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CITATION:

Koto, Hajime. On the Constitution of the so-called Intermetallic Compound, "Ag₃Al" in the Silver-rich Aluminium-Silver Alloys. *Memoirs of the College of Science, Kyoto Imperial University. Series A* 1941, 23(5): 321-324

ISSUE DATE:

1941-08-31

URL:

<http://hdl.handle.net/2433/257267>

RIGHT:

On the Constitution of the so-called Intermetallic Compound, " Ag_3Al " in the Silver-rich Aluminium-Silver Alloys¹

By Hajime Kotô

(Received November 1, 1940)

Abstract

Microscopic examination, X-ray analysis and accurate chemical analysis were made with regard to specimens of various compositions corresponding to and also near to the so-called intermetallic compound, " Ag_3Al ."

As the result of these researches, it was concluded that the intermetallic compound represented by the formula, Ag_3Al has a narrow range of homogeneity for composition of about 0.24% Al, and its composition is rather close to the formula $\text{Ag}_{10}\text{Al}_3$.

Introduction

In the aluminium-silver alloys, two intermetallic compounds are generally recognized; the one corresponds to Ag_3Al (β' -phase) which is of the complex cubic structure belonging to the β -manganese type and the other, Ag_2Al (γ -phase) which is of the close-packed hexagonal type.

In the present experiment, the constitution of the former was determined by microscopical examination, X-ray analysis and accurate chemical analysis, as will be described below.

Specimens

The silver used was of the utmost purity (1000/1000), especially prepared at the Imperial Mint, Osaka; the aluminium was also of the highest purity, (99.996%) made in France. Under a layer of sodium chloride, the silver was first melted in a graphite crucible, and then aluminium was thrown into the melt. The mixture was well stirred, and cast into an iron mould (6.5 mm. in inner diameter and 60 mm. long). Alloys of various compositions were prepared in this way, as shown in Table 1.

The alloys thus obtained were first quenched from 350° and 200°C respectively in ice-water after annealing at 700°C for an hour and slow

1. This paper was read at the April meeting of the Chemical Society of Japan (1938) and also at the meeting of the Japan Institute of Metals (1939).

Table 1

| By Synthesis Wt. - % Al | By Analysis Wt. - % Al. |
|----------------------------|----------------------------|
| 7.6920 | 7.56 |
| 7.6000 | 7.54 |
| 7.5000 | 7.34 |
| 7.4074 | 7.33 |
| 7.3000 | 7.09 |
| 7.2000 | 6.84 |

cooling down to 350° or 200°C. Then they were again quenched from 350° and 200°C respectively in ice-water, after annealing at 350° and 200°C for 15 and 70 days respectively in a vacuum glass tube. As can be seen in Table 1, the compositions

of the specimens thus obtained were precisely determined by estimation of the silver content by the Gay-Lussac method.

The Micro-structure

The micro-photographs of some of the specimens quenched from 350°C in ice-water are reproduced in Photos 1~6, Plate I.

As can be seen in Photo 1, Plate I, the micro-structure of the specimen containing 6.84 per cent. of aluminium shows that it is mainly composed of the β' phase, except for a small quantity of α phase. Moreover, the micro-structures of the specimens quenched from 350°C containing 7.09 and 7.33 per cent. of aluminium respectively, both consist of the homogeneous phase, as shown in Photos 2 and 3. While Photos 4~6 indicate that all the specimens quenched from 350°C containing respectively 7.34, 7.54 and 7.56 per cent. of aluminium, bear the γ - and β' -phases.

Photos 7~11 in the same Plate show the micro-structures of the specimens quenched from 200°C in ice-water.

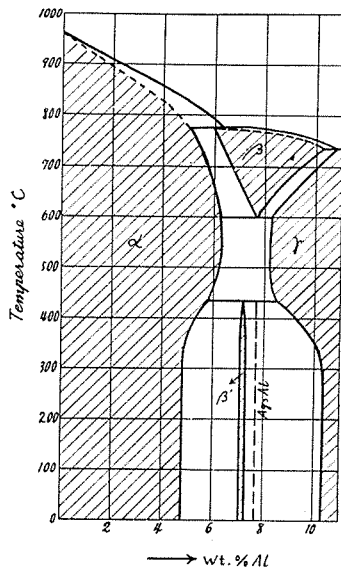
As is seen from these photographs, when quenched from 200°C, the specimens containing respectively 7.09 and 7.33 per cent. of aluminium are homogeneous, while those containing respectively 6.84, 7.34 and 7.54 per cent. of aluminium are heterogeneous, similarly to the case of those quenched from 350°C.

From the result of the microscopical examination mentioned above, the composition of the so-called intermetallic compound, "Ag₃Al" may be said to be 7.21 per cent. of aluminium, which is the mean value of 7.33 and 7.09 per cent. of aluminium. Thus we may consider from the above data and also various formulae as shown in Table 2 that the composition of the so-called intermetallic compound, "Ag₃Al" is rather close to the formula, Ag₁₆Al₃, corresponding to 7.22 per cent. of aluminium.

Table 2

| The Formula | Wt. - % Al |
|---------------------------------|-------------|
| $Ag_3 Al$ | 7.69 |
| $Ag_{34}Al_{11}$ | 7.51 |
| $Ag_{31}Al_{10}$ | 7.46 |
| $Ag_{28}Al_9$ | 7.44 |
| $Ag_{25}Al_8$ | 7.41 |
| $Ag_{22}Al_7$ | 7.37 |
| $Ag_{19}Al_6$ | 7.32 |
| $Ag_{16}Al_5$ | 7.22 |
| $Ag_{13}Al_4$ | 7.14 |
| $Ag_{10}Al_3$ | 6.98 |
| $Ag_7 Al_2$ | 6.67 |
| $Ag_4 Al$ | 5.88 |

Fig. 1



Moreover, when quenched from 350° or 200°C, the specimens respectively containing 7.33 and 7.09 per cent. of aluminium are both homogeneous. Consequently it may be considered that the β' phase has a narrow range of homogeneity for the composition of about 0.24%Al, as shown in Fig. 1.

The Crystal Structure

Adopting $K\alpha$ radiation of copper, photographs were taken, by the Debye-Scherrer method, and with the aid of a cylindrical camera of 7.03 cm. in diameter. Some of the spectra thus obtained are reproduced in Photos 12~21, Plate II.

As can be seen in Photo 14, the spectral lines of the specimen quenched from 350°C in ice-water containing 6.84 per cent. of aluminium, are composed of many lines on the diffraction pattern of the β' -phase, and also several lines due to the planes (200) and (113) of the α -phase. Photos 15 and 16 show the photographs taken by the powder method with the microscopically homogeneous alloys quenched from 350°C in ice-water containing respectively 7.09 and 7.33 per cent. of aluminium. In these photographs, Photos 15 and 16, spectral lines of the γ -phase could hardly be detected, since many of the spectral lines of the γ - and β' -phases overlap. While in Photos 17~19, which

are taken with the alloys quenched from 350°C in ice-water containing 7.34, 7.54 and 7.56 per cent. of aluminium respectively, a faint spectral line due to the plane (111 $\bar{2}$ 2) of γ -phase is observed besides that of β' -phase. Accordingly, the γ -phase was distinguished from the β' -phase. Furthermore, in Photo 20 taken with the specimen containing 9 per cent. of aluminium, the β' -and γ -phases were clearly detected. It will be noticed that the spectra taken with the specimens quenched from 200°C, are not here reproduced; they were essentially the same as those from specimens quenched from 350°C.

Though the result of the microscopical examination is not clearly confirmed by that of the X-ray analysis, we may conclude that the former is substantially in agreement with the latter.

Conclusion

The experimental results which have hitherto been described in connection with the specimens of the aluminium-silver alloys quenched from 350° and 200°C respectively in ice-water, lead us to the following conclusion:—

(a) The constitutional formula of the so-called intermetallic compound, “Ag₃Al” is rather near to Ag₁₆Al₅.

(b) According to the previous constitutional diagram, the so-called intermetallic compound, “Ag₃Al” is insoluble in both aluminium and silver in the solid state, but it was now found that the so-called “Ag₃Al” is slightly soluble in these two elements.

In conclusion, the writer wishes to express his sincere thanks to Prof. D. Uno for his kind guidance, during the progress of this investigation and to Ass. Prof. H. Hirata for his valuable advice in the X-ray analysis. His thanks are also due to Dr. H. Komatsubara and Mr. G. Chikauchi at the Imperial Mint, Osaka, for their kind efforts with respect to the chemical analysis of the specimens, and to Mr. S. Nakamura for his efficient aid throughout the present research. The expense for the experiments has been defrayed from a grant made to Prof. D. Uno by the Ministry of Education for the Promotion of Scientific Research, to which the author's thanks are due.

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Plate I

(Quenched from 350°C in ice-water, after annealing for 15 days in vacuum.)

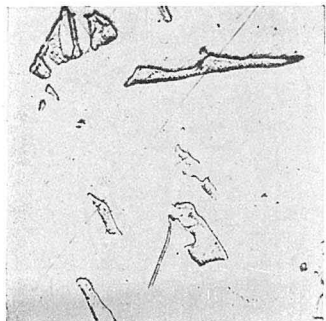


Photo 1. 6.84%Al ×160

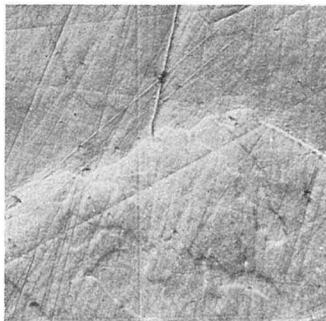


Photo 2. 7.09%Al ×160



Photo 3. 7.33%Al ×160

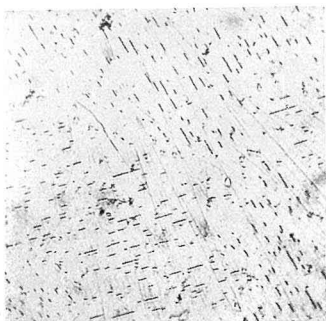


Photo 4. 7.34%Al ×160

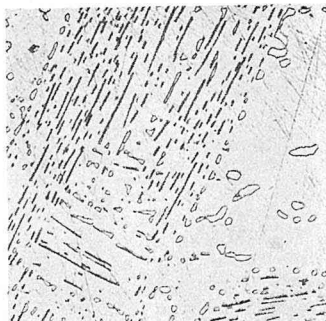


Photo 5. 7.64%Al ×160

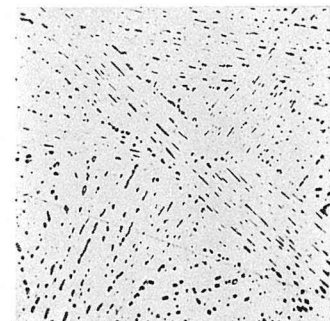


Photo 6. 7.56%Al ×160

(Quenched from 200°C in ice-water, after annealing for 70 days in vacuum.)

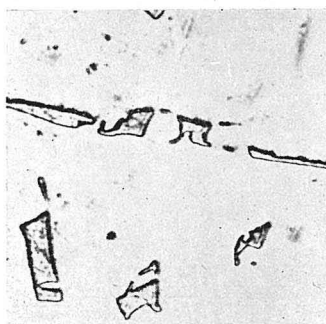


Photo 7. 6.84%Al ×160

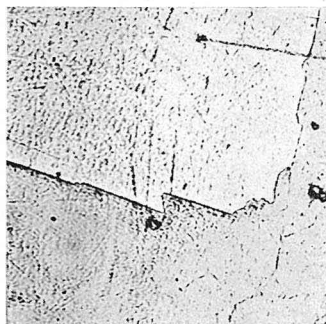


Photo 8. 7.09%Al ×160



Photo 9. 7.33%Al ×160

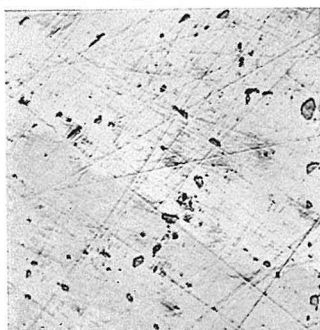


Photo 10. 7.34%Al ×160



Photo 11. 7.54%Al ×160

Hajime Kotô

Plate II

(Quenched from 350°C in ice-water, after annealing for 15 days in vacuum.)

