World Academy of Science, Engineering and Technology
International Journal of Materials and Metallurgical Engineering
Vol:9, No:01, 2015

Intelligent Materials and Functional Aspects of Shape Memory Alloys

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Abstract : Shape-memory alloys are a new class of functional materials with a peculiar property known as shape memory effect. These alloys return to a previously defined shape on heating after deformation in low temperature product phase region and take place in a class of functional materials due to this property. The origin of this phenomenon lies in the fact that the material changes its internal crystalline structure with changing temperature. Shape memory effect is based on martensitic transitions, which govern the remarkable changes in internal crystalline structure of materials. Martensitic transformation, which is a solid state phase transformation, occurs in thermal manner in material on cooling from high temperature parent phase region. This transformation is governed by changes in the crystalline structure of the material. Shape memory alloys cycle between original and deformed shapes in bulk level on heating and cooling, and can be used as a thermal actuator or temperature-sensitive elements due to this property. Martensitic transformations usually occur with the cooperative movement of atoms by means of lattice invariant shears. The ordered parent phase structures turn into twinned structures with this movement in crystallographic manner in thermal induced case. The twinned martensites turn into the twinned or oriented martensite by stressing the material at low temperature martensitic phase condition. The detwinned martensite turns into the parent phase structure on first heating, first cycle, and parent phase structures turn into the twinned and detwinned structures respectively in irreversible and reversible memory cases. On the other hand, shape memory materials are very important and useful in many interdisciplinary fields such as medicine, pharmacy, bioengineering, metallurgy and many engineering fields. The choice of material as well as actuator and sensor to combine it with the host structure is very essential to develop main materials and structures. Copper based alloys exhibit this property in metastable beta-phase region, which has bcc-based structures at high temperature parent phase field, and these structures martensitically turn into layered complex structures with lattice twinning following two ordered reactions on cooling. Martensitic transition occurs as self-accommodated martensite with inhomogeneous shears, lattice invariant shears which occur in two opposite directions, <110 > -type directions on the {110}-type plane of austenite matrix which is basal plane of martensite. This kind of shear can be called as {110}<110> -type mode and gives rise to the formation of layered structures, like 3R, 9R or 18R depending on the stacking sequences on the close-packed planes of the ordered lattice. In the present contribution, x-ray diffraction and transmission electron microscopy (TEM) studies were carried out on two copper based alloys which have the chemical compositions in weight; Cu-26.1%Zn 4%Al and Cu-11%Al-6%Mn. X-ray diffraction profiles and electron diffraction patterns reveal that both alloys exhibit super lattice reflections inherited from parent phase due to the displacive character of martensitic transformation. X-ray diffractograms taken in a long time interval show that locations and intensities of diffraction peaks change with the aging time at room temperature. In particular, some of the successive peak pairs providing a special relation between Miller indices come close each other.

Keywords : Shape memory effect, martensite, twinning, detwinning, self-accommodation, layered structures
Conference Title : ICAM 2015 : International Conference on Advanced Materials
Conference Location : Jeddah, Saudi Arabia
Conference Dates : January 26-27, 2015