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X-RAY AND MICROHARDNESS INVESTIGATIONS OF RAPIDLY QUENCHED Al-RICH Al-Ni ALLOYS

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Introduction

The development of techniques for the rapid quenching of alloys from the liquid state has led to the investigation of non-equilibrium alloy systems over the past decade. However, few results have been published so far about aluminium base Al-Ni alloys. The maximum terminal solid solubility of Ni in Al, given as 0.023 at.% Ni (1) has been raised to about 1.0 at.% Ni by splat cooling at 20°C (2). While Jones (3) has reported that his measurements on Al-Ni alloys proved irreproducible, Bletry (4) and Tonejc and Bonefačić (5) have obtained metastable Al-rich Al-Ni solid solutions up to 5.5 at.% Ni.

The present paper deals with some new results obtained with Al 0.81-11.2 at.% Ni alloys subjected to liquid-quenching treatment using "two-piston" quenching apparatus (6,7).

Experimental

Details on the preparation of the alloys, quenching, and the measurements of lattice parameters have been reported previously (7,8). The appearance of phases was checked by means of a Nonius Guinier-de Wolf quadruple focusing camera with crystal-monochromated CuKα radiation. The annealing treatments of liquid quenched flakes were carried out in oil baths, for temperatures up to 200°C, and in Pyrex capsules in a furnace with a nitrogen atmosphere. After each annealing the flakes were air quenched and submitted to X-ray or microhardness measurements.

Results and Discussion

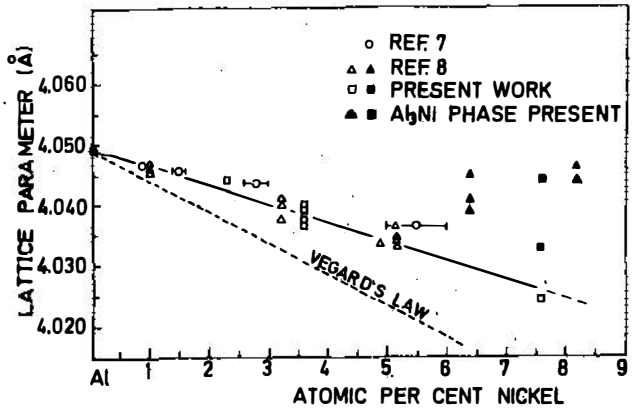

FIG. 1

Lattice parameters of fcc solid solutions in Al-rich Al-Ni alloys plotted against nickel concentrations.

The lattice parameters of the metastable Al-Ni solid solutions are plotted vs the concentration of nickel in Fig. 1. As seen from this figure, in our experiments we succeeded in dissolving as much as 7.7 at.% Ni in Al. This value is about 335 times greater than the equilibrium solid solution of Ni in Al determined in the Al-Ni phase diagram. The line, which indicates the change in lattice parameters vs concentration of Ni, shows a positive deviation from Vegard's law.

Microhardness measurements on Al-Ni alloys show (Fig.2) that the hardness of flakes containing Al-Ni solid solution (o, x, ▲, △) is about 1.5 to 2.5 times greater than the hardness of flakes with no Ni in solutions (□, ■).

No difference in hardness is found between the flakes containing only Al-Ni solid solution (o) and those which besides Al-Ni solid solution contain very small quantities of the Al_3Ni phase (x). However, in flakes with less Ni in solution and a fair content of the Al_3Ni phase (△, ▲), hardness is slightly decreased in comparison with solid solution flakes with the same Ni content. This appears to apply exclusively to those flakes which contain more than 5 at.% Ni. The

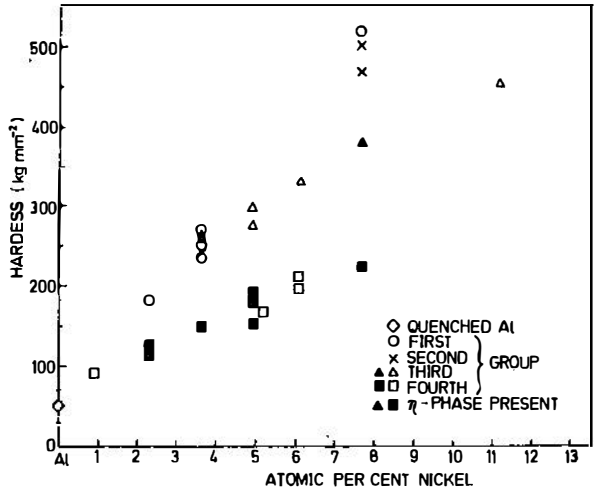

FIG. 2

The variation of microhardness (20 g load at room temperature) of four groups of rapidly quenched flakes with nickel content. o Flakes containing only solid solution; x Flakes containing partial solid solution and a small amount of Al_3Ni; ▲ , ▲ Flakes containing partial solid solution and a large amount of Al_3Ni; □ , ■ Flakes containing Al_3Ni phase and no Ni atoms in solution.

presence of a new metastable η-phase appears to have no effect on hardness.

The results of X-ray measurements on Al-Ni solid solutions (3.6 and 7.7 at.% Ni) are represented in Fig. 3a and 3b. After annealing for ten minutes at temperatures of up to 500°C, the lattice parameters show no change up to 150°C for the solution with 3.6 at.% Ni (Fig. 3a). The hardness increases to 150°C. (Fig. 4), indicating that some structural change occurs in this temperature region. This process is now being studied. Al-3.6 at.% Ni solid solution decomposes between 150° and 350°C reaching full equilibrium at 500°C (Fig.3a). The decomposition of the solid solution is accompanied by a decrease in hardness up to 350°C (Fig. 4), at which temperature hardness reaches the value of the isochronally annealed flakes, which contain the Al_3Ni phase at the very beginning of the hardness measurements.

Al-7.7 at.% Ni solid solution is less stable than solutions with lower Ni content: it decomposes at temperatures between 100° and 200°C (Fig. 3b) reaching

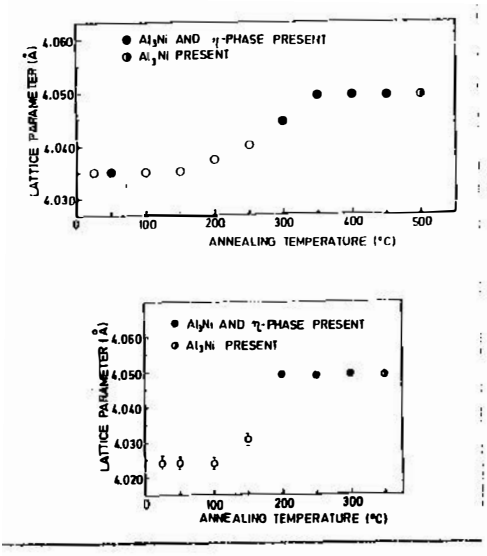

FIG. 3

The change of lattice parameter of Al-Ni solid solution with annealing temperature after annealing for ten minutes at each temperature for (a) 3.6 at.% Ni and (b) 7.7 at.% Ni.

equilibrium state already at 300°C.

After annealing at various temperatures the decomposition of Al-Ni supersaturated solid solutions is accompanied by the simultaneous appearance of an intermediate metastable phase (we called it η-phase) and the equilibrium Al_3Ni phase. In some of the quenched Al-Ni alloys the η-phase was present as well. In annealed flakes containing the η-phase, this phase disappeared after 20 hours at 300°C, or after 20 minutes at 500°C.

Fourteen X-ray reflections from this new metastable η-phase were detected and indexed as an orthorombic unit cell of a=6.40 Å, b=7.56 Å and

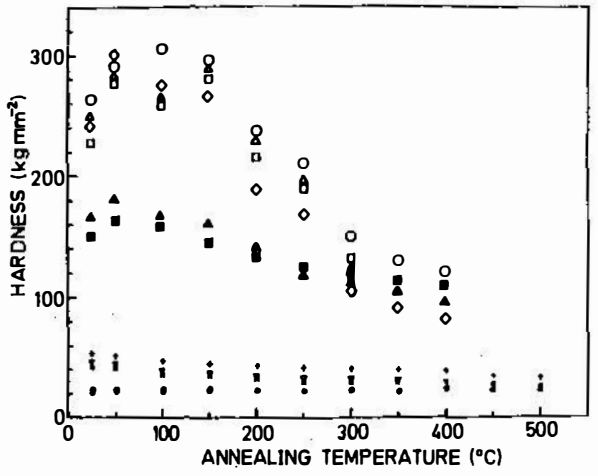

FIG. 4

○, △, ◇, □ Quenched flakes of Al-3.6 at.% Ni alloy containing only solid solution; ▲, ■ Quenched flakes of Al-3.6 at.% Ni alloy containing Al_3Ni phase and no Ni atoms in solution; +, ▽, × Quenched flakes of pure Al; ● Al-single crystals.

c=9.56 Å. From the missing reflections it can be concluded that D_{2h}^{7}-Pmna is the most probable space group of this phase.

Acknowledgements

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DISCUSSION :

J.J. van den Broek: Could an analysis of the X-ray line profiles give useful information about the type and magnitude of the deformation and stresses in the specimens ? Would this be a good link between normal X-ray work and hardness measurement or are there too many complications ?

A. Bonefačić In our laboratory the analysis of the X-ray line profiles is in progress. From the preliminary results obtained, we consider that there exsist both particle size and strain hardening, however the particle size effect is dominant.

R. Maddin : have more a comment than a question. The use of hardness or microhardness measurements from which to compare solid solution strengthening is most dangerous because of the complexity of the method. Hardness measures the resistance to the penetration into a metal of an indentor and hence combines yield stress with the rate of strain hardening. The yield stress and rate of strain hardening are themselves most complicated mechanisms. Consider, for example, the investigation of von Göller and Sachs almost 50 years ago who showed how the addition of Zn to Cu complicated both the yield stress and rate of strain hardening in the Cu-Zn system. The more Zn is added the higher the yield stress but the lower the rate of work hardening at values of strain up to about 0.1 to 0.2 strain. Similar behaviour occurs in Al crystals quenched from both the liquid state and from temperatures near the melting point

Comparison of effects from hardness measurements is at best, to be taken quite cautiously.

R.W. Cahn : The difficulty mentioned by prof. Maddin can in principle be overcome by the old technique of "Meyer analysis" - i.e. compating the sizes of impressions by spherical indenters: from this, we can separate out the "work-hardening component" from the "flow-stress component".

M. Paić : Microhardness measurements are the only technique which can be used with the ultrarapidly quenched alloys which up to now have been obtained in the form of very small and thin flakes.