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Thermomechanical Transformations Governing Reversibility in Shape Memory Alloys

Abstract: Shape memory alloys take place in a class of advanced smart materials by exhibiting a peculiar property called shape memory effect. This phenomenon is initiated with thermomechanical treatments on cooling and deformation and performed thermally on heating and cooling, with which shape of the material cycles between original and deformed shapes in reversible way. Therefore, this behavior can be called thermal memory or thermoelasticity. 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 governed by the thermomechanical transformations, thermal and stress induced martensitic transformations. Thermal induced martensitic transformations occur on cooling with cooperative movement of atoms in $\langle 110 \rangle$ -type directions on a $\{110\}$ -type plane of austenite matrix, along with lattice twinning reaction, and ordered parent phase structures turn into the twinned martensite structures. The twinned structures turn into detwinned martensite structures by means of stress induced martensitic transformations with deformation.

These alloys exhibit another property, called superelasticity, which is performed with mechanically stressing and releasing the material 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, unlike normal elastic materials behavior, loading and releasing paths are different, and cycling loop 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. However, lattice twinning and detwinning reactions play important role at martensitic transformations, and these reactions are driven by inhomogeneous lattice invariant shear.

Copper based alloys exhibit this property in metastable beta-phase region. Lattice twinning 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 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 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.

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



Biography: Dr. Adiguzel graduated from Department of Physics, Ankara University, Turkey in 1974 and received PhD-degree from Dicle University, Diyarbakir-Turkey. He has studied at Surrey University, Guildford, UK, as a post-doctoral research scientist in 1986-1987, and studied on shape memory alloys. He worked as research assistant, 1975-80, at Dicle University and shifted to Firat University, Elazig, Turkey in 1980. He became professor in 1996, and he has been retired on November 28, 2019, due to the age limit of 67, following academic life of 45 years. He published over 80 papers in international and national journals; He joined over 120 conferences and symposia in international and national level as participant, invited speaker or keynote speaker with contributions of oral or poster. He served the program chair or conference chair/co-chair in some of these activities. In particular, he joined in last six years (2014 - 2019) over 60 conferences as Keynote Speaker and Conference Co-Chair organized by different companies. Also, he joined over 180 online conferences in the same way in pandemic period of 2020-2023. He supervised 5 PhD- theses and 3 M. Sc- theses. Dr. Adiguzel served his directorate of Graduate School of Natural and Applied Sciences, Firat University, in 1999-2004. He received a certificate awarded to him and his experimental group in recognition of significant contribution of 2 patterns to the Powder Diffraction File – Release 2000. The ICDD (International Centre for Diffraction Data) also appreciates cooperation of his group and interest in Powder Diffraction File.