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Lattice Twinning and Detwinning Processes in Phase Transformation in Shape Memory Alloys

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Abstract : Shape memory effect is a peculiar property exhibited by certain alloy systems and based on martensitic transformation, and shape memory properties are closely related to the microstructures of the material. Shape memory effect is linked with martensitic transformation, which is a solid state phase transformation and occurs with the cooperative movement of atoms by means of lattice invariant shears on cooling from high-temperature parent phase. Lattice twinning and detwinning can be considered as elementary processes activated during the transformation. Thermally induced martensite occurs as martensite variants, in self-accommodating manner and consists of lattice twins. Also, this martensite is called the twinned martensite or multivariant martensite. Deformation of shape memory alloys in martensitic state proceeds through a martensite variant reorientation. The martensite variants turn into the reoriented single variants with deformation, and the reorientation process has great importance for the shape memory behavior. Copper based alloys exhibit this property in metastable β- phase region, which has DO3 –type ordered lattice in ternary case at high temperature, and these structures martensiticaly turn into the layered complex structures with lattice twinning mechanism, on cooling from high temperature parent phase region. The twinning occurs as martensite variants with lattice invariant shears in two opposite directions, <110 > -type directions on the {110}- type plane of austenite matrix. Lattice invariant shear is not uniform in copper based ternary alloys and gives rise to the formation of unusual layered structures, like 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 atomic layers in case of 18R-structure. On the other hand, the deformed material recovers the original shape on heating above the austenite finish temperature. Meanwhile, the material returns to the twinned martensite structures (thermally induced martensite structure) in one way (irreversible) shape memory effect on cooling below the martensite finish temperature, whereas the material returns to the detwinned martensite structure (deformed martensite) in two-way (reversible) shape memory effect. Shortly one can say that the microstructural mechanisms, responsible for the shape memory effect are the twinning and detwinning processes as well as martensitic transformation. In the present contribution, x-ray diffraction, transmission electron microscopy (TEM) and differential scanning calorimetry (DSC) studies were carried out on two copper-based ternary alloys, CuZnAl, and CuAlMn.

Keywords : shape memory effect, martensitic transformation, twinning and detwinning, layered structures
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