MICROSTRUCTURAL CHARACTERIZATION OF LAYERED MARTENSITE STRUCTURES IN COPPER BASED SHAPE MEMORY ALLOYS

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Introduction

Shape memory alloys take place in a class of functional materials by exhibiting a peculiar property called shape memory effect. This property is characterized by the recoverability of desired shape on the material at different conditions. Shape memory phenomena leads to martensitic transition, which occurs on cooling from high temperatures. Shape memory effect refers to the strain recovery of materials resulting from martensite to austenite transformation, reverse transition, when heated above reverse transformation temperature after deforming the material in the martensitic phase. These alloys also cycle between two particular shapes with changing temperature.

Copper based alloys exhibit this property in β-phase field. These alloys are metastable at high temperature and undergo two ordered transitions on cooling, and bcc structures turn into B2(CsCl) or $DO_3(Fe_3Al)$ -type ordered structures. These ordered structures martensitically undergo non-conventional structures on further cooling [1-3].

Martensitic transformations occur by two or more lattice invariant shears on a {110}-type plane of austenite matrix which is basal plane for martensite, as a first step.

The product phases have the unusual complex structures called long period layered structures such as 3R, 9R or 18R depending on the stacking sequences on the close-packed planes of the ordered lattice. In case the parent phase has a B2-type superlattice, the stacking sequence is ABCBCACAB(9R). The stacking is AB'CB'CA'CA'BA'BC'BC'AC'AB'A(18R) in case the parent phase has a DO3-type ordered lattice [2, 4].

The Stackings of $(110)_β$ -planes in DO_3-type structure and formation of layered structures are shown in Figure1.

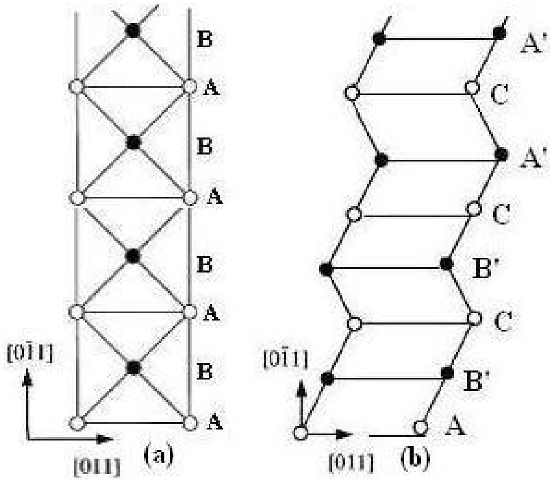

Figure 1: a- Stacking of $(110)_β$ -planes in DO_3-type structure, b- inhomogeneous shear and formation of layered structures.

Experimental

Two copper based ternary shape memory alloys were selected for investigation: a CuZnAl alloy with a nominal compositions by weight of 26.1%zink, 4%aluminium, the balance copper, while the other was a CuAlMn alloy with a nominal composition by weight of 11% aluminum, 6% manganese and the balance copper. Powder specimens for X-ray examination were prepared by filling the alloys. Specimens for TEM examination were also prepared from 3mm diameter discs and thinned down mechanically to 0.3mm thickness.

All of the specimens obtained from these alloys were heated in evacuated quartz tubes in the β-phase field (15 minutes at 830°C for CuZnAl and 20 minutes at 700°C for CuAlMn) for homogenization and quenched in iced-brine.

These specimens were also given different post-quench heat treatments and aged at room temperature.

TEM and X-ray diffraction studies carried out on these specimens. TEM specimens were examined in a JEOL 200CX electron microscope, and X-ray diffraction profiles were taken from the quenched specimens using Cu-K_α radiation with wavelength 1.5418 Å.

Results and Discussion

X-ray powder diffractograms were taken several times from the specimens given different heat treatments. An x-ray diffraction profile taken from the quenched CuAlMn alloy sample is shown in Figure 2.

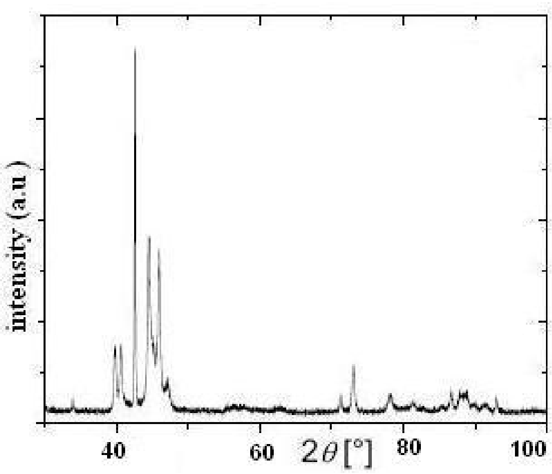

Figure 2: An x -ray powder diffractogram taken from CuAlMn alloy sample.

Electron diffraction patterns were also taken from CuZnAl and CuAlMn alloys which are not given here. X-ray powder diffractograms and electron diffraction patterns reveal that both alloys exhibit superlattice reflections in quenched case.

X-ray powder diffractograms and electron diffraction patterns taken from the specimens in a large time interval were compared with each other. It has been observed that electron diffraction patterns exhibit similar characteristics, but some changes have been occurred in peak locations on the x-ray diffractograms with aging duration. These changes are attributed to new transitions which have diffusive character. It means that some neighbor atoms change locations. On the other hand, the alloys have the layered complex structure in martensitic state. The monoclinic distortion of 18R-type structure contributes to the martensite stabilization which proceeds by a diffusion-controlled process [5].

Metastable phases of copper-based shape memory alloys are very sensitive to the ageing effects, and heat treatments can change the relative stability and the configurational order of crystal planes. The parent phase is highly symmetric and the product phase is internally twinned and complex.

Also, several types of microscopic deformation involving changes can occur in the stacking sequence of close-packed planes of material with martensite formation [2]. This change gives rise the increase in the complexity of crystal structure. Atom locations in the lattice sites in the crystal unit cell are very important for the analysis and process of transformation. It can be concluded from the above results that the copper-based shape memory alloys are very sensitive to the ageing treatments. Ageing the alloy in martensitic case causes the disordered transition. This result can be attributed to a rearrangement of atoms. Product martensite phase has complex layered structure.

References

1. Adiguzel, O. Martensite Ordering and Stabilization in Cooper Based Shape Memory Alloys, *Materials Research Bulletin,* **30** (1995), (1995) 755-760.

2. Zhu, J.J, Liew, K.M. Description of deformation in shape memory alloys from DO_3 austenite to 18R martensite by group theory, *Acta Materialia*, **51** (2003)2443-2456

3**.** Sutou Y. *et al*, Effect of grain size and texture on pseudoelasticity in Cu–Al–Mn-based shape memory wire, *Acta Materialia*, 53 (2005)4121-4133.

4. Pelegrina J.L and.Romero, R. Calorimetry in Cu–Zn–Al alloys under different structural and microstructural conditions, *Materials Science and Engineering A*, 282 (2000) 16-22.

5. Li, Z, Gong, S., Wang, M.P. Macroscopic shape change of Cu13Zn15Al shape memory alloy on successive heating, *Journal of Alloys and Compounds*, 452 (2008) 307-311.