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Energy Storage and Energy Dissipation at Transformation Cycles in Shape Memory Alloys

A series of ally systems exhibit a peculiar property called shape memory effect with special chemical compositions in the ß-phase fields. This phenomenon is initiated with thermomechanical processes on cooling and deformation and performed thermally on heating and cooling, with which shape of the materials cycles between original and deformed shapes in reversible way. This is plastic deformation, due to the soft character in low temperature condition, they keep the deformed shape after releasing and recover the original shape on heating. Strain energy is stored with this deformation and release on heating by recovering the original shape by means of reverse endothermic austenitic transformation.

Shape memory effect is governed by crystallographic transformations, thermal, and stress induced martensitic transformations. Thermal induced transformations are exothermic reactions and occur on cooling with the cooperative movement of atoms in <110 > -type directions on {110}-type planes of austenite matrix along with the lattice twinning and ordered parent phase structures turn into twinned martensitic structure. Twinned structures turn into detwinned martensite by means of stress induced martensitic transformation with deformation. Forward martensitic and reverse austenitic transformations are solid state reactions; these reactions do not occur at the equilibrium temperature at Gibbs Free Energy Temperature Diagram and a driving force is necessary for the transformations.

These alloys exhibit another property, called superelasticity, which is performed by mechanically stressing and releasing at a constant temperature at the parent phase region, and material recovers the original shape upon releasing, by exhibiting elastic material behavior. Superelasticity is performed in non-linear way in stress-strain diagram, unlike normal elastic materials behavior, loading and releasing paths are different, and hysteresis loop (transformation cycle) refers to the energy dissipation.

Superelasticity is also result of stress induced martensitic transformation, and the ordered parent phase structures turn into the detwinned martensite structures by stressing. Therefore, twinning and detwinning reaction play important role in memory behavior of shape memory alloys.

Copper based alloys exhibit this property in metastable beta-phase region. Lattice twinning and lattice invariant shear is not uniform in these alloys and cause the formation of complex layered structures. The layered structures can be described by different unit cells as 3R, 9R or 18R depending on the stacking sequences on the close-packed planes of the ordered lattice. The unit cell and periodicity are completed through 18 layers in direction z, in case of 18R martensite, and unit cells are not periodic in short range in direction z.

In the present contribution, x-ray diffraction and transmission electron microscopy (TEM) studies were carried out on two copper- based CuAlMn and CuZnAl alloys. X-ray diffraction profiles and electron diffraction patterns exhibit super lattice reflections. X-ray diffractograms taken in a long-time interval show that diffraction angles and intensities of diffraction peaks change with the aging duration at room temperature. This result refers to the rearrangement of atoms in diffusive manner.