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Nanoscale aspects of shape reversibility and phase transformations in shape memory alloys

A series of alloy systems called shape memory alloys exhibit a peculiar property called the shape memory effect. This phenomenon is initiated on cooling and deformation and performed on heating, and performed on heating and cooling, with which shape of materials cycles between original and deformed shapes in a reversible way in the bulk level. Therefore, this behavior can be called thermal memory or thermoelasticity. These alloys exhibit another property, superelasticity, which is performed by stressing and releasing the material at a constant temperature at the parent phase region. Superelasticity exhibits ordinary elastic material behavior, but it is performed in a non-linear way; loading and unloading paths are different in the stress-strain diagram, and the hysteresis loop reveals energy dissipation Thermoelasticity is governed by the thermal and stress-induced martensitic transformations on cooling and stressing, and reverse austenitic transformation on heating. Superelasticity is governed by stress-induced martensitic and reverse austenitic transformations by stressing and releasing materials, with which ordered parent phase structures turn into detwinned martensitic structures and ordered parent phase structures, respectively. These transformations occur with the movements of atoms on an atomic scale at the sub-nano level. Thermal induced martensite occurs on cooling along with lattice twinning and ordered parent phase structures turn into twinned martensite structures by means of lattice invariant shears, and these structures turn into detwinned martensitic structures with deformation by means of stress-induced transformation. Lattice twinning occurs in two opposite directions, <110 > -type directions on the {110}-type plane of austenite matrix in a self-accommodating manner, by means of lattice invariant shear. Copper-based alloys exhibit this property in the metastable beta-phase region, which has bcc-based structures at a high-temperature parent phase field. Lattice invariant shear and lattice twinning are not uniform in these alloys and cause the formation of complex layered structures, depending on the stacking sequences on the close-packed planes of the ordered lattice. In the present contribution, x-ray and electron diffraction studies were carried out on two solution-treated copper-based CuZnAl and CuAlMn alloys. Electron and x-ray diffraction exhibit superlattice reflections. Specimens of these alloys were aged at room temperature, at which both alloys are in a martensitic state, and a series of x-ray diffractions were taken at different stages of aging in a long-term interval. X-ray diffraction profiles taken from the aged specimens in martensitic conditions reveal that crystal structures of alloys change in a diffusive manner.

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

Recent Publications

1. Adiguzel O, et al (2021). Lattice Reactions Governing Thermoelasticity and Superelasticity in Shape Memory Alloys. Phys Sci & Biophys J 2021, 5(1): 000170
2. Adiguzel, O. (2020). Factors and Lattice Reactions Governing Phase Transformations in Beta Phase Alloys. In: Bonča, J., Kruchinin, S. (eds) Advanced Nanomaterials for Detection of CBRN, 101-109.
3. Adiguzel, O. (2020). Thermally and Stress Induced Phase Transformations and Reversibility in Shape Memory Alloys. In: Sidorenko, A., Hahn, H. (eds) Functional Nanostructures and Sensors for CBRN Defence and Environmental Safety and Security, 105-112.
4. Adiguzel, O. (2018). Thermoelasticity, Superelasticity and Nanoscale Aspects of Structural Transformations in Shape Memory Alloys. In: Struble, L., Tebaldi, G. (eds) Materials for Sustainable Infrastructure, 287–293.
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Biography

Osman Adiguzel graduated from the Department of Physics, Ankara University, Turkey in 1974 and received Ph.D.- degree from Dicle University, Diyarbakir-Turkey. He studied at Surrey University, Guildford, UK, as a post-doctoral research scientist from 1986 to 1987, and studied shape memory alloys. He worked as a research assistant, from 1975 to 1980, at Dicle University and shifted to Firat University, Elazig, Turkey in 1980. He became a 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 at the international and national level as a participant, invited speaker, or keynote speaker with contributions of oral or poster. He served as the program chair or conference chair/co-chair in some of these activities. In particular, he joined last six years (2014 - 2019) over 60 conferences as Keynote Speaker and Conference Co-Chair organized by different companies. He supervised 5 Ph.D.- theses and 3 M. Sc- theses in his academic life. Also, he joined over 70 online conferences in the same way in the pandemic period of 2020-2021. Dr. Adiguzel served his directorate of the Graduate School of Natural and Applied Sciences, Firat University, from 1999-to 2004. He received a certificate awarded to him and his experimental group in recognition of the significant contribution of 2 patterns to the Powder Diffraction File – Release 2000. The ICDD (International Centre for Diffraction Data) also appreciates the cooperation of his group and interest in the Powder Diffraction File.

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