Synthesis, hardness analyses on Nanocrystalline Silver coated Al-Cu-Mg-Ag nano Alloy

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Abstract:

By using Precipitation technique, we have been prepared 37 nm silver coated Al-Cu-Mg-Ag nanocrystalline alloy. The effect of precipitate size of silver coated Al-Cu-Mg-Ag nanocrystalline alloy using XRD measurement is 37 nm. SEM has been used to studied morphological nature and EDAX measurement shows that necessary elements are presented in this prepared sample. Using the Vickers hardness test, we can calculate hardness value and also compare with bulk material.

Keywords: nanocrystalline, hardness, precipitation, synthesis, average size

Introduction

A systematic study of size effect on the mechanical properties of composite material is essential for understanding their technological applications [1–3].Aluminium alloys are useful structural materials because of the combination of mechanical and physical properties they exhibit [4]. This is the case for the strength and corrosion resistance of the important classes of precipitation-hardenable Al alloys (2xxx, 6xxx and 7xxx series) used extensively in automotive and aerospace applications [4].

ISSN 2229-5518

In general, we can change size modification result in detrimental changes to other properties. These alloys have a desirable combination of strength, damage tolerance and density that is suitable for many engineering applications [5]. The phenomenon of plastic deformation triggering the formation of self-organized microstructures that actually improve wear resistance has been widely recognized for over a decade. The effect can be exploited through severe plastic deformation (SPD), in which the grain size in an alloy is reduced to the nanoscale, boosting the material's strength. Similarly, friction can be used to induce a transition in silver coatings that ultimately leads to a reduction in friction and wear. Silver (Ag) and copper (Cu) nanoparticles have shown great potential in variety applications due to their excellent electrical and thermal properties resulting high demand in the market. Decreasing in size to nanometer scale has shown distinct improvement in these inherent properties due to larger surface-to-volume ratio. Ag and Cu nanoparticles are also shown higher surface reactivity, and therefore being used to improve interfacial and catalytic process (1).

Currently, different types of methods have been used for the synthesis of Ag coated alloy [4,5]. But chemical method is an easy way to synthesize Ag coated Al-Cu-Mg-Ag nanocrystalline alloy.

EXPERIMENTAL DETAILS

A typical procedure was performed as follows in the literature (Ref.1-5). 0.38 grams of Al_2O_3, Silver oxide 0.48 gram, Cupper fillings 1 gram, and Magnesium oxide 0.16 gram mixing together and dissolved in 100 ml de-ionised water along with 1 gram of starch, and 2.5 ml of capping agent [i.e 5 ml H_2O + 5ml of capping agent] and making vigorous stirring process condition for 1 hr. After 1 h stirring is over and then add 1 mole of (10.59 g of Sodium Carbonate dissolve in 100 ml of de-ionised water) with free flow reflexive time and added with first solution. And continue the stirring for both the solution for 1 hr and added $AgNO_3$ solution (1ml) and continuing the stirring condition further 2 hrs. After all the solution transfer to centrifuge apparatus which helps to collecting the nano-Ag coated Al-Mg-Cu-Ag alloy deposited at the bottom of the test-tube. Then, finally collected sample was dissolved in de-ionised water, again centrifuge finally filtered and got Nano Ag coated Al-

Mg-Cu-Ag alloy in powder form. After making annealing in 300°C for 3 hrs and got single phase formation of nano Ag coated Al-Mg-Cu-Ag alloy.

RESULT AND DISCUSSION

Fig.1 shows the X-ray diffraction results for nano crystalline Ag coated Al- Mg-Cu-Ag annealed at 300°C for 3h sample. Three sets of peaks are observed corresponding to metallic AgAl, AgMg and MgCu nano alloy. The spectrum shows 5 major diffraction intensity peaks at 2θ = 30.898, 38.061, 44.254, 64.412, 77.343 and 81.435 and corresponding to the diffraction planes (2 1 1), (1 1 0), (2 2 2), (1 1 0) and (5 3 0) (Referred standard JCPDS data file) respectively. The XRD pattern could be indexed to the Cubic structure. The information of the particle size was obtained from the Full width at Half maximum (FWHM) of the diffraction peaks using the Scherrer formula

$$D = 0.9\lambda / \beta \operatorname{Cos}(\theta)$$

Here, wave length λ is ($Cu_{K\alpha}$ = 1.5406Å), β – is FWHM, θ is the diffraction angle. The average size of the nano-alloy have been calculated using well known Scherrer formula and average grain size was found to be 37nm. The sample face cantered cubic structure was confirmed through XRD. EDXA (Energy dispersive X-ray analysis) for the prepared Ag coated Al-Mg-Cu-Ag nano-particles annealed 300ºC/3hr sample have yielded the weight% and Atomic % as shown in Fig.2. Each element how much % of weight as well as Atomic% concentration was tabulated table 1. The following are the obtained graph which shows the necessary results of the composition of the elements regarding their spectrum counts which starts from 1 to 4. From this results revels that the formation of alloys were confirmed.

High resolution scanning electron microscopy (HRSEM) picture indicates that morphological nature of prepared sample as shown in figure 3. From the HRSEM image the average particle size 37 nm was obtained in Ag coated Al-Mg-Cu-Ag nano-particles, this is exactly matching with XRD measurement average particle size. The HR-SEM results are very much agreed with XRD result. HRSEM picture represents the more or less controlled size (i.e., well defined size of the particle), shape of the nano-alloy is in spherical and homogeneity in nature.

The Vickers hardness test was developed in 1921 by Robert L. Smith and George E.

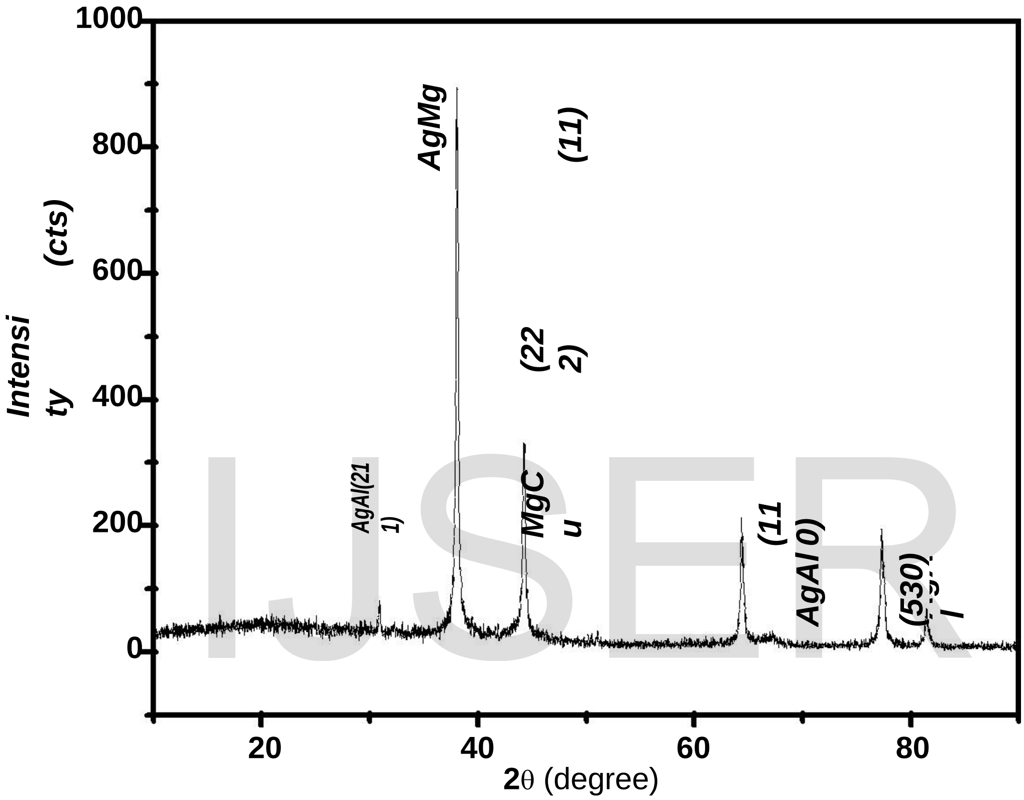

Fig. 1 XRD pattern of Ag coated Al-Mg-Cu-Ag Alloy

Sandland. It is an alternative method to measure the hardness of materials. The Vickers test is often easier to use than other hardness tests since the required calculations are independent of the size of the indenter, and the indenter can be used for all materials irrespective of hardness. The basic principle, as with all common measures of hardness, is to observe the questioned material's ability to resist plastic deformation from a standard source. The Vickers test can be used for all metals and has one of the widest scales among hardness tests. The unit of hardness given by the test is known as the Vickers Pyramid Number (HV) or Diamond

ISSN 2229-5518

Pyramid Hardness (DPH). The hardness number can be converted into units of pascals, but should not be confused with pressure, which also has units of Pascal. The hardness number is determined by the load over the surface area of the indentation and not the area normal to the force, and is therefore not pressure.

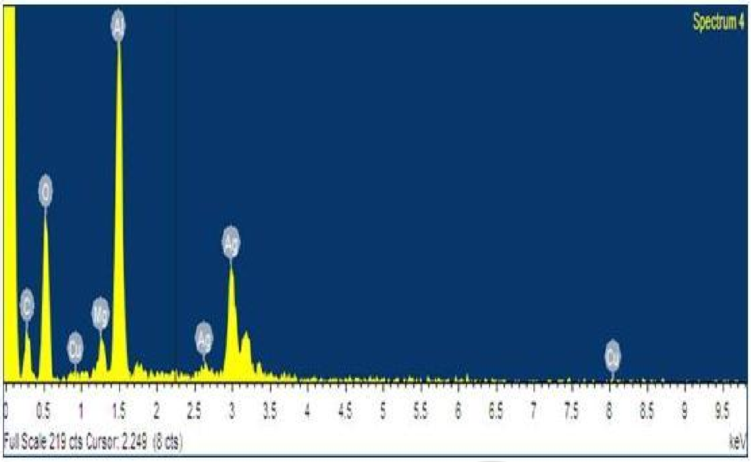

Fig. 2 EDXA (Energy dispersive X-ray analysis) for the prepared Ag coated Al-Mg-Cu-Ag nano alloy.

Table 1 shows Atomic% concentration of elements presented in prepared sample

Element	**Weight%**	**Atomic%**
Cu K	33.79	51.51
O K	33.45	38.27
Mg K	2.34	1.76
Al K	6.47	4.39
Ag L	23.96	4.07
Totals	100.00	100.00

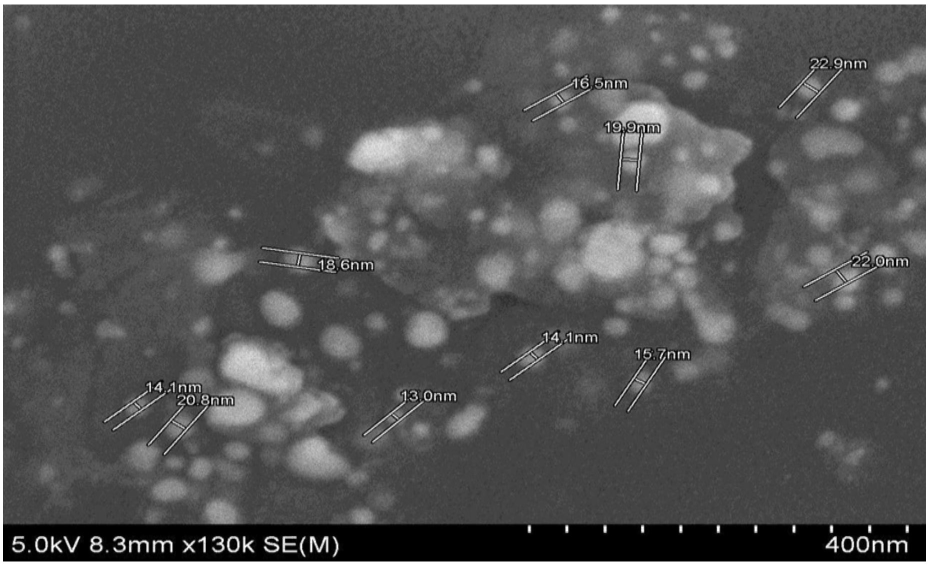

Fig. 3 shows High resolution scanning electron microscopy (HRSEM) picture

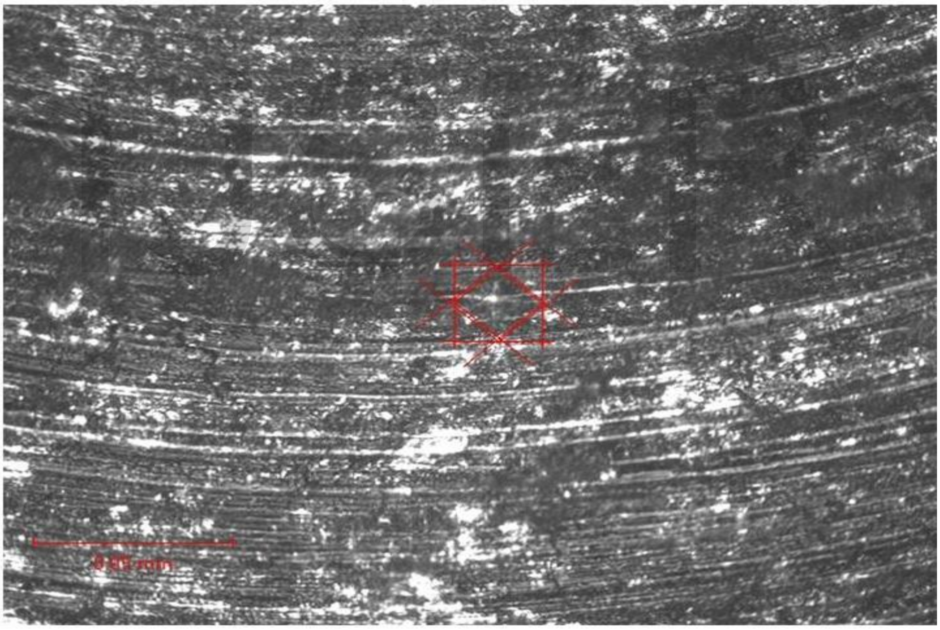

Fig. 4 shows hardness test of the prepared sample.

It was decided that the indenter shape should be capable of producing geometrically similar impressions, irrespective of size; the impression should have well-defined points of measurement and the indenter should have high resistance to self-deformation. A diamond in the form of a square-based pyramid satisfied these conditions. It had been established that the ideal size of a Brinell impression was ⅜ of the ball diameter. As two tangents to the circle at the ends of a chord 3*d*/8 long intersect at 136°, it was decided to use this as the included angle of the indenter, giving an angle to the horizontal plane of 22° on each side. The angle was varied experimentally and it was found that the hardness value obtained on a homogeneous piece of material remained constant, irrespective of load. Accordingly, loads of various magnitudes are applied to a flat surface, depending on the hardness of the material to be measured. The HV number is then determined by the ratio *F/A*, where *F* is the force applied to the diamond in kilograms-force and *A* is the surface area of the resulting indentation in square millimetres. *A* can be determined by the formula.

$$A = \frac{d^2}{2\sin(136^\circ/2)},$$

This can be approximated by evaluating the sine term to give;

$$A \approx \frac{d^2}{1.8544},$$

Where *d* is the average length of the diagonal left by the indenter in millimeters. Hence

$$HV = \frac{F}{A} \approx \frac{1.8544F}{d^2},$$

Where *F* is in kg f and *d* is in millimetres. The corresponding units of HV are then kilograms force per square millimetre (kgf/mm²). Fig. 4 indicates depth value of the indenter formed in the sample. By using hardness test method, we calculate that value of the prepared sample is

38.48 HV (377.4 MPa). When F= 4.98 N or 0.508 kg f applied to the sample, thickness value is 0.05 mm we get, Hardness value= 377.4 MPa or 38.48 HV.

But for bulk sample, the hardness value of copper ranges from 343- 369 MPa , for silver 250 MPa, Aluminium value ranges from a 160- 350 MPa and Magnesium the brinell hardness test value is 260 MPa approximately. Comparing those values, hardness value of the prepared sample is very much greater than bulk sample value. This is due to decreasing in size; rigidity of the sample will increase uniformly throughout the sample. It is one of the stiffness behaviour of the material associated with mechanical property.

CONCLUSION

Ag coated Al-Mg-Cu-Ag nano crystalline materials were synthesized by using Chemical precipitation technique and obtained average grain size was found to be 37 nm from the XRD measurement as well as exactly matching with HR-SEM results also. Surface morphological properties were studied using HR-SEM and confirms that well defined controlled uniform spherical and homogeneity of the particle was obtained. The elemental analysis (EDXA) result clearly shows that the nanocrystalline Ag coated Al-Mg-Cu-Ag alloy formation was confirmed through this measurement, and further the hardness of the material is found by Vickers test thus the value shows 38.48HV i.e., 377.4MPa. It is greater than bulk sample of the same material, due to nano sized leads to increase in rigidity of the prepared sample.

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