EXPLOSION SYNTHESES OF HIGH ENTROPY ALLOYS IN FE-W-AL-TI-NI–B-C SYSTEM

Nikoloz Chikhradze[1,2,a], Davit Tsverava[1,2,b], Mikheiil Chikhradze[2,3,c], George Janikashvili[2,d]

[1] *G. Tsulukidze Mining Institute, 7, E. Mindeli Str., 0186, Tbilisi, Georgia,*
[2] *Georgian Technical University, 77, Kostava Str., 0160, Tbilisi, Georgia,*
[3] *F. Tavadze Institute of Metallurgy and Materials Science, 0186, Tbilisi, Georgia,*
[a] *chikhradze@mining.org.ge*, [b]*datotsverava@gmail.com*, [c]*m.chikhradze@gtu.ge,* [d]*g_janika@yahoo.com*

According to the latest definitions [1], High-Entropy Alloys (HEAs) are the alloys where the concentration of basic (at least 5) elements varies between 5-35%. The HEA have higher mixing entropy than the conventional alloys and intermetallic compounds and form the stabile solid solutions with disordered structure [1, 2, 3, 4, 5, 6, 7]. In 2004, by two groups of J.W Yeh [1] and B. Kantor [4] were published important results about the unique and special properties of HEAs, in particular high hardness, wear-resistance, significantly high strength, structural stability, good corrosion and oxidation-resistance.

HEAs "exotic", core effects are: high configurational entropy; sluggish diffusion; lattice distortion and cocktail effect [8]. The "High Entropy effect" is the base for the formation of HEAs. The microstructure of HEA is often characterized with lattice distortion and nano-precipitates, which contributes to interesting mechanical properties [9].

Core effects endow the extraordinary properties of HEAs and stimulate the increasing interest for development of new generation materials for multifunctional applications.

At the current stage the volume of investigations towards high entropy materials is extended from single phase solid solution structure to multi-phase structures, containing solid solution phases, intermetallic compounds, oxides, borides and etc. [8, 9, 10, 11].

Promised direction in this field are the high-entropy composites, prepared based on the HEAs matrix-reinforced with hard ceramic compounds. Reinforcement of HEA matrix by Intermetallics and ceramic compounds are additional tools/and challenge to improve/or design new properties of HEA based composites. Accordance evaluation "HEA is still in earlier stages hence a detailed investigation is needed" [8]. Especially, It should be underlined that HEAs, as the composite materials, are less investigated and the studies in that direction are now quite intensive.

On the other hand, nanostructure materials expose completely unique physical and mechanical, chemical, optical and other properties, which provide the increasing interest towards those materials.

Accordingly, there is a huge potential to find new properties in the field of multi-component high-entropy nanostructure materials.

Therefore, the elaboration of new technologies for the production high entropy, nano-structured bulk alloys/nanocomposites is one of the challenge for scientific centers of materials science.

In the paper the Fe-W-Al-Ti-Ni–B-C system was selected for the investigations. Arguments for selection of composition was following: a) Wide possibilities to syntheses of intermetallics, borides, oxides, carbides and solid solutions with different structural modifications (TiB_2, TiC, B_4C, W_2B_5, WB_2 WB, WB_4 and other) b) Experience of authors and results (obtained in previous research) of sintering of nanocomposites by mechanical alloying (MA) and explosive compaction (EC) in comparably simple systems (Ti-Al-Ni, Ti-Al-B and Ti-Al-B-C) [12, 13, 14, 15]; c) Composition are very attractive for practical application (energy sector, defense, ballistics, machine building, chemical industries, anti-corrosion coatings, electronics, nuclear power plant and etc.).

Based to detailed literature data review, it can be concluded, that conventional technologies are not convenient to fabricate the bulk high entropy nanocomposites for the industrial applications. The analyses shows, that the explosive compaction technology is most attractive for the synthesis of high-entropy nanocomposites

In the study, the mechanical alloying (MA), followed by adiabatic explosive consolidation was considered for sintering of bulk high entropy nanocomposites in Fe-W-Al-Ti-Ni–B-C system.

Research methodology

The selection of percentage content of elements in blend were determined on the base of thermodynamic analysis and existing phase diagrams available in scientific databases. The principle of minimization of Gibbs free energy was used for phase equilibrium analysis in multi component systems.

For MA and nanopowder production, the high energetic "Fritsch" Planetary premium line mill and vibration mill "Retsch" was used. The time of the processing was varied in range: 1h; 2h; 5h; 15; 30h. 36h. The ratio of balls to blend was 10:1. The phase composition and particle sizes of the powders were controlled by X-ray diffraction system and SEM.

The selection of explosive loading parameters (ratio of blend and explosive, container size, etc) determined according to the mathematical and computer modeling using "LS DYNA" code. The stress-deformed condition of the reaction mixture under explosive loadings, were determined according to solutions of mathematical physics and elasticity theory and by the computer program created by authors.

For shock wave generation (explosive compaction experiments) the industrial explosives (Ammonite, Mixtures of Ammonite and Ammonium Nitrate, Powergel, Hexogen) are used in the experiments.

The explosive compaction were performed at the underground explosive chamber.

The MA nano blend was charged in Steel 3 alloy-tube container and at the first stage the pre-densification of the mixtures were performed by static press installation (intensity of loading P=500-1000 kg/cm^2). Cylindrical ampoule-containers were closed at both sides.

A cardboard box was filled with the powdered explosive and placed around the cylindrical sample container and detonated. The experiments were performed at room temperature. The shock wave pressure (loading intensity) were varied in range 3-20Gpa. The set conditions the explosive were detonated by electrical-detonator. High pressure developed by explosive and temperature initiate the syntheses and consolidate the nanopowder. The compacting process accompanied with the syntheses and resulting simultaneously obtaining the bulk high entropy alloys. The phase analyses and structure-property of bulks HEA compact samples were studied. The obtained results and discussions are presented in the paper.

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