

Fabrication of Superconducting Materials based on Magnesium diboride by SHS Technique in Centrifuge

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Abstract. The superconducting nanocomposites based on magnesium diboride were produced by self-propagating high-temperature synthesis (SHS) under the effect of centrifugal force in high-temperature centrifuge. The centrifugal rotational speed shaft was within the limits of 2000 rpm. The critical transition temperature (T_c) and current density were determined by magnetometric measurements by the Physical Property Measurement System (PPMS, Ever Cool-II) Quantum Design. It was found that the critical transition temperature (T_c) of sample is in the range of 37.5K and the critical current density (J_c) is in the range of about $0.8 \times 10^8 \text{ A/cm}^2$.

Introduction

The discovery of superconductivity in magnesium diboride MgB_2 , renewed abundant interest in non-oxides materials for superconductivity and relatively high critical temperature (at about 40 K), which offers expectations to obtaining even higher T_c 's for simple compounds [1]. The application of superconductivity can lead to formation of novel efficient energy delivery systems and devices and ultrafast electronic computers [2-3]. There are several conceptual different methods to synthesis of superconducting magnesium diboride, such as high temperature solid state formation, chemical vapor deposition, arc casting and melting in the vacuum, etc [4]. One of the prospective methods of synthesis of magnesium diboride is a self-propagating high-temperature synthesis [5]. In the present paper, the laboratory samples based on magnesium diboride were synthesized by combustion synthesis under the effect of centrifugal force in high-temperature centrifuge [6]. Due to this setup it is possible to create the following conditions: the temperature of chemical reaction up to 3000 K, and centrifugal acceleration up to 2000g. High-temperature centrifuge shown in Figure 1, a consists three main parts: the engine, shaft with three reactors, the ignition system of combustion during the rotation. The reactor consists a quartz tube with 35 mm diameter and 130 mm in length, which placed in a metal sleeve closed at both sides of the lids. The covers have several small holes used for eliminate the outlet gases from the combustion process and to ignite composition by electrically heated coil.

Experimental Part

The initial reagents were amorphous boron powder (20 microns), magnesium powder (250 microns) for synthesis superconducting magnesium diboride. The initial powders of Mg (55.3%) and B (44.7%) were mixed well in the ball mill machine and was compacted into discs by a steel cylindrical press – for milder pressure 0.4 GPa. Nonstoichiometric mixture (excess of magnesium) was

prepared in order to decrease the loss of magnesium during the synthesis due to its high volatility at high temperature. Because the system magnesium and boron weakly exothermic, and for excitation of combustion process was used the mixture (55% CuO + 12% Al + 33% Al₂O₃) to ignite the samples. Schematic diagram of loading the initial mixture in the centrifuge was shown in Figure 1 b.

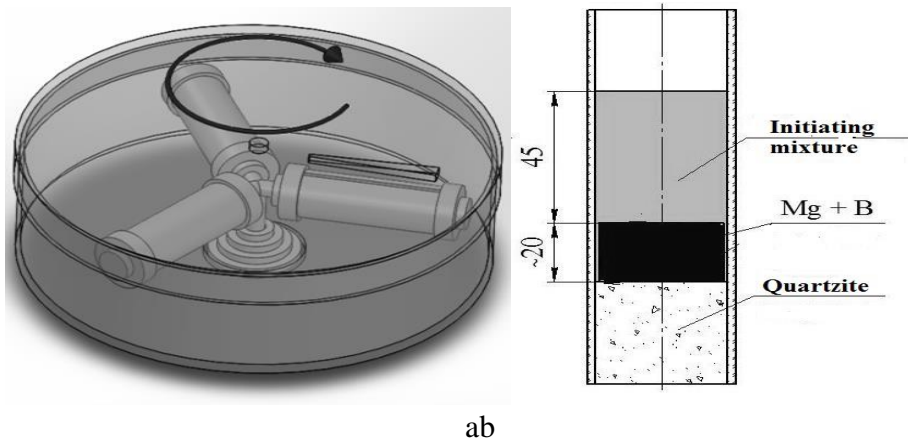


Figure 1. (a) – High temperature centrifuge reactor; (b) - Schematic diagram of loading of the initial mixture.

According to the layer-by layer XRD analyses of products the formation of magnesium diboride appears during 0.8 s after the ignition of combustion. The synthesized product exhibited about 70% of MgB₂ phase by weight. Besides MgB₂ phase was formed following phases in this system: magnesium oxide (22% by mass), and have been identified a small amount of Mg, MgB₄, SiO₂ and intermetallic phases CuMg₂, AlB₂. Figure 2 shows morphology of a sample after the combustion process in the centrifuge. The average particle size is in the range of 250-300 nm.

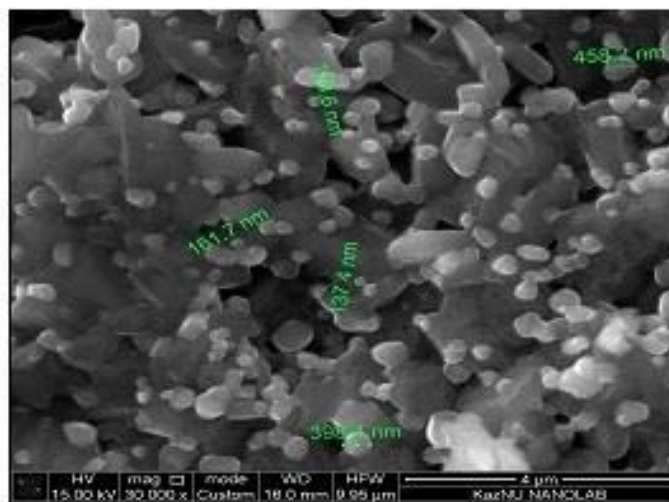


Figure 2. The SEM image of the magnesium diboride obtained in a centrifuge reactor by combustion process

It is evident that the sample has kept its original shape. SEM layer-by layer analysis revealed that the film cover of brown color was identified as the intermetallic phases of CuMg₂ and AlB₂ formed on the sample surface. Relying on this result, we can be assumed that the initiating mixture during combustion process not only transferred its heat energy, but also partially interacted with the surface layer of the sample. The superconducting characteristics of samples were measured by magnetic measurement method (Quantum Design PPMS Ever Cool-II) under temperature range of 1.9-100 K and magnetic field of 10 Oe in both zero-field-cooled (ZFC) and in field-cooled (FC)

states. It was found to decrease in the magnetic moment of the samples at temperatures $37 < T < 38\text{K}$, proceeded by a sharp response of the magnetic moment of the transition material in the diamagnetic state at $T = 37.5\text{K}$ in the measurement of temperature dependences of the magnetization of the sample (Figure 3). The lower T_c in the present sample could be possibly due to the presence of small amount of MgO phase and the resulting off stoichiometry of the desired superconducting phase of MgB_2 .

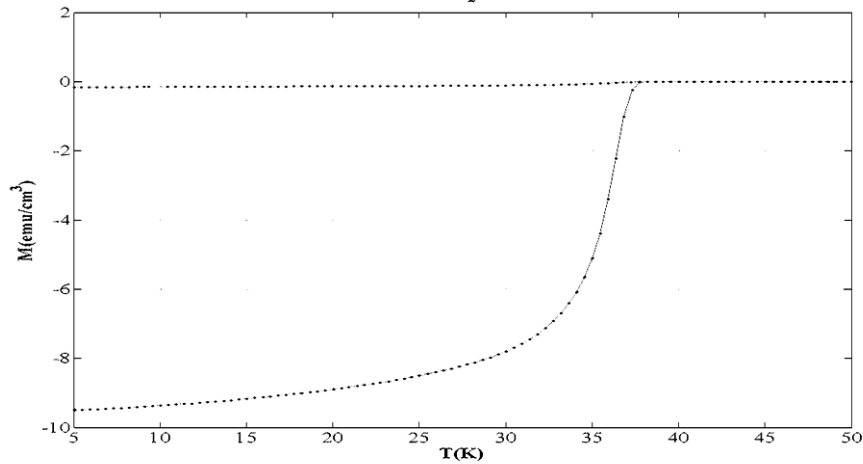


Figure 3. Field-cooled and zero-field-cooled magnetization of MgB_2 (produced in a centrifuge at 2000 rpm) as a function of temperature in an applied field of 10 Oe showing the superconducting transition temperature.

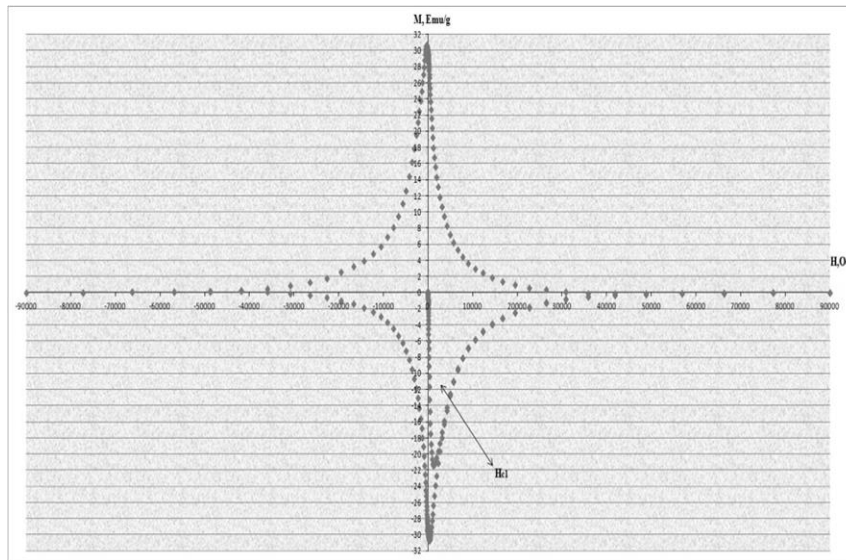


Figure 4. The curves of hysteresis loop for the sample produced in a centrifuge at 2000 rpm.

This temperature is characterizing the transition temperature from the normal to the superconducting state, indicating the nucleation of the superconducting phase in the samples at these cryogenic temperatures. One of the basic characteristics of superconductivity “the critical current density” was calculated and analyzed. The value of the critical current density of the samples was calculated by the Bean’s formula [7]:

$$J_c = 30 \cdot \Delta M / d,$$

Where, J_c – critical current density, d – average size of particle ~250 nm, ΔM - the difference in the decreasing and increasing of the magnetization curve defined by the magnetic hysteresis obtained from Figure 4. The value of the critical current density of MgB₂ powders were found that is equal to $0.8 \times 10^8 \text{ A/cm}^2$.

Summary

The superconducting material based on magnesium diboride was synthesized by the centrifuge technique by using combustion synthesis. It was found that the centrifugal force contributes to the intensification of the process and reduce the period of formation of the superconductor structure. At the same time the injection of impurities into the surface layers of the synthesized materials has no significant effect on the critical transition temperature of samples. In this regard, further investigation of the influence of the centrifugal acceleration on the combustion processes of magnesium diboride and on its superconducting properties is appeared more promising.

Acknowledgments

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References

- [1] Nagamatsu J., Nakagawa N., Muranaka T., Zenitani Y. and Akimitsu J. Superconductivity at 39 K in magnesium diboride, *Nature*, Vol. 410 (2001), p. 4.
- [2] Phillips J.C. *Physics of High-Tc Superconductors*, J.C. Phillips. - Boston: Academic Press, Vol. 5 (1989), p. 393.
- [3] Shackelford J.F. *Introduction to Material Science for Engineers*, J.F. Shackelford. - Upper Saddle River, New Jersey: Prentice Hall, Vol.4 (2000), p. 877.
- [4] Buzea C, and Yamashita T., Review of the superconducting properties of MgB₂, *Supercond. Sci. Technol.*, 14, (2001) R115–R146.
- [5] Przybylski, K, Stobierski, L., Chmista, J., and Kołodziejczyk, A., Synthesis and properties of MgB₂ obtained by SHS method, *Physica C*, (2003), Vol. 387, no. 2, pp. 148–152.
- [6] Ksandopulo G.I. Non – chain autoacceleration of the self – propagating high temperature synthesis (SHS) wave at rotation conditions, *International Journal of Self Propagating High Temperature Synthesis*, Vol. 24, (2015), p. 8-13.
- [7] Bean C.P. Magnetization of High-Field Superconductors // *Rev.Mod.Phys.*, Vol. 36 (1964), p. 31-39.

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