# The Influence of Precipitated Phase in Al-4%Cu Alloy under High Magnetic Field

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**Key Words:** G.P. sections, high magnetic field, Θ phase, Al-Cu alloys, SEM, XRD.

**Abstract**

Nonferrous metals have a very important position in industry. At present, parts of shipbuilding, automobile, and aircraft etc. are designed and manufactured accurately, simultaneity need light-weight and high-strength. Aluminum copper alloys are one kind of typical precipitation hardening alloy which has been widely used. It is interesting to investigate transformation behavior of precipitated phase in such kind of alloys under high magnetic field. Transformation of materials under high magnetic field is many different compared with conventional condition. The author prepared the Al-4%Cu alloy.

## 1. INTRODUCTION

Recently high magnetic field and cryogenic treatment is new method to improve material characters, more and more be paid attention to. Sometimes we need material have good characters during very low temperature, just like in astrospace or polar region. In this study we choose the material is Al-4%Cu, compare characters during different aging time and temperature, with or without high magnetic field and cryogenic treatment. We use Vickers micro-hardness, OM, XRD, TEM to analysis the results. [1, 2, 3]

## 2. EXPERIMENTAL METHOD

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The first of all is heat treatment , 450 $^{o}$C homogenizing annealing, 530 $^{o}$C solid solution and water quenching immediately. After we separate A, B group. A group aging temperature: 180 $^{o}$C, aging time: 10, 30 min, 1, 4, 10, 20, 50h. B group separate two teams: one with high magnetic field, the other without. Both teams aging temperature is 130 $^{o}$C, aging time:10, 30 min, 1, 2, 4, 10h. In this study, the parameter of high magnetic field as follows: max intensity 10 T(0-10T), the size of vacuum 100(diameter)×460 mm, from 0 to 10 T speedup time: 12 minutes [4]. Table 1 is the chemical compositions of specimens.

**Table 1** Chemical composition of specimens (%)

| Al | Cu | Fe | Si | Zr | Mg |
|---|---|---|---|---|---|
| 95.7 | 4.00 | 0.223 | 0.0301 | 0.0025 | 0.0019 |

## 3. EXPERIMENTAL RESULT

### 3.1 Metallographical microstructure

Fig. 1 is Al-4%Cu alloy microstructure .The white area is α-Al, the black particle and small black section is the second phase .In Fig. 1 we can find crassitude columnar crystals, there are some pores in the crystal boundary and imbalance phase, dendritic-segregation.

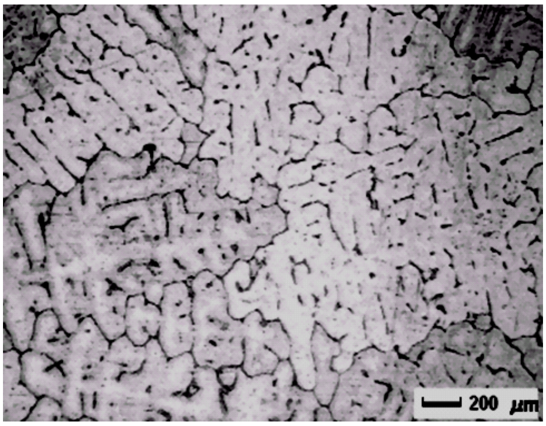


**Fig. 1** Al-4%Cu alloy microstructure

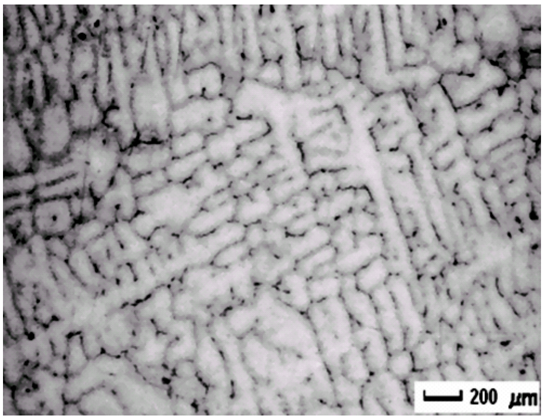


**Fig. 2** Al-4%Cu alloy microstructure after 450 $^{o}$C uniform anneal

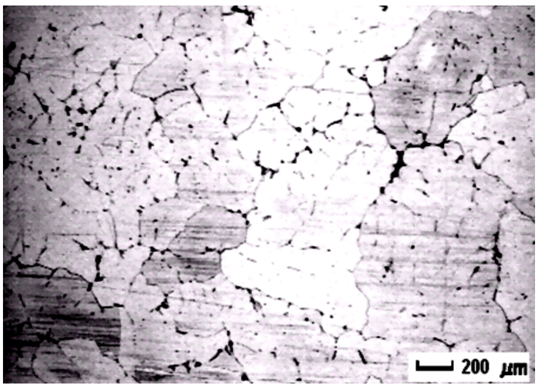


**Fig. 3** Al-4%Cu alloy after 530 $^{o}$C solid solution microstructure

The solid solution process is:

α(supersaturation)→G.P.section→$\theta''$ transition phase →$\theta'$ transition phase→$\theta$ ($CuAl_2$) stable phase.

Fig. 2 Al-4%Cu alloy microstructure after 450 $^{o}$C and 10h homogenizing annealing. We can see specimen after homogenizing annealing ,there are lots of second phase separated out in crystal grain then dendritic segregation nearly disappear ,along crystal boundary there are many imbalance phase melted.

Fig. 3 is the Al-4%Cu alloy 530 $^{o}$C keeps warm 2 hours carry on the solid solution treatment, the test specimen microstructure result, may see from the chart, the intragranular is nearly out-of-sight the second phase. The dendritic segregation which saw in the cast condition and in the uniformized annealing's metallography did not look nearly in the solid solution treatment.

3.2 Micro-hardness

Fig. 4 is 180℃ in the effectiveness test specimen entire effectiveness process the micro-hardness test result. As shown in Fig. 3-4, may see from the chart: Has a very short stationary process at the first stage degree of hardness value, then degree of hardness value starts to rise, that is because the G.P. area forms reason. But the G.P. area's formation also has achieves is saturated, when the G.P. area is saturated, appeared, its appearance causes degree of hardness to rise achieves the peak value finally. Is the process which the curve of hardness drops, is also the process namely effectiveness stage which the alloy softens. This is because the appearance $\theta'$ phase creates degree of hardness drop, we discovered that degree of hardness value drops rapidly, is the last process, the alloy softens completely, degree of hardness value no longer drops, this stage $\theta$ phase has formed. The appearance $\theta$ phase means entire process effectiveness the conclusion. [5]

As shown in Fig. 5, may see from the chart: The two have a drop tendency (not to strengthen magnetic field obviously) from the very beginning, will achieve the certain extent later also to have a rise, afterward entered a gentler stage (not to strengthen magnetic field also to have a drop rise process), finally enhanced rapidly.

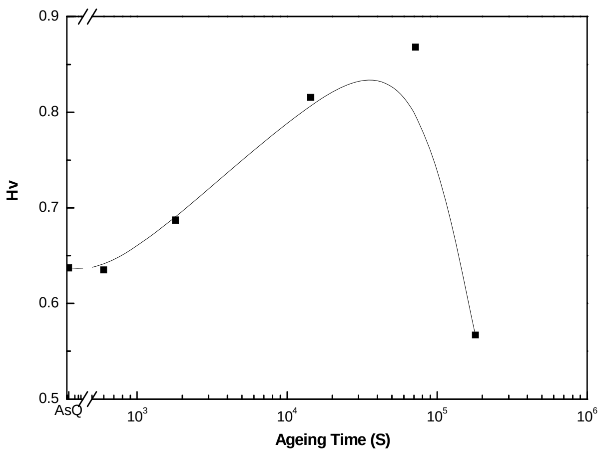


**Fig. 4** Micro-hardness of the specimens after 180 °C aging

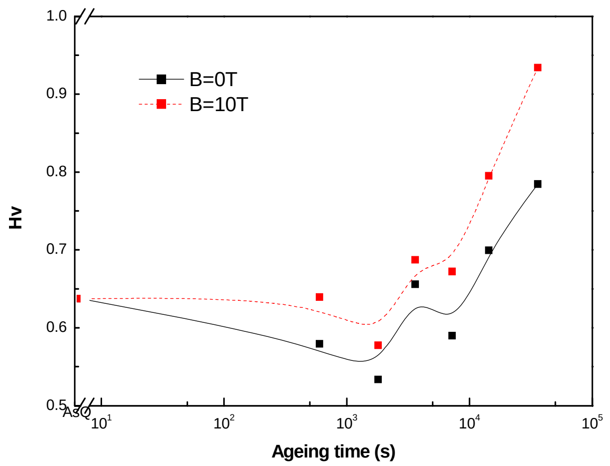


**Fig. 5** Microhardness of the specimens after high magnetic field or without

3.3 XRD

Fig. 6 Shows the Al-Cu alloy after 130 °C aging 120 minute XRD results. From the chart may clearly see under the high magnetic field cause $Al_2Cu$ in the Al-Cu alloy disappear in the solid state changes, this explained that the high magnetic field will restrain the second phase separate out. As shown in Fig. 7, may see from the chart: Respectively is from bottom to top the cast condition, the melting, effectiveness 600s, effectiveness 1800s, the effectiveness 3600 s XRD image, uses three strong peaks the methods to label separately first on the cast condition image on belongs to α-Al and the $Al_2Cu$ peak, then in turn upward α-Al and the $Al_2Cu$ peak will correspond in the position to carry on the indication.

**Table 2** XRD parameters in ASTM of Al and Al2Cu ($\theta$).

| | | | | | |
|---|---|---|---|---|---|
| d | 2.338 | 2.0248 | 1.4317 | 1.2210 | 1.1690 |
| $2\theta$ | 38.472 | 44.721 | 65.096 | 78.229 | 82.436 |
| hkl | 111 | 200 | 220 | 311 | 222 |
| I | 999 | 455 | 230 | 228 | 62 |

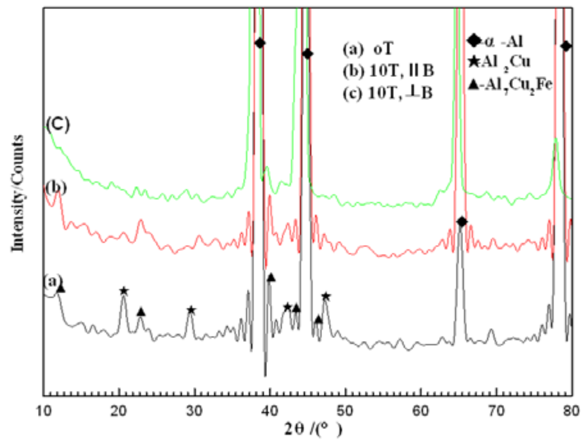


**Fig. 6** XRD result after 130 aging 120 min with high magnetic field or without

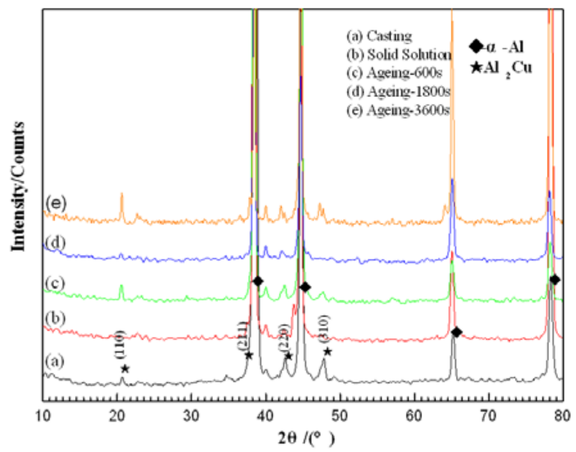


**Fig. 7** XRD results of the specimens after 180 °C aging

We discovered discovers the $Al_2Cu$ peak above the cast condition curve not to discover in the melting curve, i.e. the solid solution treatment causes the Cu atom basically completely to melt into α-Al, therefore in the test specimen the $Al_2Cu$ content are very few, causes from the XRD test result to discover that the $Al_2Cu$ diffraction intensity is very low, basically is very difficult to distinguish.

Along with the effectiveness time's extension, we discovered that the $Al_2Cu$ peak appeared in effectiveness 600s, 1800s and on the effectiveness 3600 s image, possibly is as a result of the test specimen surface condition influence which prepares causes in the effectiveness 1800s curve the $Al_2Cu$ peak is not obvious, but already might see the aging treatment of metal after effectiveness 600s and 3600s the test specimen $Al_2Cu$ diffraction intensity strengthens in turn, this explained that along with effectiveness time's increase, the separation $Al_2Cu$ quantity increases gradually.

3.4 TEM

All samples' TEM observation carries on along the Al substrate's direction. 130 $^{o}$C has not executed strengthens the magnetic field effectiveness 60 minutes test specimens transmission electron microscope result as shown in Fig. 9, Fig. 9 is Al-4%Cu the alloy G.P. area appearance.

In executes strengthens the magnetic field in the situation identical temperature effectiveness same time test specimen transmission electron microscope result as shown in Fig. 9, Fig. 9 is Al-4%Cu the alloy G.P. area appearance.

Is opposite is non-uniform in Fig. 8, obviously good many, because it does not looks like Fig. 8 such colors distributed such non-uniform, namely executes strengthens in the magnetic field effectiveness test specimen the G.P. area distribution to be evener.

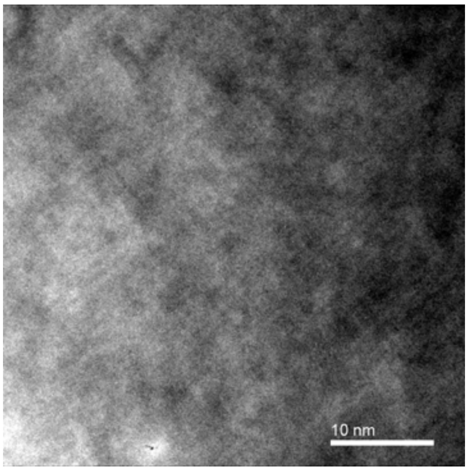


**Fig. 8** TEM results 130℃ aging 60 min, B=0T

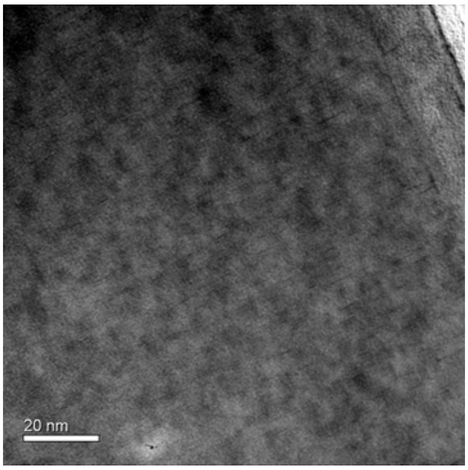


**Fig. 9** TEM results 130℃ aging 60 min, B=10T

## 4. CONCLUSIONS

1. Homogenizing annealing and then solid solution next aging make the second phase separated out in crystal grain, imbalance phase melted and dendritic segregation reduce, along crystal boundary there are many imbalance phase melted.
2. With high magnetic field Vickers hardness is higher than without.
3. High magnetic field cause G.P. section distributing more uniform, and the specimens which after high magnetic field Vickers hardness higher than un-high magnetic field.
4. From all aging process, high magnetic field restrain the second phase particle separate out.

## ACKNOWLEDGMENTS

This research was financially supported by The Ministry of Education, Science and Technology (MEST) and Korea Industry Technology Foundation (KOTEF) through the Human Resource Training Project for Regional Innovation and Second-Phase of BK (Brain Korea) 21 Project.

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