Shock-wave Synthesis of Titanium Diboride in Copper Matrix and Compaction of TiB_2-Cu Nanocomposites

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Abstract

We studied formation of nanostructured TiB_2-Cu composites under shock wave conditions. We investigated the influence of preliminary mechanical activation (MA) of Ti-B-Cu powder mixtures on the peculiarities of the reaction between Ti and B under shock wave. In the MA-ed mixture the reaction proceeded completely while in the non-activated mixture the reagents remained along with the product – titanium diboride. The size of titanium diboride particles in the central part of the compact was 100-300 nm.

Keywords : shock-wave synthesis, compaction, nanocomposites, titanium diboride

1. Introduction

In the recent years, there has been an increased interest to the new methods of synthesis and compaction of nanostructured materials. Shock wave synthesis creates the conditions that are never implemented in any other methods: extremely high pressures and high strain rates occurring during time intervals of the order of 10^{-6} sec [1]. At present, shock wave synthesis is of interest for production of phases in a metastable state and nanostructured materials.

TiB_2-Cu composites in a nanostructured state are candidates for high-strength conductive and erosion-resistant materials. The goal of this work was to investigate the influence of preliminary MA of Ti-B-Cu powder mixtures on the peculiarities of the reaction between Ti and B under shock-wave conditions. The microstructures of the shock-wave compacts were also addressed.

2. Experimental and Results

Copper, titanium and amorphous boron powders were used. The composition of the mixtures was (Ti-2,1B)+ 60wt.%Cu. Mechanical activation of the powder mixtures was carried out in the high-energy planetary ball mill AGO-2 of friction type with ball acceleration 600 $m \cdot s^{-2}$ [2]. The vials were vacuum pumped and filled with argon up to the pressure of 0.3 MPa. The powders were placed in air in a steel 80 mm long ampoule with 15 mm external and 10 mm internal diameter. The ampoule was put along the axis of the cylindrical charge of an explosive. The ampoule was plastically compressed during the explosion and, in turn, compressed the powder sample to 8 mm in diameter.

Fig. 1 shows XRD patterns of the mixtures MA-ed for 2 и 5 min. No new phases are formed during the activation. Transmission electron micrograph (Fig. 2) shows that the reagents in the MA-ed mixture are dispersed at a nanolevel. So, the preliminary MA creates the conditions for Ti-B interaction to proceed in the composite agglomerates with increased interfaces between the reagents. XRD phase analysis (Fig. 3) indicates that in the activated mixture the reaction proceeds completely while in the non-activated mixture the reagents remain along with the product of the reaction – titanium diboride.

It was found that the yield of the reaction increases with increasing the pressure during shock wave synthesis [3].

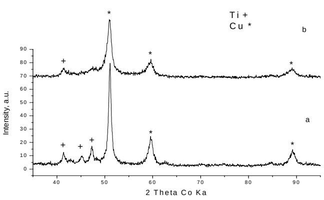


Fig. 1. XRD patterns of (Ti-2,1B)+60 wt.% Cu MA-ed for 2 – a, for 5 min – b.

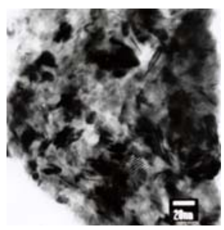


Fig. 2. TEM of (Ti-2,1B)+60 wt.% Cu MA-ed for 2 min.

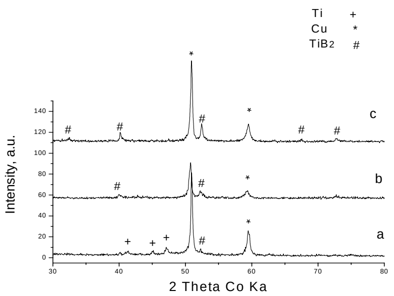
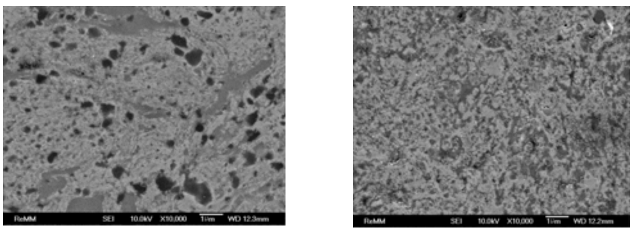


Fig. 3. XRD patterns of the shock-wave compacted samples (Ti-2,1B)+60wt.% Cu: non-activated mixture - a, mixture MA-ed for 2 min - b, mixture MA-ed for 5 min - c.

In our experiments the calculated pressure in the shock wave was 3 GPa. So, using the preliminary MA the completeness of the reaction could be achieved under relatively low pressures. This result is very important because the lower is the dynamic pressure, the lower is the temperature of the compact so that formation of fine particles of the product can be expected. The completeness of the reaction in the MA-ed mixture can be attributed to the drastic increase in Ti/B interfaces during MA-processing, which provide a large number of new ignition sites in the sample.



a b

Fig. 4. Microstructure of the shock-wave compacted sample (Ti-2,1B)-60wt.%Cu, MA-ed for 2 min (SEM, etched in $(NH_4)_2S_2O_8$ aq. solution): zone 1 – a, zone 2 – b.

The sample shock-wave compacted from (Ti-2,1B)- 60wt.%Cu mixture activated for 2 min shows two-zoned structure: peripheral layer 1,5 mm thick (zone 1) and the central part (zone 2). The zoned structure of the compact is due to the geometrical effects of the interaction of the shock wave with a material in a cylindrical ampoule. Etching in $(NH_4)_2S_2O_8$ aqueous solution revealed TiB_2 particles in zone 1. The average size of titanium diboride particles in this zone is 0,2 – 0,5 μm, however, there are some enlarged particles 1 μm in size (Fig. 4, a). After etching in $(NH_4)_2S_2O_8$ aqueous solution separate titanium diboride particles were not revealed in zone 2. Fig.4, b shows that this zone has a more uniform microstructure compared to zone 1. The particles of titanium diboride could be well distinguished after etching the sample in $FeCl_3$ solution (Fig. 5).

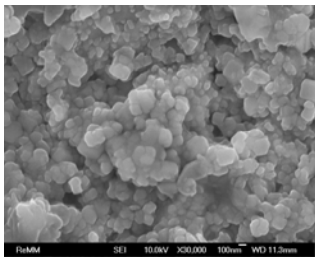


Fig. 5. Microstructure of zone 2 of the shock-wave compacted sample (Ti-2,1B)-60wt.%Cu, MA-ed for 2 min (SEM, etched in $FeCl_3$ solution).

The average particle size of titanium diboride in zone 2 is 0,1-0,3 μm. Small size of TiB_2 particles is due to relatively low pressure developed in the shock wave and, as a consequence, moderate temperatures within the sample. In composite structures with increased interfaces formed from Ti and B powders plastically deformed with copper matrix during MA, heat dissipation from the reaction zone was accelerated that also favored formation of the fine particles of the product.

3. Summary

Titanium diboride with particles size 100-300 nm was synthesized in copper matrix under shock wave conditions. Preliminary mechanical activation of Ti-B-Cu powder mixtures allowed increasing the yield of the reaction between Ti and B. Small particle size of the product is belived to be due to low shock-wave pressure, moderate average temperatures and heat dissipation by copper matrix brought in the intimate contact with the reagents by the preliminary mechanical activation of the powders. This work was supported by a grant (Integration Project №106) from the Siberian Branch of Russian Academy of Sciences (2006-2008).

4. References

1. N.N. Thadhani, Progress in Mater.Sci. **37,** p.117 (1993)
2. E.G. Avvakumov, A.R. Potkin, O.I. Samarin, Planetary mill. Authors certificate №975068, USSR, Patent Bulletin №43. (1982)
3. V.I. Mali, V.A.Neronov, V.P.Perminov, M.A. Korchagin and T.S. Teslenko, Proceedings of X APAM Topical seminar "Nanoscience and technology", Novosibirsk, Russia, p.369 (2003)