SYNTHESES OF TI-AL-SI-B-C NANOCOMPOSITES BY MECHANICAL ALLOYING AND EXPLOSIVE COMPACTION

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Abstract. Nanocomposites of Ti-Al-Si-B-C systems are characterized with unique physical and mechanical properties. They are attractive and can be used wide range of areas including aerospace, power engineering, machine and chemical fields. The coarse crystalline Ti, Al, C powders and amorphous B were used as initial elements. Different compositions of Ti, Al and C were prepared for mechanical alloying. Determination and selection of blend compositions was made on the base of phase diagrams. The powders were mixed according the selected ratios of components to produce the blend. Blends were processed in high energetic "Fritsch" Planetary premium line ball mill for mechanical alloying, syntheses of new phases and ultrafine particles formation. The blends processing time was variable and change between: 1 to 10 hours. The optimal technological regimes of blend preparation were determined experimentally. Ball milled blends investigated in order to determine properties after milling and mechanical alloying. Ultrafine bland were consolidated using explosive compaction technology. Explosive consolidation technology was used for bulk composite formation. Consolidated samples were processed and prepared for the structural investigations. The paper includes structural investigations results of milling process and explosive compaction of compositions of Ti-Al-B-C powders, optimal technological parameters for explosive compaction and formation of bulk ultrafine-grained composites. The current article also includes the structural investigations of prepared samples.

1. Introduction

The increasing role and interest towards advanced materials is promoted and in direct connection with the development of engineering and materials science. Therefore there are number of investigations for the development of Ceramic and metal-ceramic composite materials by different conventional technologies [1-3]. The composite nanostructure materials are expected to be characterized with unique mechanical and physical properties which can work resist at high temperature and aggressive media. Majority of such materials represent the prospective materials for application in modern machine building, airspace, chemical and metallurgical industry and other fields. At the same time, it must be mentioned, that the wide application of composite materials is restricted due to the absence of effective technologies for the production of such materials. Industrial application of nanocrytalline materials requires the low cost production of the relevant quantity of nanopowder and simple technology for the consolidation of nanoparticles for obtaining bulk materials. In this point, it is very important to develop technologies which are orientated on industry and are characterized with resource-saving, environmentally friendly characteristics.

Several conventional methods are known for obtaining bulk ultrafine grained/nanostructured materials[4]. Some of those methods require use of high pressure and high temperature for long period of time. Because of significant coarsening of the ultrafine grains, nanostructure effects are decreased. Mechanical Alloying (MA) involves repeated cold welding, fracturing, and re-welding of powder particles in a high-energy ball mill. Because of the specific advantages, MA is used to synthesize a variety of ultrafine grained materials and nanocomposites. An important attribute of these nanocomposites is in preventing or minimizing grain growth till very high temperatures [5].

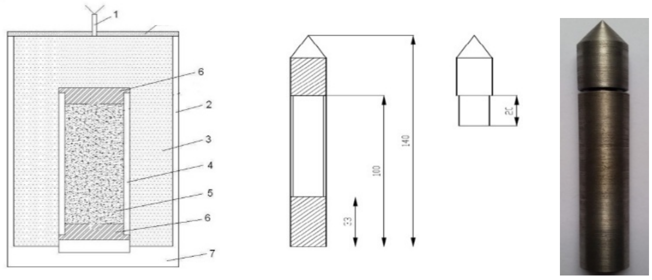
Technology preparing powders my Mechanical Alloying (MA) technique and synthesis of bulk materials from ultrafine grained powders of Ti-Al-Si-B-C system are described in this work. One of the main problems for production of bulk nanostructured samples are connected with following: limitations on the sizes and geometry of bulk material, energy consumption; needs for complicated facility, difficulties to control grains sizes; significant coarsening of structure upon high temperature conditions for extended period of time.

Therefore, main objectives of the work can be formulated as follow: a) MA for obtaining nanopowder materials as precursors for synthesis of bulk materials and b) Explosive Consolidation (EC) technology for fabrication of the bulk nanostructured materials.

2. Experimental procedure

Different compositions of Si-C-B, Ti-Al-B-C and Ti-Al-C were prepared for MA procedures at the first stage. Preliminary selection of blend compositions was made on the basis of theoretical investigations. Different initial compositions of Si-B-C and Ti–Al–B–C systems, including: 2Ti/Al/C, 3Ti/2Al/1C and 3Ti/6Al/4B/1C elemental molar ratios. Compositions were selected according to the phase diagrams for binary and ternary systems. Coarse powders of Ti, Al, C, Si and amorphous Boron were used as starting precursors. Different compositions (with different elemental molar ratios) of Si-C-B, Ti-Al-B-C and Ti-Al-C were prepared for MA. Compositions were selected according to the phase diagrams for binary and ternary systems. Precursors were classified by vibratory sieves. The particles size of Ti and Al powders was less than 200 μm.

For MA and nanopowder production, the high energetic "Fritsch" Planetary premium line ball mill was used. The mill was equipped with Zirconium Oxide jars and balls. Ratio ball to powder by mass was 5:1. The time of the processing was varied in range: 1; 3; 5, 10 hours. Rotation speed of the jars was 500 rpm. MA was applied for the Ti-Al-B-C powders for 1-10 h processing time and prepared for applying EC technique. Preliminary works showed that the EC of metal-ceramic compositions is not only feasible but can produce materials of almost theoretical densities [6]. The major advantages of EC for bulk nanomaterials production are realization of high pressure, short processing time, and super high cooling rate (adiabatic cooling). The powder blend was loaded in the steel tube container (Fig.1-b,c). Cylindrical container/tube was closed from the both sides. A card box was filled with the powdered explosive and placed around the cylindrical powder container (Fig. 1-a). The experiments were performed at room temperature. The shock wave pressure (loading intensity) was around 10 GPa. The explosive was detonated by electrical detonator.



a b c

Fig. 1. a) Schematic view of assembly for fabrication bulk rod: (1) electrical detonator, (2) explosive's container, (3) explosive, (4) steel tube, (5) reaction mixture, (6) steel plugs, (7) base table, (8) detonator seizer; b) Schematic Container; c) Steel Container

The EC experiments were performed at the underground explosive chamber. For shock wave generation the industrial explosives were used in the experiments. The optimal shock wave loading pressure is varied in the range of (7-10) GPa. In these conditions the configuration of loading/unloading waves in powder and container allows one to initiate the syntheses in the reaction mixture, to simultaneously consolidate it and to fix the phase composition under adiabatic cooling.

Conclusions

- Different compositions of Ti-Al-Si-B-C were selected for formation of composites with nano structure. The optimal regimes for MA of Ti-Al-Si-B-C powders, such as ball to powder ratio, rotation speed, media conditions were established.
- The optimal shock wave loading pressure was selected and tested experimentally.
- Were established the following: if shock wave pressure and developed energy exceed the strength limits of the container the resulting effects are destruction.
- The microstructure and particle sizes were studied after MA and Before EC. By preliminary investigations is established, that the structure of bulk samples is not uniform. Structure is presented by nanosized and coarse grains.
- SEM investigations were carried out for EC samples.
- Regimes for obtaining nanocomposites in Ti-Al-Si-B-C composition has been elaborated.

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