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Properties of hot pressed MgB_2/Ti tapes

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ABSTRACT

Hot axial and hot isostatic pressing was applied for single-core MgB_2/Ti tapes. Differences in transport current density, *n*-exponents and critical current anisotropy are discussed and related to the grain connectivity influenced by pressing. The magnetic Hall probe scanning measurements allowed observing the isolated regions for axially hot pressed sample attributed to the longitudinally oriented cracks introduced by pressing. The highest current densities were measured for the tape subjected to hot isostatic pressing due to improved connectivity.

1. Introduction

MgB_2 wires prepared by in situ technique using Mg + B powders mixture have usually low core density due to the volume shrinking caused by Mg + B→ MgB_2 conversion [1]. Recent review of Eisterer is well presenting critical currents, connectivity, current percolation and parameters influencing $J_c(\mu_0 H)$ performance of MgB_2 [2]. The method of mechanical alloying (MA) is a variant of the in situ technique. Mg and B are intensively milled in a planetary ball mill where high energy milling leads to a partial reaction to MgB_2 [3–5]. This fine-particles precursor powder is highly reactive and can be processed further at relatively low temperatures [4,5]. High density MgB_2 with very high current densities (10^4 A cm^{-2} at 14−16 T) has been presented recently for carbon doped MA powder [6,7]. High reactivity of MA powder causes the creation of Fe_2B layer at the core/Fe interface even at low temperatures, which influences the phase purity (boron deficiency) and also the thermal and electrical properties of composite wire [8,9]. Recently, titanium as a sheath material has been used and no reaction or diffusion up to 900 °C was observed [10]. Effect of hot isostatic pressing has been applied for bulk samples [11] and also for wires [12]. The J_c improvement for ex situ MgB_2 wire was attributed to the large amount of crystalline defects [12].

The aim of this contribution is to show how the applied hot axial and isostatic pressure can influence the transport current densities of MgB_2 tapes made from not doped mechanically alloyed powder in chemically inert Ti sheath.

2. Experimental

MA/Ti composite was prepared by two-axial rolling deformation into mono-filamentary tape of 0.35 mm in thickness and 3.3 mm in width [8]. Hot pressed sample (HP) at 80 MPa and hot isostatically pressed one (HIP) by 1 GPa were done at temperature 650 °C. Hot pressing was performed between two stainless steel anvils covered by BN powder (to protect the sample gliding) in gaseous axial press and pressing direction was applied perpendicularly to flat side of the tape. Hot isostatic pressing was done in the set composed of three stage compressor and high pressure chamber 30 mm in diameter filled by pure Ar [13]. The reference not pressed sample (N) was annealed at 650 °C in argon pressure slightly higher than atmosphere. Vickers microhardness measurements (HV 0.05–50 g) were performed in the cores cross-section of studied tapes to see the effect of densification. Critical currents (I_c at 1 μV cm^{-1}) of tapes (N, HP and HIP) were measured in paral-

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lel and perpendicular external magnetic field orientation to the tape side at liquid helium temperature.

We have explored also the local magnetic field close to the transverse section of the above-described HP and HIP samples using high-resolution (5 μm) scanning Hall probe microscope (SHPM) [14,15]. Perpendicular magnetic field was applied to the transverse section of the sample. All scans consisted of 200 × 60 points with the steps of 5 μm in both *x* and *y* directions, which gave the overall scanned area 1 mm × 0.3 mm. The distance of the Hall probe from the sample surface was 25 μm ± 5 μm. Both samples were placed on the same SHPM sample holder and cooled down to 20 K in zero field. Then, external magnetic field of B = +150 mT was applied. Magnetic field distribution in close proximity of the sample surface was imaged.

3. Results and discussion

Fig. 1a shows the magnetic field dependence of critical current density for N, HP and HIP tape. It is apparent that $J_c(\mu_0 H)$ is influenced by the applied pressing. The lowered J_c is measured for HP tape (10^4 A cm^{-2} at 8.0 T), which correlates with the lowered core density expressed by the micro hardness data in Table 1 (HV 0.05 = 290). The highest J_c (10^4 A cm^{-2} at 10.8 T) was measured for HIP sample having the highest core density (see Table 1) and consequently improved grain connectivity. The current density at 10 T is increased from 10,000 to 16,700 A cm^{-2} by hot isostatic pressing at 1 GPa (improvement by 67%). HP and HIP tapes show also slightly less steep J_c decrease with field than N (see dotted lines in Fig. 1a). Fig. 1b presents the plot of $n(\mu_0 H)$ values evaluated from $I-V$ curves, which correlates with $J_c(\mu_0 H)$ data. As visible, all three $n(\mu_0 H)$ characteristics follow well a linear dependences for semi logarithmic plot (exponential decrease) in the selected field range but *n*-exponents decrease less rapidly with field than J_c. While the J_c drop by one order of magnitude is observed for the field increase by 4.5 T (see Fig. 1a), 10 times decreased n occurs in the field range of 8.5 T. Apparently lowered *n*-exponents for HP sample can be attributed to globally worsened grain connectivity (see the core microhardness in Table 1) and consequent current redistribution inside the MgB_2 core.

Fig. 1c compares the anisotropy factor ($k_a = I_{c\text{-par}}/I_{c\text{-perp}}$) of all three tapes annealed at the same temperature 650 °C, the insert shows the critical currents measured in parallel and perpendicular field for HP tape. An exponential increase of k_a with field was measured for each sample, but their absolute values are different. Crit-

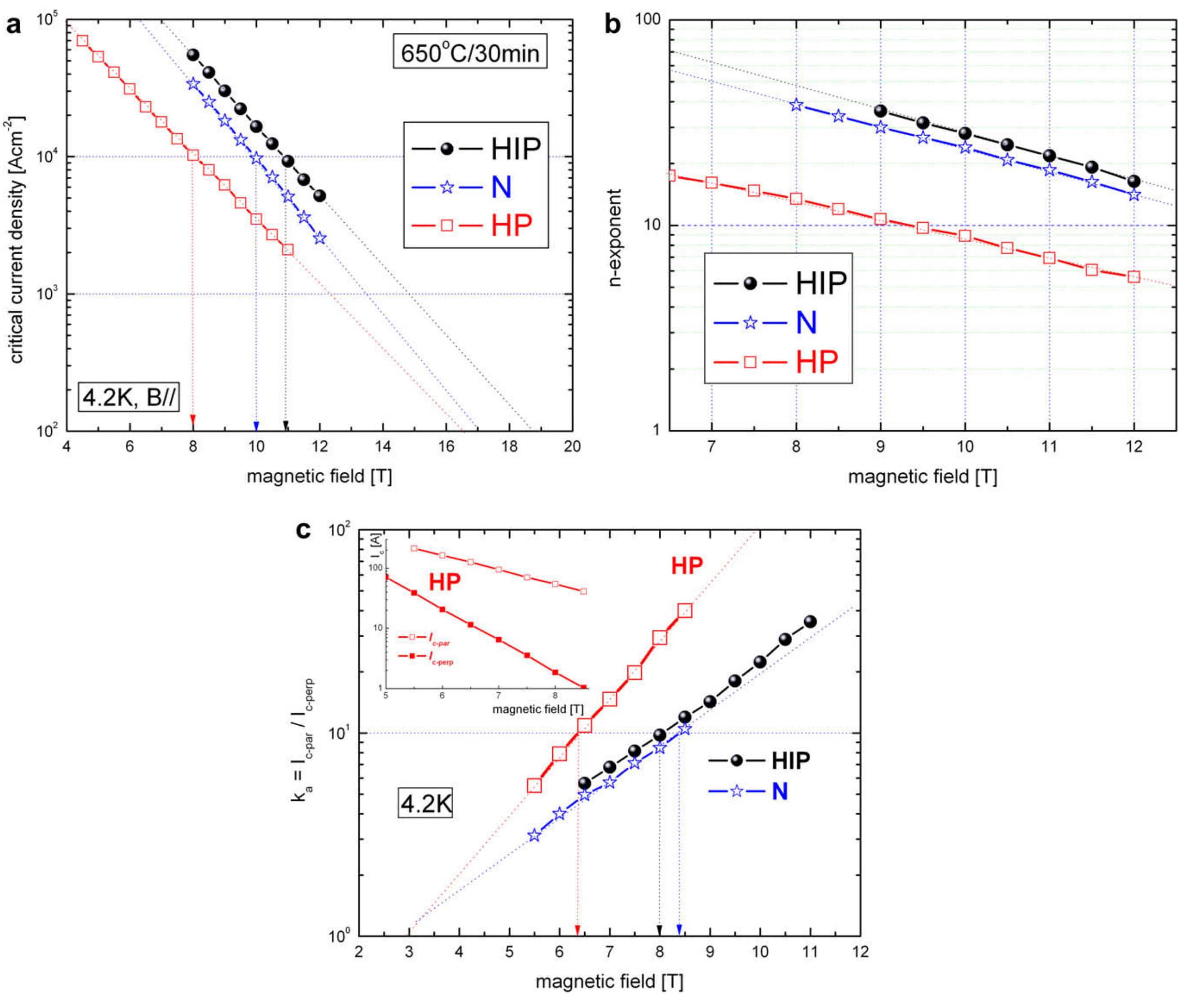

Fig. 1. Transport current densities measured at 4.2 K in parallel external field (a), corresponding *n*-exponents (b) and anisotropy factor $k_a = I_{c\text{-par}}/I_{c\text{-perp}}$ (c) as a function of field magnitude for HP, HIP compared with the reference sample N.