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Effects of Sn and Al on Phase Stability and Mechanical Properties of Metastable Beta Ti Alloys

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Abstract : We have developed and studied a metastable beta Ti alloy, which shows super-elasticity and low Young’s modulus according to the phase stability of its beta phase. The super-elasticity and low Young’s modulus are required in a wide range of applications in various industrial fields. For example, the metallic implant with low Young’s modulus and non-toxicity is desirable because the large difference of Young’s modulus between the human bone and the implant material may cause a stress-shielding phenomenon. We have investigated the role of Sn and Al in metastable beta Ti-Cr-Sn, Ti-Cr-Al, Ti-V-Sn, and Ti-V-Al alloys. The metastable beta Ti-Cr-Sn, Ti-Cr-Al, Ti-V-Sn, and Ti-V-Al alloys form during quenching from the beta field at high temperature. While Cr and V act as beta stabilizers, Sn and Al are considered as elements to suppress the athermal omega phase produced during quenching. The athermal omega phase degrades the properties of super-elasticity and Young’s modulus. Although Al and Sn as single elements are considered as an alpha stabilizer and neutral, respectively, Sn and Al acted also as beta stabilizers when added simultaneously with beta stabilized element of Cr or V in this experiment. The quenched microstructure of Ti-Cr-Sn, Ti-Cr-Al, Ti-V-Sn, and Ti-V-Al alloys shifts from martensitic structure to beta single-phase structure with increasing Cr or V. The Young’s modulus of Ti-Cr-Sn, Ti-Cr-Al, Ti-V-Sn, and Ti-V-Al alloys decreased and then increased with increasing Cr or V, each showing its own minimum value of Young's modulus respectively. The composition of the alloy with the minimum Young’s modulus is a near border composition where the quenched microstructure shifts from martensite to beta. The border composition of Ti-Cr-Sn and Ti-V-Sn alloys required only less amount of each beta stabilizer, Cr or V, than Ti-Cr-Al and Ti-V-Al alloys. This indicates that the effect of Sn as a beta stabilizer is stronger than Al. Sn and Al influenced the competitive relation between stress-induced martensitic transformation and slip deformation. Thus, super-elastic properties of metastable beta Ti-Cr-Sn, Ti-Cr-Al, Ti-V-Sn, and Ti-V-Al alloys varied depending on the alloyed element, Sn or Al.

Keywords : metastable beta Ti alloy, super-elasticity, low Young’s modulus, stress-induced martensitic transformation, beta stabilized element
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