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Microstructural characterization of Ti-Ta-based surface alloy fabricated on TiNi SMA by additive pulsed electron-beam melting of film/substrate system

L.L. Meisner[a,d], A.B. Markov[b], V.P. Rotshtein[a,c], G.E. Ozur[b], S.N. Meisner[a*], E.V. Yakovlev[b], V.O. Semin[a,d], Yu.P. Mironov[a], T.M. Poletika[a], S.L. Girsova[a], D.A. Shepel[b]

[a]*Institute of Strength Physics and Materials Science SB RAS, 2/4 Academichesky Ave., Tomsk, Russia*

[b]*Institute of High Current Electronics, Siberian Branch, Russian Academy of Sciences, Russia,*

[c]*Tomsk State Pedagogical University, Tomsk, Russia*

[d]*National Research Tomsk State University, Tomsk, Russia*

Abstract. TiNi shape memory alloys (SMAs) are unique metallic biomaterials due to the combination of superelastisity and high corrosion resistance. Important limitations for biomedical applications of TiNi SMAs are the release of toxic Ni into adjacent tissues, as well as insufficient level of X-ray visibility. These limitations can be overcome by fabrication of a Ti-Ta-based surface alloy on the TiNi substrate, since Ti-Ta alloys being high-temperature SMAs are attractive biomaterials with potentially good mechanical compatibility with TiNi substrate. In the present work, this approach is realized for the first time through the multiple (N=20) alternation of magnetron co-deposition of $Ti_{70}Ta_{30}$ (at.%) thin films and their liquid-phase mixing with TiNi substrate by microsecond low-energy, high current electron beam (~2 μs, ~15 keV, ~2 J/cm^2). Surface SEM/EDS, AES, XRD and cross-sectional HRTEM/EDS/SAED analyses were used for microstructural characterization of studied material. It was found that ~1 μm-thick Ti-Ta-based surface alloy with a composition close to that of co-deposited films has been formed, and it consists of several sublayers with a depth-graded amorphous-nanocrystalline structure. Nanocrystalline sublayers consist essentially of randomly oriented grains of α"(Ti-Ta)-martensite and β(Ti-Ta)-austenite (bcc-disordered). Beneath the surface alloy, ~1 μm-thick intermediate zone has been formed. It has also a multilayer predominantly randomly oriented nanocrystalline structure and characterized by a monotonous depth replacement of Ta with Ni and a diffusion transition to TiNi substrate. The depth-graded structure of studied material is associated with the features of additive thin-film deposition/pulsed melting manufacturing process.
