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Thermomechanical and thermoresponsive reactions in shape memory alloys

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Shape memory alloys take place in a class of adaptive structural materials called intelligent or smart materials by giving stimulus response to changes in the external conditions. These alloys exhibit dual characteristics, shape memory effect (SME) and superelasticity (SE) with the recoverability of two certain shapes at different conditions. These alloys are functional materials with these properties and used as shape memory elements in many interdisciplinary fields such as medicine, pharmacy, bioengineering, metallurgy. Shape memory effect is initiated thermomechanical treatments by cooling and deformation and performed thermally on heating and cooling. Deformation in low temperature condition is plastic deformation, with which strain energy is stored in the materials and released on heating by recovering the original shape. This phenomenon is based on martensitic transformation, which is a solid-state phase transformation and governed by the remarkable changes in internal crystalline structure of materials. With the thermomechanical treatment, ordered parent phase structures turn into the twinned martensite structures along with lattice twinning, by means of thermal induced martensitic transformation on cooling, and twinned structures turn into detwinned martensite structures by means of stress induced martensitic transformations with deformation. On heating after these treatments, detwinned martensite structures turn into the ordered parent phase structures, by means reverse austenitic structures. Thermal induced martensitic transformations occur on cooling with cooperative movement of atoms in <110 > -type directions on a {110} - type plane of austenite matrix which is basal plane of martensite. Superelasticity is performed in only mechanical manner by stressing the material and releasing in the parent austenite phase region, by recovering the original shape. Superelasticity is also result of stress induced martensitic transformation, with which the ordered parent phase structures turn into the detwinned martensite structures. Superelasticity is performed in non-linear way, unlike normal elastic materials behavior, loading and releasing paths are different, and cycling loop refers to the energy dissipation. The strain energy is stored after releasing, and these alloys are mainly used as deformation absorbent materials in control of civil structures subjected to seismic events, due to the absorbance of strain energy.

Copper based alloys exhibit this property in metastable beta-phase region. Lattice invariant shear and twinning is not uniform in copper-based alloys and cause the formation of unusual complex layered structures.

In the present contribution, x-ray diffraction and transmission electron microscopy (TEM) studies were carried out on two copper based CuZnAl and CuAlMn alloys. 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.

Keywords: Shape memory effect, martensitic transformation, thermoelasticity, superelasticity, twinning, detwinning.