Ni-free Ti-base Shape Memory Alloys

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Shape memory effect (SME) and superelasticity (SE) are associated with the crystallographically reversible nature of the martensitic transformation which appears in shape memory alloys (SMAs). Such crystallographically reversible martensitic transformation was especially named "thermoelastic martensitic transformation". The martensitic transformation itself is not a new phenomenon, but was first found long time ago in a steel which was heat-treated at a high temperature followed by rapid quenching: the martensitic transformation in most iron and steels is not thermoelastic, hence the SME does not appear. It has been found that several tens alloys show SME and SE. Among them, the Ti-Ni alloys have been successfully developed as practical materials for many applications.

The Ti-Ni alloys have been investigated since the first report on SME in a Ti-Ni alloy in 1963. However, the Ti-Ni alloys had presented many difficult problems with many puzzling phenomena for about 20 years until 1982, when the basic understanding was established on the relationship between the microstructure and the corresponding deformation behavior such as SME and SE. Since then, many puzzling phenomena have been clarified: e.g., the microstructures which cause the rhombohedral phase (R-phase) transformation to appear, the orientation dependence of shape memory (SM) and superelastic (SE) behavior observed in single crystals, the temperature dependence of deformation and fatigue behavior, the shape memory mechanism, etc.

The Ti-Ni alloys have been successfully applied as biomaterials such as orthodontic arch wires, guide wires and stents in addition to many engineering applications. Ti-Ni alloys are also considered as one of the attractive candidates for orthopedic implants, etc. However, it has been pointed out that pure Ni is a toxic element and causes Ni-hypersensitivity. Although the Ti-Ni alloys are considered as safe in the human body based on experience and scientific consideration, in order to solve the psychological problem on the risk of Ni-hypersensitivity, Ni-free Ti-based SM and SE alloys have been recently developed, e.g., Ti-Nb-Sn, Ti-Nb-Al, Ti-Nb-Ta, Ti-Nb-Zr, Ti-Nb-O, Ti-Nb-Pt, Ti-Mo-Ga, Ta-Mo-Sn and Ti-(8-10)Mo-4Nb-2V-3Al (mass%). It has been found that Ti-Nb binary alloys exhibit SME and SE at room temperature, and their SE properties can be considerably improved by thermomechanical treatment. It has been also found that SE properties of Ti-Nb alloys can be improved by the addition of alloying elements such Zr, Ta, Pt and O. The Ni-free Ti-based alloys have not been used for applications yet, but will be used for medical applications in the near future.

In this presentation, the history of the development of Ti-Ni based and Ti-based alloys is reviewed, then the basic characteristics such as the martensitic transformation and shape memory properties of both the Ti-Ni alloys and Ti-Nb alloys are explained. Much information on the new Ni-free Ti-based SM and SE alloys is to be reviewed.