G. SIWIEC, B. OLEKSIAK, P. FOLĘGA, T. MATUŁA

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WETTABILITY IN THE LIQUID Cu-Ag ALLOY – FIREPROOF MATERIAL – GAS PHASE SYSTEM

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In the present paper, results of wettability studies on the liquid metal – fireproof material – gas phase system using copper and Cu-Ag alloys as well as typical fireproof materials, i.e. aluminium oxide, magnesium oxide and graphite, are presented. Contact angle measurements were conducted at 1 373–1 573 K by means of a high-temperature microscope coupled with a camera and a computer equipped with a program for recording and analysing images. For the measurements, the sessile drop method was used.

Keywords: Cu-Ag alloys, liquid copper, wettability, contact angles, sessile drop

INTRODUCTION

Wettability on a liquid-solid contact surface (a contact angle value), along with surface tensions of liquid metals and alloys, has a significant effect on the interface phenomena during metallurgical processes of metal production, refinement and melting as well as processes related to fireproof material corrosion. It is also important for casting processes, welding, metallic coating application and composite material production [1 - 8].

For a solid-liquid-gas system (Figure 1), e.g. a liquid drop placed ona solid surface, wettability of the solid phase to the liquid phase (the contact angle) isa resultant of three interfacial tensions, i.e. surface tension at the liquid-gas interface, solid-gas interfacial tension and solid-liquid interfacial tension. Conditions for the equilibrium at the contact point of the three phases are described by the Dupre equation which determines the relationships between the values of individual interfacial tensions and the contact angle:

$$\cos\Theta = \frac{\gamma_{s/g} - \gamma_{s/c}}{\gamma} \qquad (1)$$

where:

Θ - the contact angle,

$\gamma_{s/g}$ – the solid-gas interfacial tension,

$\gamma_{s/g}$ – the solid-liquid interfacial tension.

γ - the surface tension.

In the paper, results of wettability studies on the liquid metal – fireproof material – gas phase system with the use of copper and Cu-Ag alloys as well as typical fireproof materials, i.e. aluminium oxide, magnesium oxide and graphite, are presented.

G. Siwiec B Oleksiak, T. Matuła - Silesian University of Technology, Department of Metallurgy, Katowice, Poland
P. Folęga - Silesian University of Technology, Department of Transport, Katowice, Poland

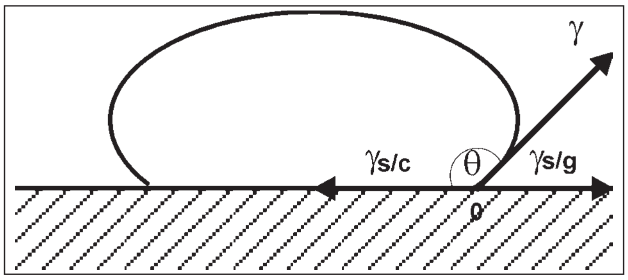

Figure 1 Equilibrium at the solid-liquid-gas interface

METHODS AND RESULTS

The contact angle measurements were conducted at 1 373 – 1 573 K using the sessile drop method. For the experiments, oxygen-free copper and copper-silver alloys with the maximum Ag content of 50 % mass were applied. A high-temperature microscope coupled with a camera and a computer equipped with a program for recording and analysing images was utilized, which enables measurements of relevant liquid metal drop geometrical parameters that are necessary for determination of contact angles. As protective atmosphere during the measurements, argon 6.0 was used. A detailed description of the research apparatus is presented in the article by Siwiec and others [9]. A sample Cu-Ag drop

Figure 2 A Cu-40 Ag alloy drop placed on aluminium oxide surface at 1 423 K

Table 1 **Results of contact angle measurements for pure copper**

Surface	Temperature / K	Contact angle / °
Al_2O_3	1 373	140±2
	1 423	140±1
	1 473	139±2
	1 523	139±1
	1 573	138±1
MgO	1 373	126±2
	1 423	126±2
	1 473	125±2
	1 523	125±2
	1 573	124±1
graphite	1 373	130±1
	1 423	130±1
	1 473	130±1
	1 523	130±1
	1 573	129±1

Table 2 **Results of contact angle measurements on the aluminium oxide surface for Cu-Ag alloys**

Ag content / %mass	Temperature / K	Contact angle / °
2	1 373	135±2
	1 423	135±2
	1 473	134±2
	1 523	131±2
	1 573	128±2
4	1 373	135±1
	1 423	134±1
	1 473	132±2
	1 523	130±2
	1 573	128±2
6	1 373	135±1
	1 423	134±1
	1 473	132±1
	1 523	128±2
	1 573	127±2
8	1 373	135±1
	1 423	133±2
	1 473	132±2
	1 523	130±2
	1 573	130±2
10	1 373	132±2
	1 423	132±2
	1 473	131±2
	1 523	130±1
	1 573	129±1
20	1 373	132±2
	1 423	132±1
	1 473	131±1
	1 523	130±1
	1 573	129±2
30	1 373	130±1
	1 423	130±1
	1 473	129±2
	1 523	129±1
	1 573	128±2
40	1 373	130±1
	1 423	129±1
	1 473	129±1
	1 523	128±2
	1 573	128±1
50	1 373	129±1
	1 423	129±1
	1 473	128±1
	1 523	126±2
	1 573	126±2

Table 3 **Results of contact angle measurements on the magnesium oxide surface for Cu-Ag alloys**

Ag content / % mas.	Temperature / K	Contact angle / °
2	1 373	132±2
	1 423	132±2
	1 473	132±2
	1 523	131±2
	1 573	131±2
4	1 373	132±2
	1 423	132±2
	1 473	131±2
	1 523	131±1
	1 573	131±1
6	1 373	130±2
	1 423	130±2
	1 473	130±1
	1 523	129±1
	1 573	130±1
8	1 373	130±2
	1 423	131±2
	1 473	131±2
	1 523	130±2
	1 573	129±2
10	1 373	131±2
	1 423	131±2
	1 473	131±2
	1 523	129±2
	1 573	129±1
20	1 373	130±2
	1 423	130±2
	1 473	131±2
	1 523	131±2
	1 573	131±2
30	1 373	132±2
	1 423	132±1
	1 473	132±1
	1 523	132±1
	1 573	131±1
40	1 373	132±2
	1 423	132±2
	1 473	132±2
	1 523	132±2
	1 573	132±2
50	1 373	132±2
	1 423	132±2
	1 473	130±2
	1 523	130±1
	1 573	130±1

shape, observed and recorded during the experiments, is shown in Figure 2.

In Tables 1 – 4, results of contact angle measurements on aluminium oxide, magnesium oxide and graphite surfaces are presented.

SUMMARY

Based on the above experiments, it can be concluded that both liquid copper and liquid copper-sliver alloys show poor wetting properties with regard to surfaces of

Table 4 **Results of contact angle measurements on the graphite surface for Cu-Ag alloys**

Ag content / % mas.	Temperature / K	Contact angle / °
2	1 373	126±2
	1 423	127±2
	1 473	126±2
	1 523	125±2
	1 573	126±2
4	1 373	130±2
	1 423	130±2
	1 473	130±2
	1 523	129±2
	1 573	129±2
6	1 373	131±2
	1 423	131±2
	1 473	131±2
	1 523	131±2
	1 573	131±2
8	1 373	128±2
	1 423	128±2
	1 473	128±2
	1 523	127±2
	1 573	127±2
10	1 373	127±2
	1 423	127±2
	1 473	127±2
	1 523	127±2
	1 573	127±2
20	1 373	128±2
	1 423	128±1
	1 473	127±2
	1 523	127±1
	1 573	126±1
30	1 373	134±2
	1 423	134±2
	1 473	133±2
	1 523	133±2
	1 573	133±2
40	1 373	135±2
	1 423	134±2
	1 473	133±2
	1 523	133±2
	1 573	133±2
50	1 373	134±2
	1 423	134±2
	1 473	133±2
	1 523	133±2
	1 573	133±2

typical fireproof materials, such as aluminium oxide, magnesium oxide and graphite. Within the entire measurement range, the contact angle values are always large: 124 ° to 140 ° with the maximum for the aluminium oxide surface. In the case of Al_2O_3 surface, silver addition slightly improves wettability (the contact angles decrease). Compared to pure copper, Cu-Ag alloys show poorer wetting properties regarding a magnesium oxide surface. While in contact with graphite, silver, dissolved in copper, basically has no effect on wettability; only with higher Ag contents (30 – 50 % mass), a small increase in the contact angles is observed. Within 1 373 – 1 573 K, the temperature has a negligible effect on contact angle values for the investigated systems.

While analysing the results of wettability studies on liquid metal (alloy)-solid metal oxide-gas phase systems, collected by Najdicz [1, 10], and considering his wettability theory, it can be assumed that, when in contact with other thermodynamically stable oxides (e.g. CaO, ZrO_2, SiO_2), liquid copper and Cu-Ag alloys will show similar behaviour to that observed for aluminium and magnesium oxides.

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Note: Nowak P is responsible for English language, Katowice, Poland