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SURFACE TENSION OF Cu-Ag ALLOYS

NAPIĘCIE POWIERZCHNIOWE STOPÓW Cu-Ag

In the paper, results of surface tension measurements with regard to liquid copper-silver alloys with the maximum silver content of 40 % mass Ag are presented. The measurements were performed at 1373–1573 K with the use of the sessile drop method. In the study, a high-temperature microscope, coupled with a camera and a computer equipped with the software designed for experiment recording and picture analysing, was applied. In order to determine surface tension values, the least square estimation of the parameters of the system of differential equations, describing the shape of a liquid sessile drop, was used.

Keywords: surface tension, sessile drop method, high-temperature microscope, liquid Cu-Ag alloys

W prezentowanej pracy przedstawiono wyniki pomiarów napięcia powierzchniowego ciekłych stopów miedzi ze srebrem o maksymalnej zawartości 40 % mas. Ag. Badania przeprowadzono w zakresie temperatur 1373-1573 K. Wykorzystano metodę kropli leżącej. Zastosowano aparaturę pomiarową składającą się z mikroskopu wysokotemperaturowego sprzężonego z kamerą i komputerem wyposażonym w oprogramowanie pozwalające na rejestrację przebiegu eksperymentu oraz analizę obrazu. Do wyznaczania napięcia powierzchniowego zastosowano procedurę obliczeniową polegającą na estymacji metodą najmniejszej sumy kwadratów parametrów układu równań różniczkowych opisujących kształt leżącej kropli cieczy.

1. Introduction

Surface tension, resulting from the effects of unbalanced attractive forces on the liquid surface particles, is one of the basic parameters of the liquid phase, together with density and viscosity. The surface tension of liquid metals and alloys significantly affects many metallurgic processes, including manufacturing, refining as well as casting of metals and alloys. Also, the role of surface tension in fusion welding, soldering or composite material manufacturing as well as hot dip metal coating and corrosion of fireproof materials cannot be neglected [1-6].

In the paper, results of surface tension measurements with regard to liquid copper-silver alloys with the maximum silver content of 40% mass Ag are presented. The Cu-Ag alloys are important materials for the electrotechnical and electronic industries [7, 8].

2. Methods

The surface tension measurements with regard to liquid Cu-Ag alloys with the maximum silver content of 40% mass Ag were performed at 1373-1573 K with the use of the sessile drop method. For the measurements, a high-temperature microscope, coupled with a camera and a computer as well as connected to the system of inert gas (argon 6.0) delivery to the heating chamber of the device, was applied. The computer was equipped with the software designed for the research apparatus operating as well as picture recording and analysing. In order to determine the surface tension values, the least square estimation of the parameters of the system of differential equations, describing the shape of a liquid sessile drop, was used. The research apparatus is presented in Figure 1. A detailed description of the measurement methodology, measurement equipment and the computational method is presented in the references [9, 10]. In Figure 2, a sample shape of a Cu-Ag sessile drop, recorded during the investigations, is shown. During the measurements, aluminium oxide plates were used as drop holders. The liquid copper-silver alloy density values, necessary for the calculations, were determined by means of the drop segmentation method [11].

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Fig. 1. A high-temperature microscope applied in the measurements of liquid Cu-Ag alloy surface tension

Fig. 2. A drop of the Cu-10% mass Ag on an Al_2O_3 plate at 1473 K, recorded during the investigations

3. Results

In Table 1, the results of liquid Cu-Ag alloy surface tension measurements are presented. The first column presents the percent fractions of silver in the alloy, while the second column presents the measurement temperatures. In the third column, the values of the drop shape factor, determined with the use of the least square estimation method based on the coordinates describing a liquid alloy drop shape, are presented. In the fourth and fifth columns, the density (applied in the calculations) and surface tension values are listed, respectively. Figures 3 and 4 show sample results of the investigations.

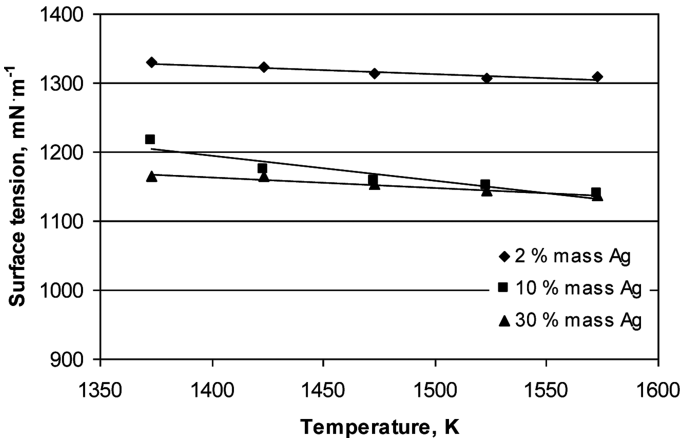

Fig. 3. The effect of temperature on the surface tension of liquid Cu-Ag alloys

TABLE 1

Results of liquid Cu-Ag alloy surface tension measurements

Ag content, % mass	Temperature, K	Drop shape factor, m^{-2}	Density, $kg \cdot m^{-3}$	Surface tension, $mN \cdot m^{-1}$
1	2	3	4	5
2	1373	59112	8016	1330
	1423	59112	7966	1322
	1473	59112	7916	1314
	1523	59092	7867	1306
	1573	58522	7817	1310
4	1373	59782	8033	1318
	1423	59785	7983	1310
	1473	59143	7933	1316
	1523	59555	7884	1299
	1573	59112	7834	1300
6	1373	61805	8050	1278
	1423	61806	8000	1270
	1473	61805	7951	1262
	1523	61375	7901	1263
	1573	60961	7852	1263
8	1373	63414	8067	1248
	1423	64644	8018	1217
	1473	64396	7969	1214
	1523	64475	7919	1205
	1573	64644	7870	1194
10	1373	65153	8085	1217
	1423	67081	8036	1175
	1473	67638	7987	1158
	1523	67638	7938	1151
	1573	67940	7888	1139
20	1373	67818	8178	1183
	1423	67705	8130	1178
	1473	68172	8082	1163
	1523	68117	8033	1157
	1573	68840	7985	1138
30	1373	69662	8279	1166
	1423	69385	8232	1164
	1473	69647	8185	1153
	1523	69730	8138	1145
	1573	69753	8091	1138
40	1373	71303	8391	1154
	1423	72275	8345	1132
	1473	74289	8299	1096
	1523	74765	8253	1083
	1573	75323	8208	1069

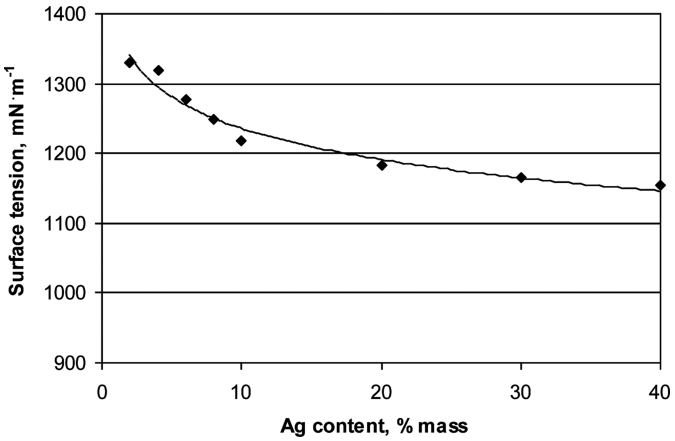

Fig. 4. The effect of silver concentration on the surface tension of liquid Cu-Ag alloys (temperature 1373 K)

4. Summary

Based on the study findings and a literature analysis (including papers [7, 9, 12, 13]), it can be concluded that the surface tension values of liquid Cu-Ag alloys are lower than the values for liquid copper and higher than the values for pure silver. With the temperature rise, the values of surface tension of liquid copper-silver alloys decrease. These changes are linear, which is characteristic for most liquid metals and alloys. Higher silver contents in the alloy lead to lower surface tension of Cu-Ag alloys.

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