



MICROSTRUCTURAL STUDIES OF CU BASED SMART MATERIAL WITH MN AND SI

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Abstract

The Cu-Al-Ni shape memory alloy billets were prepared using powder metallurgy technique by varying composition of major alloying elements such as copper and aluminium, and minor alloying elements manganese, and silicon. The sintered billets of 20 mm in diameter were machined to 18 mm in size in a lathe. The machinability of the sintered powder compacts was good. The optical micrographs revealed the presence of fine grains and intermetallic compounds.

INTRODUCTION

A shape memory alloy keeps the original shape in memory after deformation and regain its original shape when it is heated. A shape memory material has unique characteristics of relationship between stress, strain and temperature and is based on crystallographic reversible thermoplastic martensitic transformation. The phase transformation taking place at low temperature is martensite and the transformation taking place at higher temperature is known as austenite as in steel. The martensitic transformation temperatures can be “adjusted” between -200°C and 200°C . The shape memory properties are based on properties of the high temperature binary Cu-Al phase known as β , having a body centre cubic structure. Among various shape memory alloys, the costs of copper based shape memory alloys are less and have commercial significance. Cu-Al-Ni shape memory alloys are the only suitable alloys for high transformation temperatures requirement. Li et al fabricated Cu-Al-Ni-Mn shape memory alloy by adopting mechanical alloying and vacuum hot pressing followed by hot extrusion. The samples were examined with scanning electron microscopy (SEM) and X-ray

diffraction (XRD) analysis. Presence of intermetallic compounds and their distribution was revealed in the above examinations. Morin and Trivero studied the thermo mechanical fatigue behavior of Cu-Al-Ni shape memory alloy. They studied the effect of fatigue cycles and applied stress on shape and transformation temperature of SMA.

The shape memory recovery of the hot-extruded sample solution-treated at 850°C for 10 min and quenched in water was 100% as it was immersed in boiling water bath for 40 s after deformed to 4.0%. The shape memory recovery of the sample remains 100% as it was subjected to cyclic loading conditions for 100 times. Cortes et al prepared multilayer shape memory alloy thin films with different Cu-Al-Ni composition. This multilayer's were thermally treated to produce alloys by solid solution diffusion and characterized for the martensite phase. Aydogdu et al investigated the role of long-term ageing on martensite characteristics and stabilization in two Cu-Al-Ni alloys. Each sample was heat-treated for long time and the heat-treatment time was selected in such a manner that the difference in time between each sample was very long. The XRD performed on the samples revealed variation in 'd' spacing among the selected pairs of selected diffraction planes in the martensite formed Segui et al presented the changes in the martensitic transformation of a two different composition Cu-Al-Ni-Ti alloy by hot-rolling at two different temperatures 600 and 800°C . Mechanical properties of the alloy and internal friction were significantly improved by thermal treatments. Dagdelen et al revealed the martensitic transformation behavior, morphology and transition temperatures in copper-based shape memory alloys were strongly influenced by heat treatments. The

effects of various quenching methods such as up-quenching and stepquenching in a water bath at 100 °C and in an oil bath at 200° C was studied on two way shape memory Cu–Al–Ni alloys. The changes in entropy and enthalpy at the martensitic transition were determined by means of differential scanning calorimeter (DSC) measurements. The SMA's are used in automotive, aerospace, robotics and in biomedical industries.

Experimental work

Powder metallurgy is the process of blending fine powdered materials, pressing them into a desired shape known as compacting, and then heating the compressed material in a controlled atmosphere to bond the material which is sintering. The powder metallurgy process generally consists of four basic steps: powder manufacture, powder blending, compacting, and sintering. Compacting is generally performed at room temperature but in few cases it is carried out at higher temperatures. Cu-Al-Ni-Mn-Si metal powders are purchased from MEPCO metal powder company, Madurai. The average particle size of powders is in the range of 27-44 microns. The cold compactions of powders for various compositions were done by using cylindrical die with bored hole to produce billets of dimension of 20 mm diameter and 30 mm height. The experiments are conducted by varying the composition of the alloying elements as shown in Table 1. The process parameters are set at two levels and the values are shown

Sample No

S.NO 1- Cu-14Al-4Ni 620 MPa 850 °C

S.NO 2 -Cu-12Al-5Ni-2Mn 560 MPa 900 °C

S.NO 3- Cu-14Al-4Ni-2Mn-0.5Si 560 MPa

The sintering process for the powder preforms were carried out in the temperature range of 850-900°C for 2 hours followed by furnace cooling. The optical microscopic examination of the samples was carried out by polishing the samples using different grades of silicon carbide abrasive sheets. Finally, the samples were polished with Alumina compound to obtain mirror finish. The polished surfaces are etched with a chemical etchant containing 5 g FeCl₃, 15 ml ethanol and 10 ml HCl. The mechanical properties of the Cu–Al–Ni cylindrical pieces were evaluated by conducting tensile test and hardness assessment on the specimens. The tensile test specimens were of 2

mm in diameter and 15 mm in gauge length. The tensile test is conducted using a specially designed fixture as shown in Figure 1 (a) to hold the specimen and in turn the fixture is held in a tensile testing machine of 200 ton capacity as shown in Figure 1 (b). The load range of the machine is very high, therefore, a load cell having 7000 N capacity is used. The shape memory properties were evaluated by carrying out bend test on thin strips of rectangular section specimens with the dimensions of 30 mm × 3mm × 0.5 mm. The shape recovery ratio (SRR) due to one-way SME was estimated using following expression:

Results and Discussion

Optical microscopy

The optical micrograph shown in Figure 2 (a), (b) and (c), corresponds to the three samples namely sample 1, sample 2 and sample 3 as given in Table 2. The micrographs reveal a combination of fine grains and coarse grains. The grain size is very small at few places because of grain refinement taking place with the addition of alloying elements 'Mn' and 'Si'. At few places dark phase is observed which indicates the presence of aluminium oxide and intermetallic compounds. In Figure 1 (a) at the central region few large grains are seen and the size of the large grain is less than 20 microns. But on the other sides of the central region and along the grain boundaries of large grains very fine grains are noted. These grains are of less than 5 micron in size. Also at few places in the large grains fine circular white and dark particles are seen and these particles are identified as CuAl₂, Al₂O₃ and Mn₃Si particles.

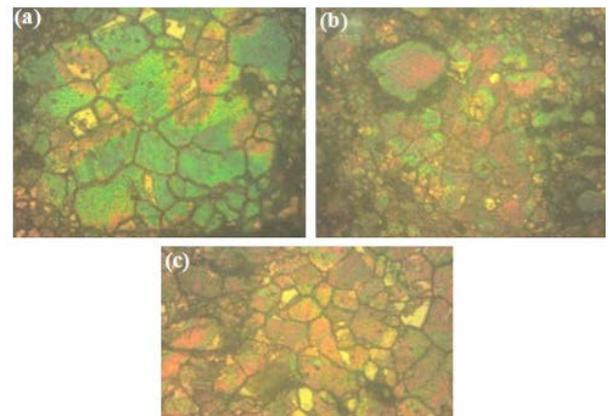


Fig.1.OM images

At few places annealing twins are also seen. These annealing twins are formed because of one hour soaking time provided during

sintering of the powder compacts. In Figure 2 (b) at the centre interdendritic growth of copper rich region is observed which is identified as reddish brown region.

One can notice that these dendrites have fine grains in it. Also, few large grains are seen and the average grain size is less than 12 microns. The microstructure reveals a combination of fine and coarse grains throughout the matrix and these grains are smaller than the grains seen in the Figure 2 (a). The green coloured regions in the micrograph reveal the presence of nickel aluminide and yellowish brown areas are identified as copper aluminides. At few places dark regions are identified as intermetallic compounds of 'Mn' and 'Si' and oxides of copper and aluminium. The micrograph shown in Figure 2 (c) reveals very fine grains at the centre and at the left side of the micrograph. At the bottom right side few large grains are noted. Even these large grains are smaller than the large grains seen in the micrograph shown in Figure 2 (a). Along the grain boundaries recrystallization has taken place because of this very fine grains are seen all over the micrograph. Also at few places in the large grains fine circular white and dark particles are seen and these particles are CuAl₂, Al₂O₃ and Mn₃Si particles. Further, few yellow grains are seen in the matrix, these fine grains are rich with aluminium.

These yellow grains are formed because this alloy contains 14% Al in it. Melting point of 'Al' is only 660 °C, therefore, during sintering it melts and forms compounds and binds the other elements together to provide strength to the powder compacts. That is why recrystallization and grain refinement is inevitable in this alloy system because sintering is carried out above the melting point of 'Al'. Further, few very fine yellow grains are seen in Figure 2(b). But the yellow grains are dispersed as fine grains throughout the matrix. Compared to Figure 2 (b), the Figure 2 (a) reveals few yellow grains and they are larger in grain size.

Conclusions

- The shape memory alloys Cu-Al-Ni with the addition of 'Mn' and 'Si' were produced by varying the process parameters such as composition, compacting pressure and sintering temperature.
- These alloys possessed good machinability, moderate ductility and strength

REFERENCES

1. Morris M.A. (1991) 'Temperature and stress dependence of the shape memory effect produced by alloying additions in Cu-AlNi alloys' Colloque, supplkment au journal de physique, Vol. 111 pp.675-680.
 2. Morin M, Trivero F. (1995) 'Influence of thermal cycling on reversible martensitic transformation in Cu-Al-Ni shape memory alloy' Journal of Materials Science and Engineering A, Vol. 196 pp.177-181.
 3. Tang S.M , Chung C.Y and Liu W.G.(1997) 'Preparation of CuAl-Ni-based shape memory alloys by mechanical alloying and powder metallurgy method' Journal of Materials Processing Technology, Vol. 63 pp.307-312.
 4. Segui C ,Pons F , Cesari E, Muntasell J, Font J .(1999) 'Characterization of a hot-rolled Cu-Al-Ni-Ti shape memory alloy' Materials Science and Engineering A, Vol. 275 pp.625-629 .
 5. Dagdelen F, Gokhan T, Aydogdu A, Aydogdu Y, Adiguzel O.(2003) 'Effects of thermal treatments on transformation behaviour in shape memory Cu-Al-Ni alloys' Materials Letters, Vol. 57 pp.1079- 1085.
 6. Ibarra A, SanJuan J, Bocanegra E.H ,No M.L.(2006) 'Thermomechanical characterization of Cu-Al-Ni shape memory alloys elaborated by powder metallurgy' Materials Science and Engineering A, Vol. 440 pp.782-786.
 7. Li Z , Pan Z.Y, Tang N, Jiang Y.B, Liu N, Fang M, Zheng F .(2006) 'Cu-Al-Ni-Mn shape memory alloy processed by mechanical alloying and powder metallurgy' Materials Science and Engineering, Vol. 417 pp.225-229.
 8. Toshihiro Omori, Naoki Koeda, Yuji Sutou, Ryosuke Kainuma and Kiyohito Ishida. (2007) 'Super plasticity of Cu-Al-Mn-Ni Shape Memory Alloy' journal of Japan Research Institute for Advanced Copper-Base Materials and Technologies Materials Transactions, Vol. 48 pp. 2914 to 2918 .
 9. Sari U, Kirind T. (2007) 'Effects of deformation on microstructure and mechanical Properties of a Cu-Al-Ni shape memory alloy', Material characterization ,Vol. 59 pp.920-929.
- Matlakhova I.A, Pereira C, Matlakhov D and Monteiro S.N. (2007) 'Structure and properties of a mono crystalline cu-al-ni alloy submitted to

thermal cycling under load' ISBN 978-1-60741789-7 pp. 113-143.

11. Izadinia M, Dehghani K. (2011) 'Structure and properties of nano structured Cu-13.2Al-5.1Ni shape memory alloy produced by melt spinning' *trans of non ferrous metal society of china* Vol. 21 pp. 20372043.

12. Pourkhorshidi S ,Parvin N, Kenevisi M.S, Naeimi M , EbrahimniaKhaniki H. (2012) 'A study on the microstructure and properties of

Cu-based shape memory alloy produced by hot extrusion of mechanically alloyed powders' *Materials Science & Engineering A*, Vol. 556 pp.658–663 .

13. Vajpai S.K ,Dube R.K, Sangal S.(2013) 'Application of rapid solidification powder metallurgy processing to prepare Cu–Al–Ni high temperature shape memory alloy strips with high strength and high ductility' *Materials Science & Engineering A* Vol. 570 pp. 32–42