Vol. **113** (2008) *ACTA PHYSICA POLONICA A* No. 1

Proceedings of the CSMAG'07 Conference, Košice, July 9–12, 2007

Effect of Nano-SiC Doping on the Superconducting Critical Parameters in MgB_2/Fe Wires and Tapes

D. Gajda[a], A.J. Zaleski[b], A. Morawski[c] and A. Kario[c]

[a]International Laboratory of High Magnetic Fields and Low Temperatures
Gajowicka 95, 53-421 Wrocław, Poland
[b]Institute of Low Temperature and Structure Research
Polish Academy of Sciences
Okólna 2, 50-422 Wrocław, Poland
[c]Institute of High Pressure Physics, Polish Academy of Sciences
Sokołowska 29/37, 01-142 Warszawa, Poland

In this paper the results of critical current measurements for MgB_2 wires and tapes in iron sheath with and without nano-SiC doping are presented. We focus on power-in-tube processing technique, using both *in situ* and *ex situ* methods. *In situ* MgB_2 wires and tapes were fabricated from MgH_2 and B or Mg and B powders. The methods such as hydrostatic extrusion and rolling were used. The samples were annealed under high Ar gas pressure (hot isostatic pressing) at 750°C and 1.0 GPa for 40 min. It was found that critical current of MgB_2/Fe superconducting wire or tape with nano-SiC dopant increased in higher magnetic field values in comparison to pure MgB_2. A significant difference of J_c in tapes made by *in situ* way from MgH_2 and Mg were found.

PACS numbers: 74.70.Ad, 74.25.Sv,

1. Introduction

Discovery of the superconductivity in MgB_2 [1] with reasonably high for application critical temperature $T_c = 39$ K caused rapid improvement of this material quality. Superconductor with such high T_c became a promising candidate for various applications operated at liquid hydrogen temperature 20 K or cryocooler refrigeration. One of the advantages of the MgB_2 is the low cost of raw material and relatively easy technological process of composites mixing and low temperature annealing regime. The main problem is the high magnesium activity and difficult to control easy oxidation. Up to now iron seems to be mostly used sheath material for manufacturing MgB_2 wires and tapes. It has been found that chemical doping, especially nano-SiC [3], and high pressure heat treatment have a positive influence on transport properties.

2. The methods of MgB_2/Fe wires preparation

Starting powders were mixed in nominal composition ratio (Mg:B = 1:2). This process was performed in Ar atmosphere, because of the high magnesium reactivity with oxygen. Closed Fe tubes have been firstly drawn from diameters 13.8 mm to 2.25 mm and then hydrostatically extruded (HE) from ⌀2.25 first to ⌀1.62 mm and secondly to the wire of the diameter of ⌀1.58 mm or tapes 0.4×2.8 mm. Some of them were further drawn to ⌀1 mm. Tapes were made by rolling from hydroextruded wires after that they were annealed in hot isostatic pressing (HIP) process with the use of water cooled high pressure chamber, under high Ar gas pressure (p) of 1.0 GPa, at temperature ($T_{\rm w}$) of 750°C, for 15 min (t). The sample preparation was performed in the Institute of High Pressures, PAS, in Warsaw [2].

3. Experiment

The sample no. 54a (tape — $p = 1$ GPa, $T_{\rm w} = 750$°C for $t = 40$ min) has MgB_2 with 5% nano-SiC addition in the core. The sample no. 55a (tape — $p = 1$ GPa, $T_{\rm w} = 750$°C for $t = 40$ min), no. 55b (wire — $p = 0.8$ GPa, $T_{\rm w} = 750$°C for $t = 40$ min) and no. 55c (tape — $p = 0.8$ GPa, $T_{\rm w} = 750$°C, $t = 40$ min) were obtained from MgH_2 and B without the nano-SiC additions and the sample no. 56a (tape — $p = 1$ GPa, $T_{\rm w} = 750$°C for $t = 40$ min, Fig. 1), no. 56b (wire — $p = 0.8$ GPa, $T_{\rm w} = 750$°C for $t = 40$ min) and no. 56c (wire — $p = 0.35$ GPa, $T_{\rm w} = 650$°C for $t = 15$ min, $T_{\rm w} = 750$°C for $t = 40$ min) were prepared from Mg and B, again without any doping. Critical current ($I_{\rm c}$) of the tape and wires was measured by a four-probe resistive method, for the samples of the length equal to about 25 mm. The wire diameter was in the range 0.68–1.6 mm and tapes dimensions were 0.4×2.8 mm and 0.6×2.5 mm. All measurements were made at 4.2 K. Maximum measurement current was 150 A. Steady magnetic field was generated by the Bitter-type magnet with maximum field equal to 15 T. The critical transport current was measured employing two techniques: current change in constant magnetic field and constant current — with the magnetic field changing up to 14 T. The use of two measurements methods ensured higher accuracy in evaluating $I_{\rm c}$ of superconductor. The 1 μV/cm criterion was used for $I_{\rm c}$ evaluation. Additionally, the superconducting wires no. 56b and no. 56c were also investigated for the two directions of the magnetic field: perpendicularly and parallel to the conductor length (such measurements were repeated 6 times). The HIP-ed tapes, all in Fe sheath, are characterized by flat $J_{\rm c} = f(B)$ relations with the exception of the tapes obtained from MgH_2 for which (as for the wires) the high $J_{\rm c}$ is

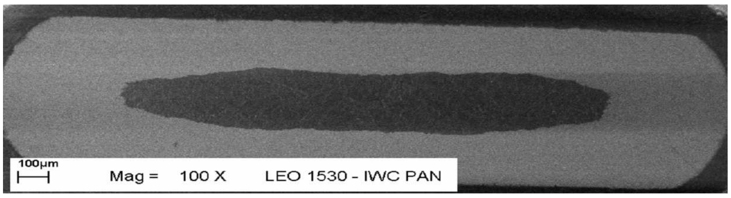
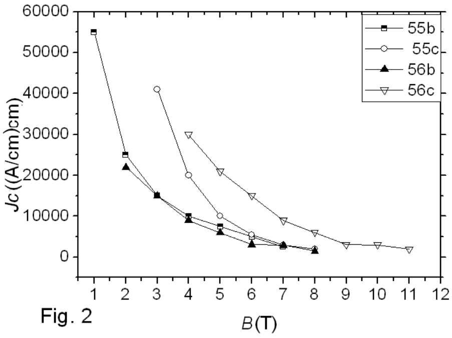


Fig. 1. The cross-section of the thicker state of the tape no. 56 after HIP 0.6×2 mm.



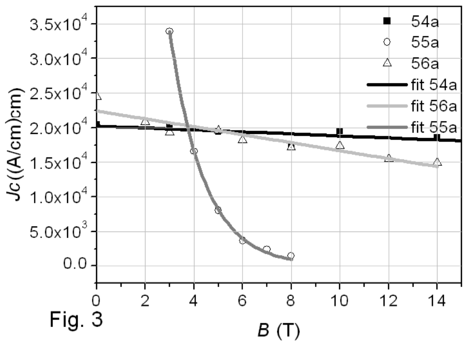


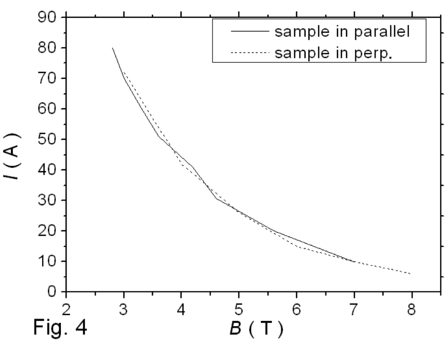
Fig. 2. $J_c = f(B)$ for samples no. 55b, 55c, 56b, and 56c, a function of technological parametrs.

Fig. 3. $J_c = f(B)$ for samples no. 54a, 55a, and 56a, a function of technological parameters.

characteristic of low magnetic field region and for higher field (over 4 T) the J_c becomes relatively small [4].

4. Conclusions

The highest current densities of Fe sheathed tapes at higher magnetic fields were obtained for the sample no. 54a made with 5% at. SiC addition (Fig. 3). The repeated measurements of the Fe sheathed MgB_2 wire no. 56b during three



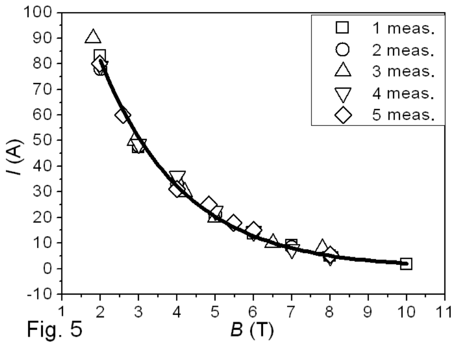


Fig. 4. $I-B$ curves for wire no. 56b measured perpendicular and parallel.

Fig. 5. $I-B$ curves for wire no. 56 after 6 measurements.

months did not show any I_c degradation (Fig. 5). Surprisingly, the measurement of the current I_c for different magnetic field geometries did not show any differences. Critical current in lower magnetic field (up to 4 T, Fig. 2 and 3) for tape no. 55a, no. 55b and no. 55c obtained by the *in situ* method from MgH_2 and B powders is much higher comparing with the samples no. 54a and no. 56a, no. 56b and no. 56c. Critical current of these samples in higher magnetic field is considerably lower than in samples prepared from the elementary boron (no. 54a and no. 56a, no. 56b and no. 56c).

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