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Shape Reversibility and Energy Dissipation in Transformation Cycles in Shape Memory Alloys

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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 materials cycles between original and deformed shapes in reversible way. Therefore, this behavior can be called Thermoelasticity. This is plastic deformation with which strain energy is stored in the material and releases on heating by recovering original shape. This phenomenon is based on thermomechanical 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 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. Also, reverse austenitic transformation is an endothermic austenitic transformation, and occurs on heating, and detwinned martensite structures turn into the ordered parent phase structure. These transformations are driven by lattice invariant shears. Martensitic and austenitic transformations are solid state transformation, and these transformations do not start 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 with stressing and releasing the material in elasticity limit at a constant temperature in parent phase region, and shape recovery occurs upon releasing, by exhibiting elastic material behavior. Stress-strain curve exhibit non-linear behavior, stressing and releasing paths are different, and hysteresis loop refers to the energy dissipation. Superelasticity is the result of stress-induced martensitic transformation, and parent phase structures turn into the completely detwinned martensite structures with stressing. Copper based alloys exhibit this property in metastable β-phase region, which has bcc-based structures. Lattice invariant shears and lattice twinning are not uniform in these alloys, and the ordered parent phase structures undergo long-period layered structures with martensitic transformation. These structures can be described by different unit cells as 3R, 9R or 18R depending on the stacking sequences on the close-packed planes of ordered lattice of parent phase. In the present contribution, x-ray diffraction and transmission electron microscopy studies were carried out on copper based CuZnAl and CuAlMn alloys. X-ray diffraction profiles and electron diffraction patterns exhibit super lattice reflections inherited from parent phase due to the displacive character of the transformation. X-ray diffractograms taken in a long-time interval show that diffraction angles and intensities of diffraction peaks change with the aging time at room temperature. This result refers to a new transformation in diffusive manner.

Keywords: Shape memory effect, martensitic transformations, thermoelasticity, superelasticity, lattice twinning and 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 were focused on shape memory effect in 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.