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Texture induced anisotropy of critical current of MgB_2/Fe rolled superconducting tapes studied by synchrotron x-ray diffraction

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We have correlated the texture of carbon doped $MgB_{2-x}C_x$ superconducting grains in Fe tapes to the anisotropy of the critical current density. A percolation model of the transport current of weakly textured media shows good agreement with the data and illustrates that carbon doping is decreasing the anisotropy by scattering between the two superconducting energy gaps.

Introduction

We have measured the texture of MgB_2 superconducting grains formed inside Fe tubes, which were first filled by a precursor powder of Mg + 2B + C, rolled flat into a tape and finally heat treated at T = 600 ºC in Argon for 3 hours[1]. The MgB_2 will have the c-axis of the hexagonal unit cell aligned with the normal of the tapes as illustrated on inset of figure 1. The critical current of such a tape has a large anisotropy when a magnetic field is varied from perpendicular to in-plane as shown on figure 1a. This is due to the anisotropy of upper critical field of MgB_2 which is of the order H_{c2}||ab = 14.5 Tesla and H_{c2}||c = 3.2 Tesla. Figure 1b is showing how the critical current is decreasing with applied field and that the anisotropy is increases when the applied field is larger than H_{c2}||c for the un-doped tape. The carbon doped tape shows very little anisotropy, which can be explained by an increased scattering between the two super-conducting energy gaps of MgB_2, but the influence of the texture distribution needed to be separated from the gap anisotropy.

Texture measurements at BW5 @ Desy

By rotating the tape in a E = 100 keV synchrotron beam it was possible to penetrate the Fe sheath while collecting the diffraction pattern from the MgB_2 on a MAR345 image plate detector. Figure 2a shows how a Gaussian texture distribution of the form f(α)~exp(- α^2 / α_t^2), where α_t is the width, results in partial Debye Scherrer cones.

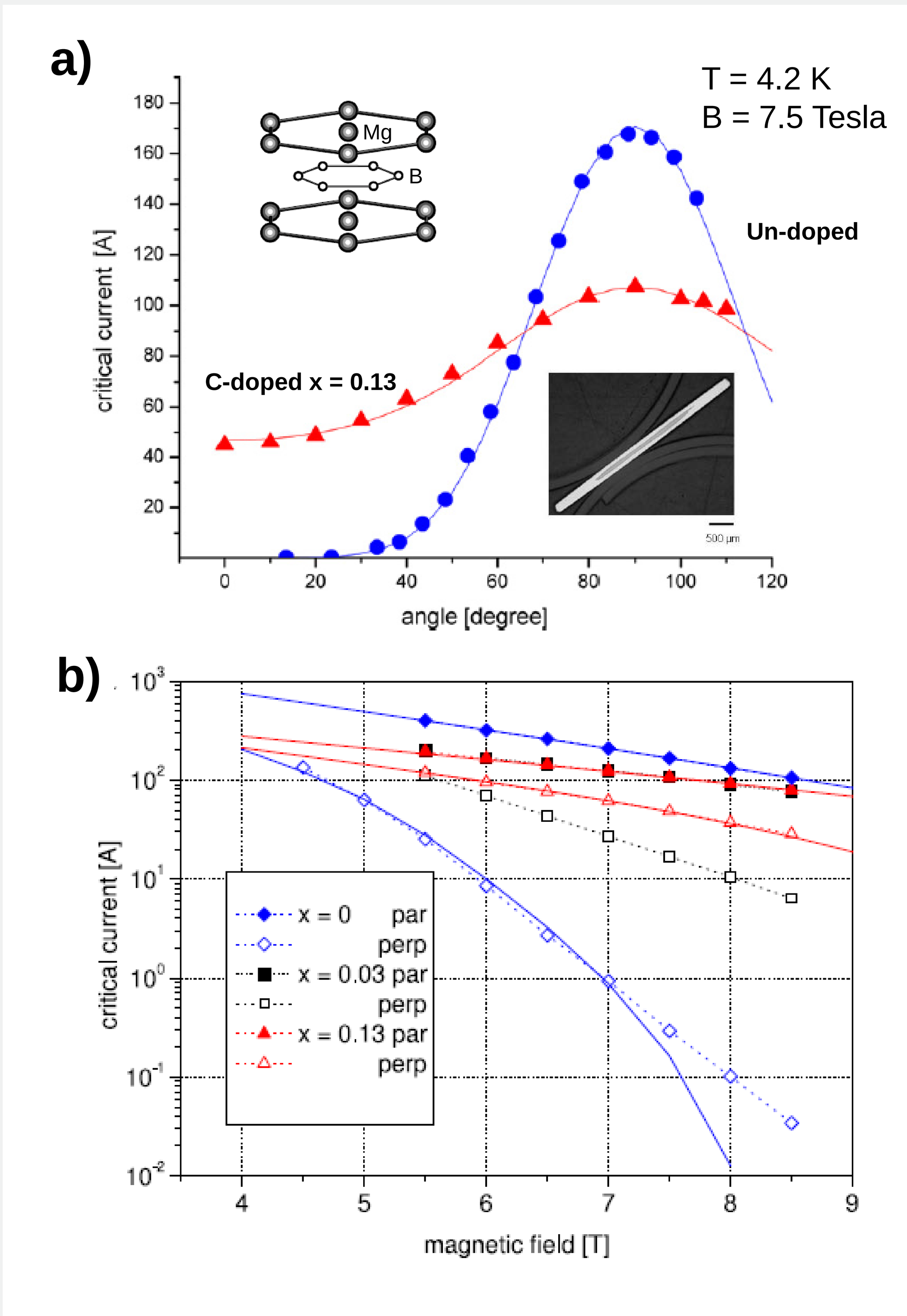

Figure 1 **a)** Critical current of $MgB_{2-x}C_x$ tape as the applied magnetic field is rotated from perpendicular to parallel with the tape plane. **b)** Critical current of $MgB_{2-x}C_x$ tapes as function of the applied magnetic field for both parallel and perpendicular field direction.

Results

Figure 2b shows the rocking curve of the MgB_2(200) and (100) reflection for both carbon and un-doped tapes. The intensity was fitted by

$$I \sim V_0\, \sigma_{(hkl)}(\alpha)\, I_0 \exp(-\mu_{Fe} l_{Fe}) \quad (1)$$

where V_0 is the illuminated volume, $\sigma_{(hkl)}(\alpha)$ *is given by the texture distribution,* I_0 *is the incident intensity,* μ_{Fe} *is the mass attenuation coefficient and* l_{Fe} *is the absorption path of the iron sheath. A texture of* α_t = 27.8 2.2º *and* α_t = 29.3 0.3º *was found for un and c-doping.*

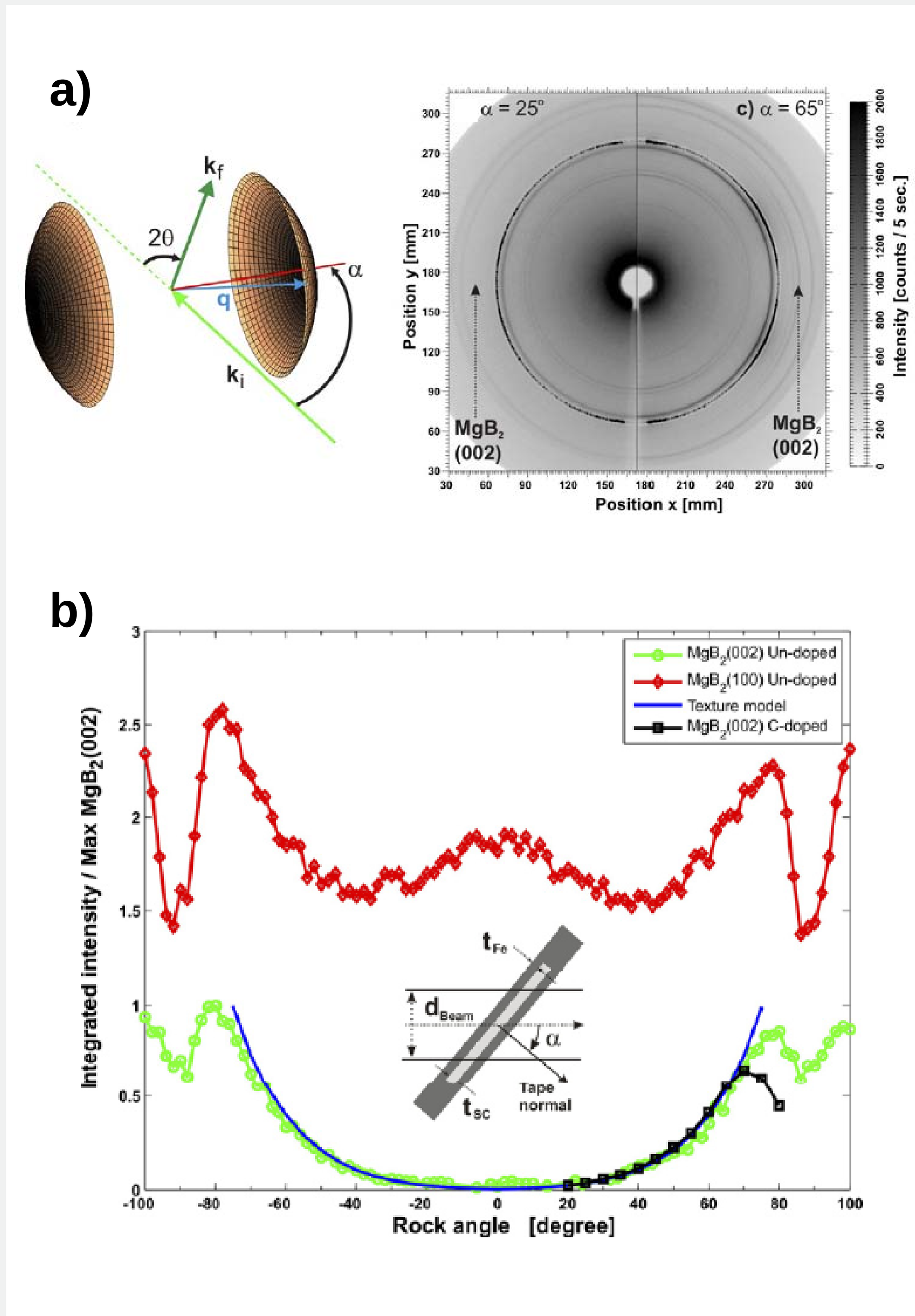

Figure 2 **a)** Illustration of the Gaussian texture distribution of the c-axis grains when an incident x-ray beam is parallel with the plane of the tape. The cutting of the Ewalds sphere in the small angle limit will appear as the intersection with a plane and cause partial Debye Scherrer cones. **b)** Rocking curve of MgB_2 (002) and (100) reflection. Inset scattering geometry.

Conclusion

A percolation path model of the transport current in $MgB_{2-x}C_x$ has been formulated by M. Eisterer and combined with the measured texture distributions it describes the critical current density quite well (solid lines of fig 1b). Thus the change of the anisotropy of the critical current of $MgB_{2-x}C_x$ can only be explained as an increased electronic scattering between the two energy gaps of the superconductor with increased carbon doping.

[1] W. Häßler, P. Kovac, M. Eisterer, A.B. Abrahamsen, M. Herrmann, C. Rodig, K. Nenkov, B. Holzapfel, T. Melisek, M. Kulich, M. von Zimmermann, J. Bednarcik and J.-C. Grivel, “Anisotropy of the critical current in MgB_2 tapes made of high energy milled precursor powder”, Supercond. Sci. Technol. 23 (2010) 065011.