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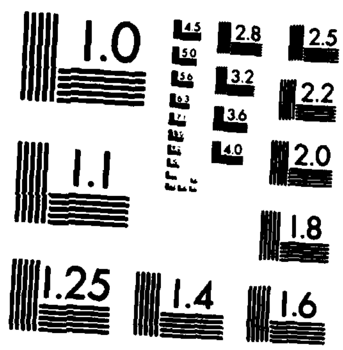

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ANNUAL LETTER REPORT

Investigation of the Elastic Behavior of Al-Li-X Alloys

ONR Task Order No. N00014-85-k0526

ONR Work Unit No. NR 031-886

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This report covers the scientific progress during the period June 1, 1985 to May 31, 1986.

Description of Research

The goal of this research is to identify and understand critical parameters governing the elastic moduli of commercially important Al-Li-X alloys (X designates copper, magnesium or both). The basic knowledge gained during the project can be used toward further development aluminum-lithium alloys in terms of optimized stiffness.

The Young's modulus, shear modulus and Poisson's ratio are calculated from the density and the propagation rate of longitudinal and transverse 10 MHz ultrasonic waves.

Scientific Progress

In the initial stage of this program the elastic moduli of four different Al-Li-Mg-Cu alloys have been measured after 16, 50 and 150 hours of aging. From 16 to 50 hours a modulus increase followed by a decrease from 50 to 150 hours was found. The overall variations in moduli were as high as 4% (3 GPa) and are caused solely by the precipitation processes during heat treatment. Calculations, taking the volume fractions and the intrinsic moduli of matrix, delta prime precipitates, and S'' into account, showed that the changes in volume fractions of delta prime could not account for the measured changes.

The contribution of equilibrium grain boundary precipitates was used to explain the differences between observed and calculated values.

The Al-Li-Cu-Mg alloy with the highest lithium content (9.6 at%) had also the highest combined amount of copper and magnesium (0.74 and 1.54 at%). This alloy exhibited a much lower modulus than expected. Optical metallography of this alloy revealed an excessive amount of constituent particles with sizes up to 20 μm. These particles were not found in the other alloys and were believed to contain lithium as well as being copper and magnesium rich. The solubility limits were exceeded resulting in large scale precipitation of insoluble primary phases during casting. Incorporation of lithium into these particles, which is now no longer present in modulus beneficial form, may explain the lower modulus of this alloy.

The elastic properties of two Al-Li-Cu alloys (8.7 and 8.0 at% lithium, both .4 at% copper) are being studied presently as a function of aging time at 190°C. So far the modulus of elasticity decreases by up to 2 GPa after 10 minutes of aging, followed by a steady increase until about 40 minutes. Then the moduli stay essentially constant over several hours of aging time. Further aging is in progress. The compositions of these alloys have been selected so that when aged essentially only the delta prime (Al_3Li) and T1 (Al_2CuLi) phase precipitate. By not stretching the material, the nucleation and growth of the T1 phase is delayed during the initial stages of aging, thus enabling us to study the change in modulus caused by delta prime precipitation and delta prime Ostwald ripening alone during the first twenty hours. The absence of the T1 phase during the first 20 hours of heat treatment has been confirmed by small angle X-ray scattering

(SAXS) experiments performed at the Oak Ridge National Laboratory. The analysis of the SAXS data as well as additional transmission electron microscopy and X-ray Guinier camera investigations, used for volume fractions and phase determination, are not completed at this point. The results obtained so far indicate, that in the solution heat treated condition delta prime precipitates are already present with a radius of about 3 nm. During initial aging volume fraction as well as particle radius of delta prime increase, and the observed initial decrease in modulus can be explained as follows.

The lithium goes out of solid solution to form Al_3Li particles, resulting in a decrease in the solid solution modulus and volume fraction. At the same time the delta prime phase, with a constant modulus about 25% higher than the one of the matrix, increases in volume fraction. These two competing effects determine the net values of E as a function of aging time. Our calculations for a 8 at% lithium alloy, using single crystal data from Muller et al. (1), show that the drop in modulus during aging depends on the initial lithium concentration of the solid solution and the averaging method used (Voigt, Reuss, Hill). The drop becomes more pronounced for alloys with higher lithium content and can completely disappear in alloys with a lithium content below about 5 at%. The measured modulus behavior will be explained quantitatively once the volume fraction analysis is finished.

Another alloy under study contains about 8.5 at.% lithium and about .9 at.% copper. In this alloy a steady increase in modulus is found during the first hour of aging (measurement intervals 10 minutes). SAXS and TEM investigations show the presence of T1 precipitates in addition to delta prime after 10 minutes of aging. The beneficial effect of T1 on the modulus has been demonstrated by us in the Al-Li-Cu-Mg alloys mentioned earlier (2) and the co-precipitation process could result in the measured modulus increase. The exact mechanism for the increase will be understood when the volume fraction analysis (SAXS, TEM, Guinier camera) is completed.

All the alloys under study are in form of rolled plate and show more or less pronounced *(110) [112] type texture components. In the* solution heat treated condition the moduli vary only maximal by about 2 % in different testing directions. However, the directionality of the moduli becomes more pronounced during aging. This is can be caused by two effects. First, the anisotropy constant of the matrix increases with decreasing lithium content (1) Second, the contributions of the precipitates may be elastically anisotropic. At this stage of the program the two effects cannot be separated quantitatively. A quantitative treatment will be attempted at the stages of aging where T1 precipitates out at the expense of delta prime and the solid solution composition stays essentially constant.

References

(1) W. Muller, E. Bubeck, and V. Gerold, "Elastic constants of Al-Li solid solutions and delta prime precipitates,", Aluminum- Lithium Alloys III, The Institute of Metals, London, 1986, p. 435

(2) E. Agyekum, W. Ruch, E.A. Starke, Jr., S.C. Jha, and T.H. Sanders, Jr., "Effect of precipitate type on the elastic properties of Al-Li-Cu and Al-Li-Cu-Mg alloys," ibid, p. 448

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