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journal or publication title	PTM 2015 - Proceedings of the International Conference on Solid-Solid Phase Transformations in Inorganic Materials
page range	421-423
year	2015-07-03
URL	http://hdl.handle.net/2297/45448

TWO-STEP AGE-HARDENING BEHAVIOR OF CU-BE AND CU-TI ALLOYS PROCESSED BY HIGH-PRESSURE TORSION

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Keywords: Cu-Be alloy, Cu-Ti alloy, High-pressure torsion, Age-hardening

Recently, many investigations of the aging behavior of age-hardenable alloy systems processed by the severe plastic deformation (SPD) technics have been conducted [1]. Reported aging responses after SPD processing are generally different from alloy to alloy. While, the reason why the difference in aging response among the alloy systems processed by the SPD technics has not been clarified yet. During the SPD processing, in addition to the significant grain refinements, vacancies are produced in very high densities which are typically close to those of vacancies in thermal equilibrium at the melting point [2]. Gibicza *et al.* reported that during storage of the SPD-processed Cu even at room temperature (RT) the vacancy concentration reduced significantly while the dislocation density and the grain sized remained unchanged [3]. Excess vacancy concentrations are well-known to have a strong effect on precipitation kinetics of second phases [4]. Therefore, natural aging of the age-hardenable alloys after the SPD processing should strongly affect aging responses on subsequent artificial aging treatments. In this study, we investigated effects of natural aging treatments on the subsequent artificial aging behaviors of Cu-1.8wt%Be-0.2wt%Co alloy and Cu-3wt%Ti alloy specimens processed by high-pressure torsion (HPT) after solution treatment. In the Cu-Be system alloy, G.P. zones first nucleate on aging at around 300 ^{o}C after a solution treatment. The G.P. zones then transform continuously to the stable γ phase via meta-stable phases. On the other hand, spinodal decomposition produces meta-stable β'-Cu_4Ti phase precipitates in the Cu-Ti alloy aged at around 350 to 500 ^{o}C.

Application of HPT processing to the Cu-Be and Cu-Ti alloys at RT under an applied pressure of 5 GPa for 10 revolutions at 1 rpm to the alloys produced ultra-fine grained structures. The average grain sizes of Cu-Be and Cu-Ti specimens were approximately 70 and 90 nm, respectively. The hardness of the Cu-Be and Cu-Ti specimens increased with equivalent strain and then saturated to constant values of 400 and 330 Hv, respectively.

Figures 1 and 2 show the change in resistivity and microhardness of the Cu-Be and Cu-Ti specimens during natural aging at 20 ^{o}C. Resistivity change $\Delta\rho$ for both the specimens exhibited gradual decrease with increasing aging time t. On the other hand, microhardness of the specimens unchanged with t. Transmission electron microscopy observation revealed that grain sizes of both the specimens remained essentially unchanged, and that no precipitated phases were formed in the specimens, even after the longest period of natural aging (= 2.6×10^6 s).

Figures 3 and 4 displays the age-hardening curves of Cu-Be and Cu-Ti specimens during artificial aging treatments at 320 ^{o}C and 350 ^{o}C after the natural aging treatment for various period, respectively. For each specimen, the microhardness increased rapidly with increasing artificial aging time, attained peak hardness and then decreased continuously on prolonged aging.

As can be noted in Figures 4 and 5, it is apparent that the influence of natural aging on aging response during subsequent artificial aging is completely different between the Cu-Be and Cu-Ti specimens. For the Cu-Be specimens, peak hardness decreased, and aging time for peak hardness increased with natural aging time. On the other hand, the Cu-Ti specimens did not show any notable change in aging response, irrespective of the natural aging time.

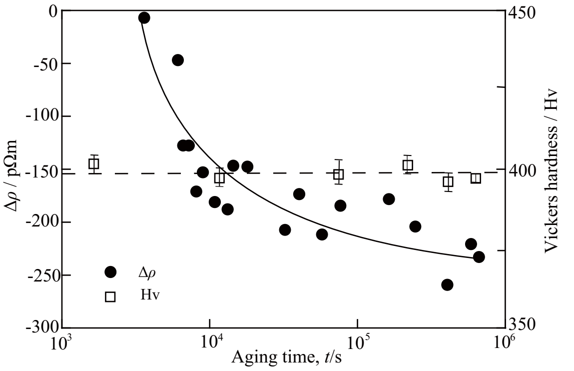

Figure 1. Change in Vickers microhardness and specific resistance of a Cu-Be-Co alloy during natural aging at 20 °C after a HPT processing.

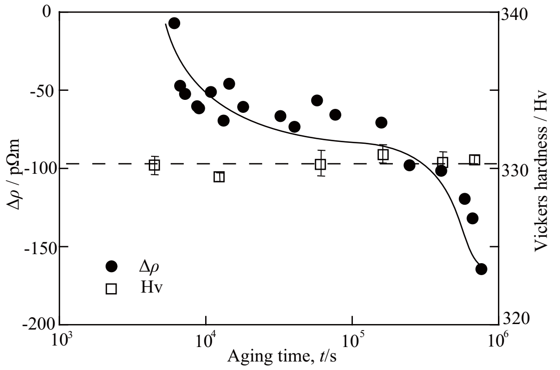

Figure 2. Change in Vickers microhardness and specific resistance of a Cu-Ti alloy during natural aging at 20 °C after a HPT processing.

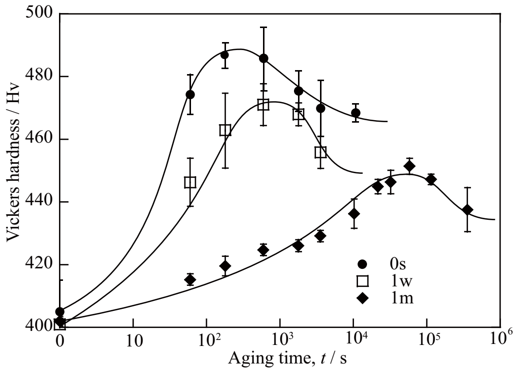

Figure 3. Age hardening curves of Cu-Be-Co alloys artificially aged at 320 °C after a HPT processing and then natural aging for 0 s, 1 week (1w) and 1 month (1m).

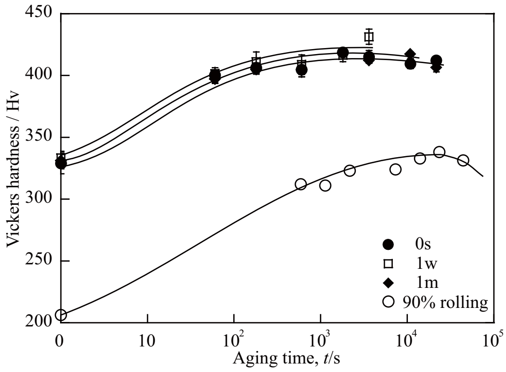

Figure 4. Age hardening curves of Cu-Ti alloys artificially aged at 350 °C after a HPT processing and then natural aging for 0 s, 1 week (1w) and 1 month (1m). Also shown is data for the alloy cold-rolled by 90% reduction and then aged at 350 °C.

References

1. S. Hirosawa et al., "Methods for Designing Concurrently Strengthened Severe Deformed Age-Hardenable Aluminum Alloys by Ultrafine-Grained and Precipitation Hardening," Metall. Mater. Trans., 44A (2013) 3921-3933.

2. M.J. Zehetbauer et al., "Deformation Induced Vacancies with Severe Plastic Deformation: Measurements and Modelling," Mater. Sci. Forum, 503-504 (2006), 57-64.

3. J. Gubicza et al., "Microstructural Stability of Cu Processed by Different Routes of Sever Plastic Deformation," Mater. Sci. Eng. A, 528 (2011), 1828-1832.

4. K.C. Russell, "The Role of Excess Vacancies in Precipitation," Scripta. Metall., 3 (1969), 313-316.