Record-high upper critical field in MgB_2 bulk samples prepared by a non-conventional rapid synthesis route

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The upper critical field (B_{c2}) sets the thermodynamic limit to the superconductivity. In the case of the MgB_2 superconductor, a big gap is present between B_{c2} values measured in bulk samples and in thin films, where B_{c2} can be as high as $\sim$ 50 T at 4.2 K. Filling this gap would unlock the potential of MgB_2 for magnet applications, which is much wished by the applied-superconductivity community because of its low cost and relatively high critical temperature, close to 40 K. This work presents the results of an extensive experimental campaign that was guided by a Design of Experiment and demanded the preparation and characterization of $\sim$ 50 samples. We measured and modeled the dependence of the upper critical field on the main synthesis parameters and established a new record for B_{c2} ($\sim$ 35 T measured at 4.2 K) by tuning the structural disorder in C-doped samples prepared by a non-conventional rapid synthesis route [1]. The idea behind is that rapid heating and cooling may freeze the system in configurations with high structural disorder as in the case of thin films. Indeed, X-ray diffraction and X-ray photoelectron spectroscopy analyses demonstrate that the rapid-synthesis route allows levels of C substitution in the B sites not attainable with conventional manufacturing routes for bulk samples. However, the achieved record appears to be an upper boundary for B_{c2} in bulk samples. Structural disorder in films seems to be able to act selectively on one of the two bands where the superconductivity in MgB_2 takes place: this enhances B_{c2} while reducing T_c only by a few Kelvins. On the other hand, the critical temperature in bulk samples decreases monotonically when the structural disorder increases, and this imposes a limit to the maximum achievable B_{c2}.

[1] D. Matera, M. Bonura, et al., Scientific Reports 10, 17656 (2020).