams (above the line of liquidus), an identical field of liquid solution is usually presented not depending on the type of the diagram of state of solid metal. However, these last years a series of works appeared which directly shows the well defined relation ship of the control of the liquid and the variation of these properties (viscosity, surface tension, conductivity electric and different) with the nature and the type of the diagram of state, these characteristics finds an image and emerges from the lines, dividing the common pole of the liquid state on various fields, which is characterized a dependent given energy with the particles of the components thus binding the various properties of liquid alloy. The properties of alloys containing copper in the liquid state are studied in several researches. However, currently, the volume of information is not sufficient for all the characteristics of these alloys. The number of the data on the density, viscosity, surface tension and other physicochemical properties of liquid copper alloys did not find for the moment of use practical. In this present work, we studied the most important physicochemical properties of principal liquid alloys containing copper (Cu-Pb, Cu-Si, Cu-Al).

**Key words:** Viscosity, liquid, conductivity, electric, copper

### INTRODUCTION

The alloys liquidate Cu-Pb belong (Sawerwald *et al.*, 1966) to the systems whose field is immiscible, which is in conformity with the diagram of balance of state, which starts with a content of 36%Pb (mass).

This system is distinguished (Vilson, 1972; Schman and Kanke, 1965) by the positive variations compared to the ideal state, these variations are weak with the tiny concentrations of Pb and important with the highest concentrations, this shows an absence of the stable formations of CuPb type in this system. At the fusion of these elements one is fixed (Schman and Kanke, 1965) endothermic effect of the mixture

$$\Delta H_{\max}^M = +7.79 \text{ KJ/g-atom}$$

With weak (at 48%at. Pb) influence of the size  $\Delta H$  compared to the temperature in the interval 1263-1473K

The immiscibility of copper with Pb is explained by the great value of dimensional factor F.D. = 23,9% (Vilson, 1972).

On Fig. 1 are presented the experimental data of the most important properties of liquid alloys of the system Cu-Pb. The isotherm of volumes specific  $1/\rho$  of liquid alloys of copper with lead to the temperature 1200°C (Fig. 1b) is laid out of a higher value of specific volumes, which are defined by the law of additivity. The computed

values of the decompression (dilation) of alloys liquidate Cu-Pb with 5% Pb (mass) constitute  $v = +0, 1\%$ , but to 36% Pb  $v = +0, 7\%$ , which serf of confirmation complementary to the positive variations of the system Cu-Pb compared to the ideal solutions.

The viscosity of copper decreases compared to the additions of lead in the interval of the studied concentrations 0-20% Pb. The analogical nature of the isotherm of viscosity at the temperature 1100°C of the alloys Cu-Pb is also studied in work Chvidkovski E.G. (Chvidkovski, 1955). The position of the isotherm of the viscosity of the alloys Cu-Pb (Fig. 1a) shows that the influence of the factor of the temperature in the interval 1100 -1200°C appears intensively more, that variation of the concentration of lead (0-20% mass).

The isotherm of the surface tension of alloys liquidate Cu-Pb (Fig. 1c) with 1200°C is characterized by the abrupt variation of the curve in the small interval of concentration of Pb (0.5-5%). Lead represents one of most surface-active components in alloys of copper. With content 8-9% of Pb in Cu the saturation of the surface layers of liquid alloy on behalf of these particles starts and  $\sigma$  practically does not change until the composition of eutectic, or sets the curve of the isotherm of the surface tension. With the increase in the temperature of the alloys Cu-Pb decreases. The flow relatively increases with the weak additions (0,5-1%) steigt (Fig. 1d) and then decreases.

### ALLOYS: COPPER SILICON (CU-SI)

Thermodynamic properties of the system Cu-Si are badly studied. The diagram of state of this system is characterized by the presence of the series of chemical bonds. The maximum value of the heat of the mixture of copper with silicon (25% compared to Si) according to data's (Srivaline *et al.*, 1969), constitutes with 1723K and exceeds considerably almost the value of heats of the mixture of all the binary alloying of copper (except system Cu-Al), which have a practical importance. In the system Cu-Si (Nikitine, 1962) the important negative variations compared to the ideal solutions in the interval of concentration of silicon are established 0-12%. For example,  $0.027N_{Si}$  (1,0% Si mass) the activity of silicon in liquid alloy is very low:  $a = 0.16 \times 10^{-7}$ ; with the  $0.076N_{Si}$  (3,5% mass)  $a = 0.45 \times 10^{-7}$  with the  $0.089N_{Si}$  (4,2% mass)  $a = 0,31 \times 10^{-3}$  on Fig. 2 presents the experimental data on the principal properties of alloys coppers silicon. The viscosity of alloys Cu-Si is studied by Chlekov A.V and the authors (1975) in the interval of silicon 1-12% concentrations at the temperatures 1050-1200°C. The alloys are prepared starting from copper (nap of impurities 0.001%) and of semiconductor silicon. The isotherms of these studied compositions are located in the zone of the highest values of viscosity than at pure copper. The influence of the temperature on the viscosity of alloys.

**Cu-Si is written in the exponential way:** In the interval of concentration 1-4% of Si one distinguishes a reduction from viscosity (Fig. 2a), but then it obviously goes up until the state, corresponding to the chemical bond CuSi (12,3%).

The influence of the concentration on the viscosity of alloys Cu-Si built by Lones (1954) with overheatings equal (50°C) to the top of the liquidus shows almost the increase almost the rhythmic increase in viscosity with the increase in the content in alloys liquidate Si up to 7% with 0.0048 (to 1% Si) until 0.0065Pa.s (to 7%).

The tension of surface of alloys. Cu-Si is measured (Gerassimov, 1971) until the silicon content equal to 18% (mass). Silicon in general decreases it of copper (Fig. 2c) and it is intense in particular in the interval of the concentration 1-4% Si. On the isotherm of the surface tension with content 10-12% Si is obviously weak. Surface-active properties of Si in Cu one can explain it by the presence in liquid alloys of the CuSi groupings with strong chemical bonds. In its turn these groupings have, cavity, a weak connection with Cu-Cu and, also, Si-Si, this is why they supplant in the surface layers, in particular in an intense way for silicon alloys weak.

Silicon exerts a considerable influence on the density of liquid alloys Cu-Si. The importance of the relative variations of volumes of liquid alloys (Fig. 2b) show, that with the content 4%Si in copper the value of voluminal

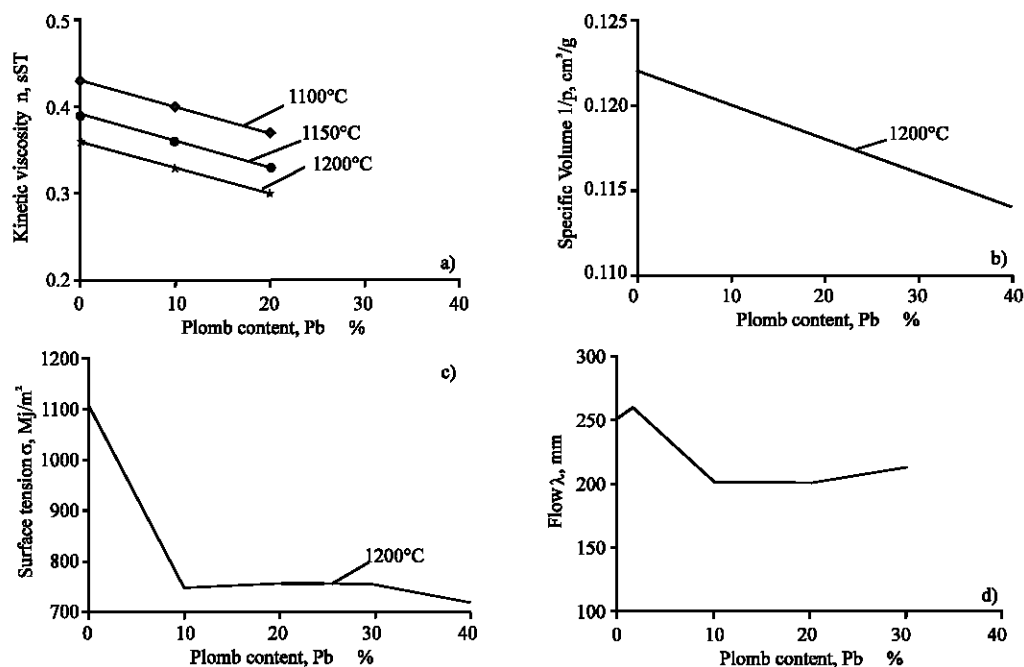


Fig.1: Properties of alloys liquidate Cu-Pb

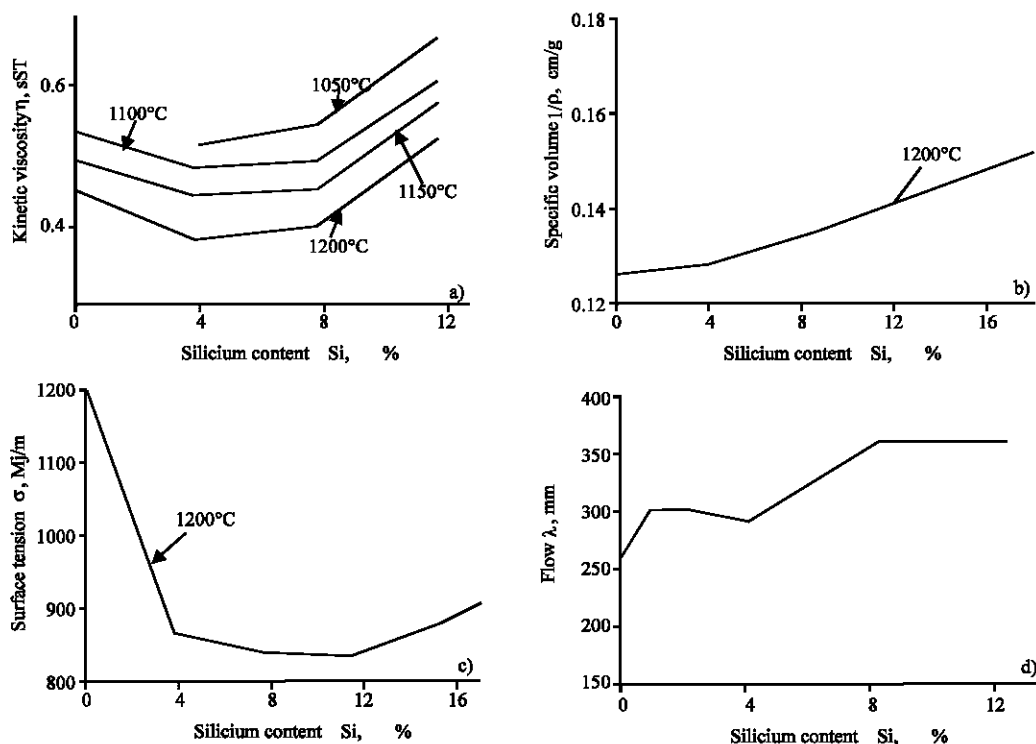


Fig. 2: Properties of alloys liquidate Cu-Si

compression  $v = -6\%$ , but near 8% Si  $v = -8.5\%$ , this confirm the presence in alloys of the intense forces of interatomic of attraction of the various atoms.

Flow of alloys Cu-Si increases itself (Fig. 2d) with the increase in the content of silicon. Pace of the variation of the flow of alloys Cu-Si is not due to the factor of the nature of the crystallization, which definite the interval of temperature, but at the variation of the thermophysical properties of liquid alloy and in particular, the reduction in the thermal conductivity of liquid alloy, variation of the value of the latent heat of crystallization (with pure silicon it is of 6mal more than at copper) and of the specific heat.

#### ALLOYS: COPPER ALUMINIUM CU-AL)

The property of liquid alloys of this system (important in the labour relation) studied cavity is insufficient in the literature and little information on their appreciably structural properties.

The fusion heats of Cu with Al are the least important while appearing with other copper binary alloying to knowing with 1473K (Thomas, 1965) and  $0.37N_{Al}$ . In the fields of the diagram of state Cu-Al corresponding to connection Cu-Al corresponding to the  $Cu_3Al$  connection,  $Cu_2Al$  is characterized by the proximity from

the value from heats from the mixture in the states solid and liquid, which makes it possible to suppose the existence in liquid alloys of the CuAl groupings with sufficient the strong connections.

For system Cu-Al is founded strong negative variations compared to the ideality (Thomas, 1965). The coefficient of activity of aluminium in these alloys liquidate with a very low value (for example, for the dilation of the solutions = 0,0055 with 1373K).

On the Fig. 3 are presented the data on the properties of liquid alloys Cu-Al obtained in this present work and in (Lones, 1954; Eretnov and Loubimov, 1966; Gebhardt and Becker, 1952). The alloys are prepared starting from Cu (nap of impurities 0,012%) and of Al (nap of the impurities not more than 0,01%).

The viscosity of liquid alloys Cu-Al obtained by us and by Lones (1954), Eretnov and Loubimov (1966), presented under an isothermic state for composition having a practical direction (up to 18% Al). The qualitative influence of aluminium on the viscosity of copper in the intervals of studied concentrations is characterized by a viscosity of positive activity. The isotherms of dynamic viscosity, according to the data (Lones, 1954) have some ruptures: with a content of 8,5% Al (eutectic) its notices a reduction in viscosity then followed by a rise, which is explained by the appearance

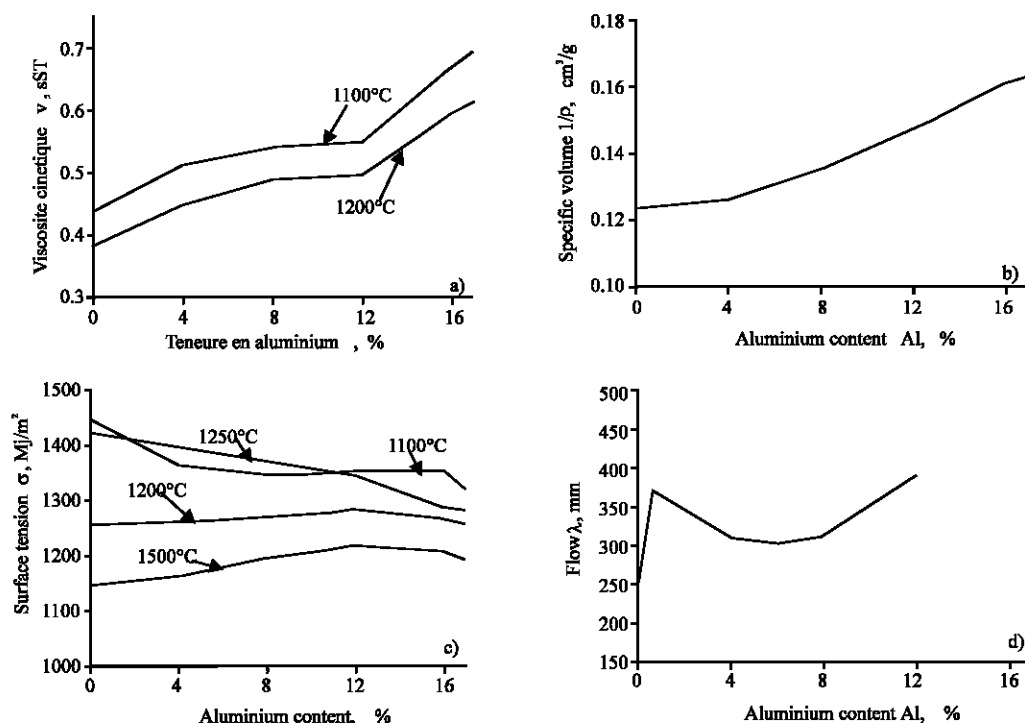


Fig. 3: Properties of alloys liquidate Cu-Al

of the structure (during crystallization)  $\beta$ -phase (phase containing the  $\text{Cu}_2\text{Al}$  connection), is marked by a second reduction in viscosity, corresponding to the field of a stable existence of  $\beta$ -phase. Our research and Eretnov and Loubimov (1966) do not have makes it possible to fix the analogical points characteristic on the isotherms of viscosity, if one does not count the visible curves of the curves, which only can testify indirectly on the variations, which occur in the structure of liquid alloys Cu-Al in the passing of the  $\alpha$ -phase field in the field  $\beta$ -phase (Fig. 3a).

In this way, in alloys Cu-Al rich in copper, aluminium shows a positive activity of the viscosity, which can be used indirectly for the confirmation of presence in the alloys liquidate a strong connection between of polarity opposed, which are able to form the  $\text{CuAl}$  grouping.

The isotherm of volumes specific (Fig. 3b) of liquid alloys Cu-Al to 1200°C lays out of a considerable positive variation compared to the calculated values the additive ones. The compression of the volume of liquid alloy of copper with 10% Al compared to the ideal solutions reaches the value = 8,0% which in experiments confirms the presence in liquid alloys Cu-Al of the strong connections between the various atoms and the existence in the liquid state of the ordered or quasi-ordered groupings  $\text{CuAl}$  type.

The surface tension of these alloys (Naiditch and Erimenko, 1962) is measured by the method (Gerassimov and Tchoursine, 1971) of the drops, while in our

experiments is carried out by the method of the pressure in the pores of the gases (helium). In spite of the use of extremely pure helium, does not have allowed avoiding the presence on the surface of liquid alloys of the oxide films. This is why the measurement of is carried out at the temperature 1500°C, which ensured a pure surface of liquid alloy and obtaining the stable indices of reproduction of the surface tension.

On the Fig. 3c are presented the isotherms  $\sigma$ -composition according to our data and those of (Naiditch and Erimenko, 1962). Near the aluminium concentrations up to 14% in our work the horizontal zones on the isotherms are fixed almost, which cavity, dependent on the influences faded of the oxide film. The presence of the horizontal zone on the isotherms is also fixed in work (Naiditch and Erimenko, 1962) and near the measurement of the surface tension of alloys Ni-Al in (Evantchenko and Erimenko, 1968). This is why with the explanation of the shape of the curves  $\sigma$ -Composition its can et al. suppose, that in the interval of concentration studied strong connections between the various atoms appear, however the  $\text{Cu}_2\text{Al}$  compound compared to Cu shows the inactive properties. The flow of the alloys (Fig. 3d) according to the curve varies with a minimum with 5% Al (not large of the interval of crystallization of the alloys Cu Al) and one with a maximum with one more (0,5-1,0%) of additions and also in the alloys rock of eutectic.

## CONCLUSION

By developing the studied results of certain properties of alloys containing copper, one can note, that in spite of the data obtained by the compositions, which adhere side rich in copper in the diagram of state (of an importance practises), one can make, in general, some conclusions, relating to natures of metal alloys. The nature of the variation of the properties of the studied systems Cu-Si, Cu-Al confirms the presence in alloys liquidate these systems the negative variations compared to the ideal solutions, however those of the alloys Cu-Pb are positive. In alloys, container of the components with strong chemical bonds Cu-Zn, Cu-Si, Cu-Al, near the measurement of viscosity, surface tension and density show an abrupt variation of the properties to the compositions, answering the intermetallic compounds on the diagram of state correspondents. With that the nature of the behaviour of liquid alloys, in which one can suppose the presence of the groupings with ordered connections, can appear in a different way. For example, in systems Cu-Zn (Hamani and Laissaoui, 2006), Cu-Al these groupings show compared to Cu, like Al and zinc an inactive nature, however in alloys Cu-Si, Cu-Sn the CuSi groupings, CuSn move volume with the surface layer. In the series of the systems, for example Cu-Zn, Cu-Sn (Hamani and Laissaoui, 2006) with the small concentrations of Sn, Zn, i.e. in alloys, considerably distant with the compositions, or appear the strong chemical bonds of the various atoms ( $\text{Cu}_{31}\text{Sn}_8$  with 32.53%Sn and CuZn with 39.8%Zn), in particular in the fields 1-5% Sn for Cu-Sn and 1-15% for Cu-Zn, energies of interaction of the various atoms obviously weaken. At this time there with liquid alloys Cu-Al even with alloys rich in copper the influence of the strong connections of made up  $\text{Cu}_3\text{Al}$  and  $\text{Cu}_2\text{Al}$  appears (being formed to 12.3 and 15% Al, respectively), which confirms the influence of aluminium on viscosity and the surface tension.

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