FEATURES OF THE STRUCTURAL-PHASE STATE OF TITANIUM NICKELIDE FORMED BY ELECTRON BEAM WIRE-FEED ADDITIVE MANUFACTURING ACCORDING TO DIFFERENT STRATEGIES*

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TiNi-based alloys (TiNi) are widely used in medicine as materials with shape memory and superelasticity effects. One of the ways that will expand the range of possible devices and constructions from TiNi is 3D printing. In the future, the printed materials can be functionally graded (have variable composition and properties) and have a given porosity. Currently, the most promising 3D printing methods are electron beam wire-feed additive manufacturing (EBAM) [1, 2] and wire arc additive manufacturing (WAAM) [3, 4]. However, during the 3D printing of TiNi-based alloys, they are contaminated with oxygen, nitrogen and carbon from the environment and multiple formation of particles of the $Ti_4Ni_2(O,N,C)_x$ type occurs. The last ones lead to significant embrittlement of the studied material [3, 4]. The WAAM method is easier to use and more cost-effective, but in this case argon is used as a protective environment, which does not entirely exclude contamination of the alloy with O, N and C atoms [3, 4]. Unlike WAAM, EBAM is carried out in a vacuum [1, 2]. This avoids contamination by the environment, but leads to increased heat input in the samples. This may lead to the diffusion of substrate atoms into the "body" of the samples.

The aim of this work was to determine the size of the zone of diffusion enrichment with Ti atoms from the substrate and its influence on the structural-phase state of the obtained samples, depending on the printing strategy.

A VT1-0 titanium plate 5 mm thick was used as the substrate material. The $Ti_{49.3}Ni_{50.7}$ (at.%) alloy wire with a diameter of 1.2 mm was chosen as the raw material. The choice of the alloy is due to its manifestation of superelasticity effect, which is actively used in medicine. The samples were printed on an EBAM machine using two strategies: thin-walled samples and bar-shaped samples. Thin-walled samples had dimensions of 25 mm in height, 30 mm in length and 3-5 mm in width. The bar-shaped samples had dimensions of 15 mm in height, 30 mm in length and 25 mm in width.

The microstructure and phase composition of the printed samples were studied using a high-resolution field emission scanning electron microscope (HR FESEM) Apreo 2 S (Thermo Fisher Scientific, Waltham, Massachusetts, United States), equipped with Octane Elect Super (EDAX, Mahwah, New Jersey, United States) EDS detector and Velocity Super (EDAX, Mahwah, New Jersey, United States) EBSD detector.)

The results of the study showed that the samples, regardless of the printing strategy, consist of the B2 phase of TiNi and the Ti_2Ni phase. In a thin-walled sample at a distance of 3 mm from the substrate, the volume fraction of the Ti_2Ni phase was about 25%. With increasing height, the volume fraction of the Ti_2Ni phase gradually decreased and at the top of the sample was 5%. In the bar-shaped sample, the volume fraction of the Ti_2Ni phase was larger and varied in height from 50% at a distance of 3 mm from the substrate to 15% at the top of the sample. In the case of a thin-walled sample, the morphology of the Ti_2Ni phase was a cellular structure, the cell walls consisted of individual crystallites. In the bar-shaped sample, the grains of the Ti_2Ni phase had an equiaxial shape. Based on the results obtained, it can be assumed that printing samples using a strategy involving contact with a larger area of the substrate leads to increased diffusion of substrate atoms into the sample compared to thin-walled samples.

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