A Study on the Diagram of Al-rich Al-Cu-Sn Alloys

Takuichi MORINAGA, Shigeo MUROMACHI and Masao YAMADA

Tokyo Institute of Technology, Faculty of Eng., Toyama University.

(Received March 6, 1953)

We studied the diagram of the Al corner of the Al-Cu-Sn alloys with various compositions as shown in Table 1 by means of thermal analysis, electric resistance and specific heat as well as microscopic examination. All the specimens used in these experiments showed the ternary monotectic reaction. This result indicates that the solubility of copper and tin in solid aluminium at the temperature of the ternary monotectic reaction (530°C) may be shown by M point in Fig. 4. The partial diagram of the aluminium corner of this ternary system obtained is shown in Fig 4. According to this diagram, the range of α solid solution is very narrow and slender along to the copper composition axis.

I. Introduction

T. Sato[1] was the first to study the diagram of Al-Cu-Sn alloys and confirmed the existence of the monotectic reaction in the pseudo-birnary system. H. K. Hardy[2] tried to determine the solubility of tin in solid aluminium, but did not examine the solubility of the aluminium-rich side of Al-Cu-Sn alloys which is of high interest. Y. Hosoi[3] carrid out some experiments on the alloys used for bearing materials, The diagram of this system hitherto obtained are vague on the aluminium-rich-side. The present study was carried out in order to determine this side of the diagram more clearly.

II. Specimens and Method

The materials used in the experiments were electrolytically refined aluminium with 0.005% of silicon, 0.003% of iron and 0.002% of copper, electrolytic copper and tin. In order to make copper easy for alloying, a mother alloy with 33% of copper was used. The chemical composition of the specimens is shown in Table 1. On differential thermal analysis, the metal block holding the specimens was of brass and the neutral body of high purity aluminium. Alumel-chromel was used as differential thermo-couple, whose sensibility was 25/1000 per mm of the scale reading. The electric resistance and the specific heat measurements were carried out by the ordinary methods. The latter was carried out under the following conditions weight of specimen 8.4g., voltage 0.12 V and current 0.4 A. As the etching reagent for microscopic examination a 10% HNO_3 aqueous solution was used.

Table. 1 Composition of the Specimens.

No.	Cu %	Sn %	Al
1	1.52	0.25	bal
2	1.55	0.5	〃
3	1.52	1.0	〃
4	2.33	0.25	〃
5	2.38	0.5	〃
6	2.34	1.0	〃
7	3.71	0.25	〃
8	3.75	0.5	〃
9	3.73	1.0	〃
10	4.76	0.25	〃
11	4.51	0.5	〃
12	4.55	1.0	〃

III. Results of Fxperiments

(1) T. Sato, E. Yazima, J. Jap. Inst. Metals, 8 (1944), 14.
(2) H. K. Hardy, A. H. Sully, J. J. Heal, Chem. Abs., 44 (1950), 1385.
(3) Y. Hoshi, Light Metals, 4 (1952), 75.

Some typical thermal analysis curves are shown in **Fig. 1**. On heating, the following reaction was found to take place at 530°.

$$L_2+\theta+\alpha \rightleftarrows L_1+L_2+\theta+\alpha$$

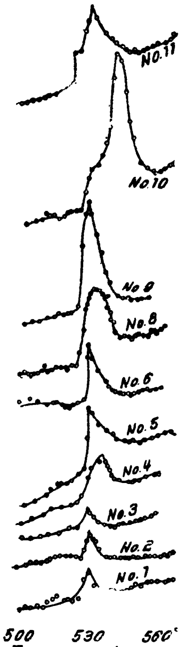
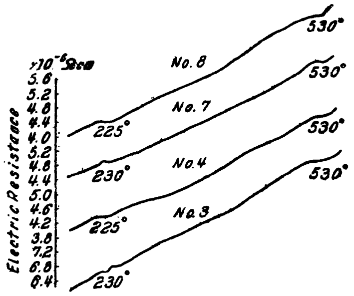


Fig. 1 The Results of Thermal Analysis.

Where L_1 and L_2 are primary and secondary liquids produced from the monotectic reaction. α is an aluminium solid solution of copper and a small amount of tin. θ is tin dissolved in a compound of $CuAl_2$. This reaction was observed in all specimens.

Fig. 2 The Change of Electric Resistance.



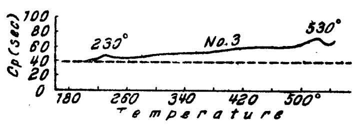


Fig. 3 The Change of Specific Heat.

Another arrest at about 535° on the curves of No. 11 was due to the temperature difference between the monotectic reaction and the dissolving of θ-phase. A few examples of resistivitytemperature curves on heating are shown in **Fig. 2**. The existence of the ternary eutectic and monotectic reactions was detected in all specimens. The former reaction took place at 530°, which coincides closely with that in the differential thermal analysis. The specific heat of the specimens is measured under the above mentioned conditions and the result obtained is shown in **Fig. 3**. This result

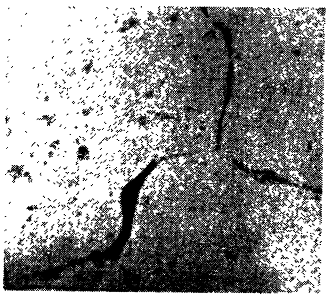


Photo. 1

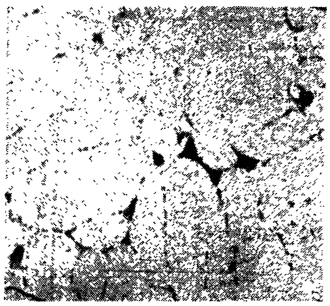
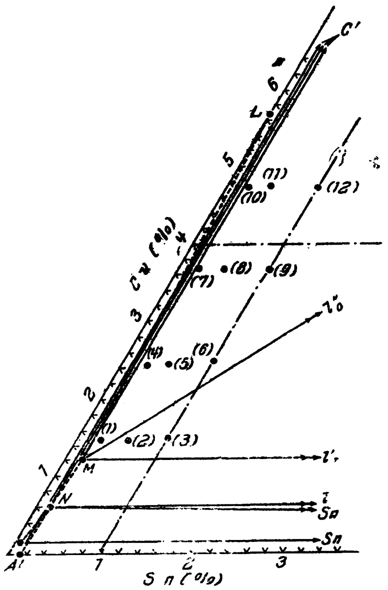


Photo. 2

consists of two thermal changes, the former corresponding to the ternary eutectic reaction and the latter coinciding with the ternary monotectic reaction. Specimens containing 4.6 % of copper and 1 % tin were quenched from 500° and 540°, respectively. As is shown in **Photo. 1** the alloy quenched from 540° had a small amount of liquid separated at the grain boundary and the other phases (α,θ) were dissolved in the martrix. On the contrary, as shown in **Photo. 2** the alloy quenched from 500° had a finer grain boundary compared with the former and consisted of threephases (α,θ,L_1).

IV. Discussion

According to T. Sato's diagram(1), the solubility of tin in θ phase was 1 % and the θ phase formed a pseudo-binary system with tin. According to H. K. Hardy(2), the maximum solubility of tin in solid aluminium was 0.1~0.3% at the eutectic temperature and it become 0.05% at 500°. The large scale diagram of the aluminium-rich side constructed from the results of the present investigation is shown in **Fig. 4**. The solubility limit of α is shown by point M which corresponds with 5.1%



(1), (2), ...etc. coincide with the composition of specimens which is shown in Table 1.
Fig. 4 The Al-Cu-Sn Diagram (Al-rich side).

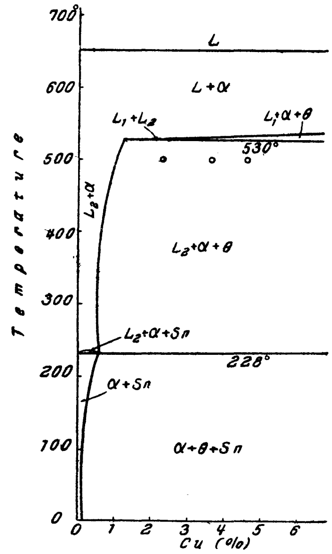


Fig. 5 Sectional Diagram of 4% Cu.

of copper at that temperature in an Al-Cu System. Some sectional diagrams based upon the experiments are shown in **Fig.** 5 and **Fig. 6.**

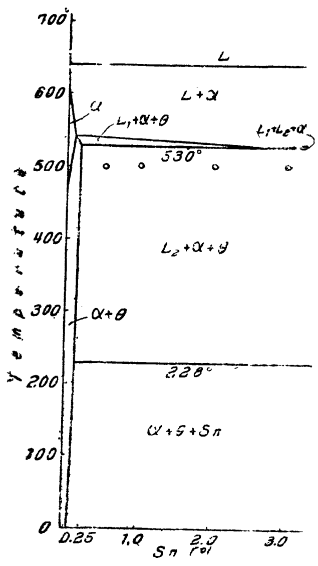


Fig. 6 Sectional Diagram of 1% Sn

V. Conclusion

The phase boundaries of the Al-Cu-Sn ternary system have been determined in the portion of the diagram extending from the aluminium corner down to the point of composition containing 90% Al. This diagram was developed from T. Sato's fundamental diagram. According to our diagram, the range of α solid solution is very narrow and slender along to the copper composition axis. This means that the solubility of copper in solid aluminium decreases with the addition of a small amount of tin from about 5.1% to less than 1.52% at the temperature of the ternary monotectic reaction (530°). This result may be very interesting for elucidating the mechanism of age-hardening of such Al-rich Al-Cu-Sn alloys.