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A comparative study of new Ge-based additions to MgB_2

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A. Background

Different Ge-based additions [1-4] were shown to improve the superconducting functional characteristics of MgB_2, such as the critical current density (J_c) and the irreversible magnetic field (H_{irr}).

Additives of Ge, GeO_2, Ge(OM), GeTe were tested and results are compared. All samples show a critical onset temperature of 37-39 K. For each additive we obtained an optimum starting composition (x= 0.005 for Ge and GeO_2 additions, and x=0.0014 for $Ge_2C_6H_{10}O_7$ addition).

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B. Experimental

Raw powders and compositions were:

(1) MgB_2 (99.5 % purity, 1-2 μm, decomposition temperature T_{dec}=890 °C, Alfa Aesar), Ge (99.999 % purity, 152 μm, melting point T_m= 937 °C, Alfa Aesar)**:** MgB_2Ge_x, *x*=0 (a), 0.005 (b), 0.01 (c), and 0.03 (d) (Fig. 1).

(2) MgB_2 (Alfa Aesar)**,** GeO_2 (99.999%, 14.3 μm, T_m = 1086 °C, Alfa Aesar)**:** $MgB_2(GeO_2)_x$, x=0 (A), 0.005 (B), 0.01 (C), and 0.03 (D) (Fig. 2).

(3) MgB_2 (Alfa Aesar)**,** $Ge_2C_6H_{10}O_7$ (99.7%, T_{dec}=320 °C, Alfa Aesar)**:** $MgB_2(Ge_2C_6H_{10}O_7)_x$, *x* = 0 ($MgB_2$), 0.0007 (GEP0.7), 0.0014 (GEP1.4), 0.0025 (GEP2.5), 0.005 (GEP5), 0.015 (GEP1.5) (Fig. 3).

(4) MgB_2 (Pavezyum, Turkey, purity >95%, particle size ~30 nm, product number PVZ-nMgB2-008), OM=$Ge_2C_6H_{10}O_7$ (RGe* – Alfa Aesar, 99.7%, T_{dec}=320 °C), RGe** (Asai Germanium Research Institute, Japan), PGe (Asai), SP (Asai)**:** $MgB_2(OM)_{0.0028}$ (Fig. 4).

(5) MgB_2 (Pavezyum)**,** crystalline GeTe, amorphous Ge20Te80 (synthesized at University of Pardubice, Faculty of Chemical Technology, Czech Republic)**:** $MgB_2(Ge_xTe_{1-x})_{0.01}$, x=0.5, and 0.2 for GeTe, and Ge20Te80, respectively (Fig. 5).

The powders were mixed in an agate mortar and sintered by SPS (FCT Systeme GmbH – HP D 5, Germany) for 3 minutes at 1150 °C, under a uniaxial pressure of 95 MPa. During sintering secondary phases formed: MgO, MgB_4, Mg_2Ge, and MgTe. J_c (Fig. 1-5.a, b) was calculated based on Bean relation, and by using *m*(*H*) loops. H_{irr} was determined for the 10^2 A/cm² criterion (Fig. 1-5.c). *m*(*T*) measurement are presented in Figs. 1d-5.d.

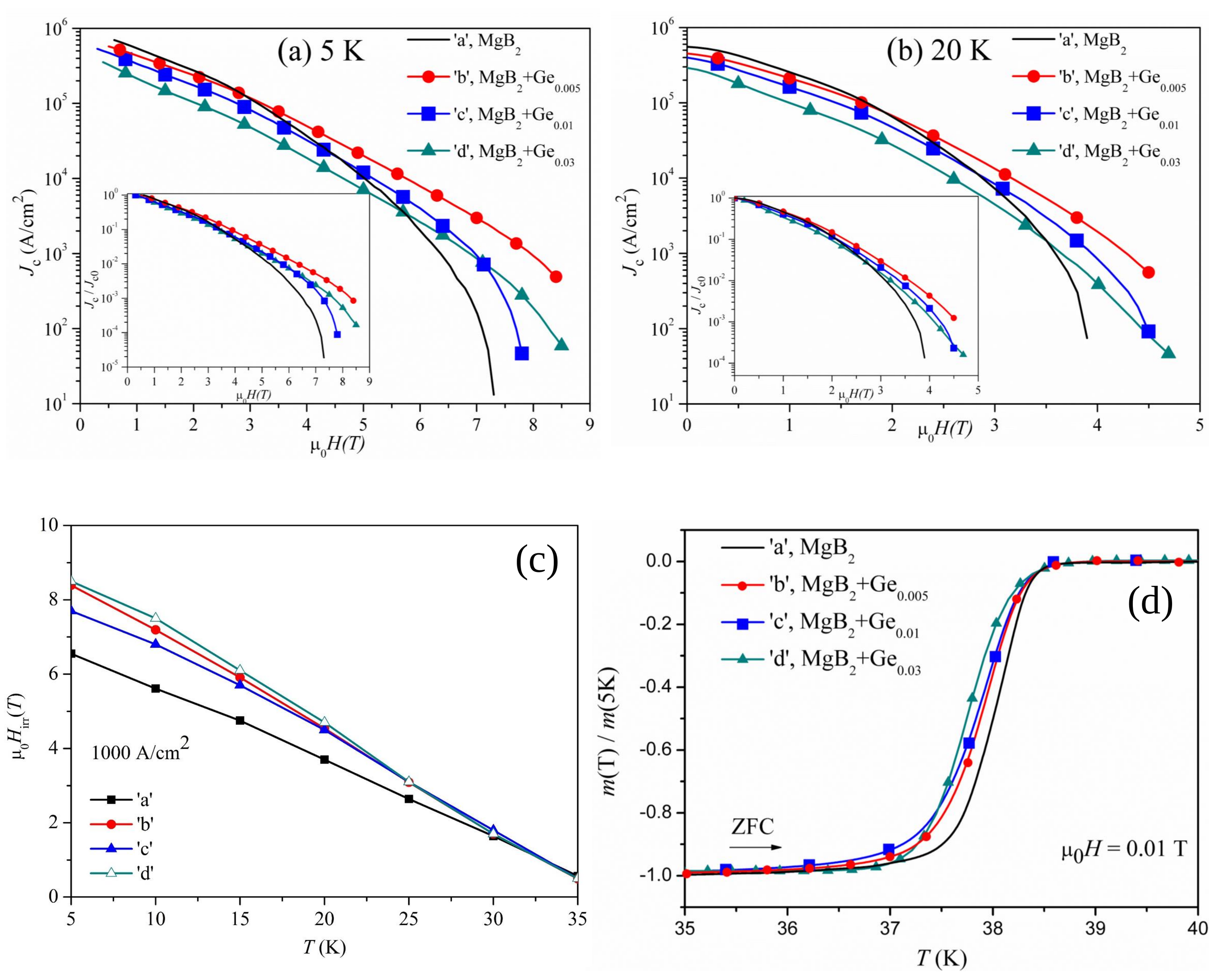

Fig. 1. Critical current density vs. magnetic field of SPSed samples at 5 K **(a)** and 20 K **(b)**, H_{irr} **(c)**, and ZFC *m*(T)/*m*(5K) **(d)** for **Ge** added MgB_2 (Alfa Aesar) [1, 2].

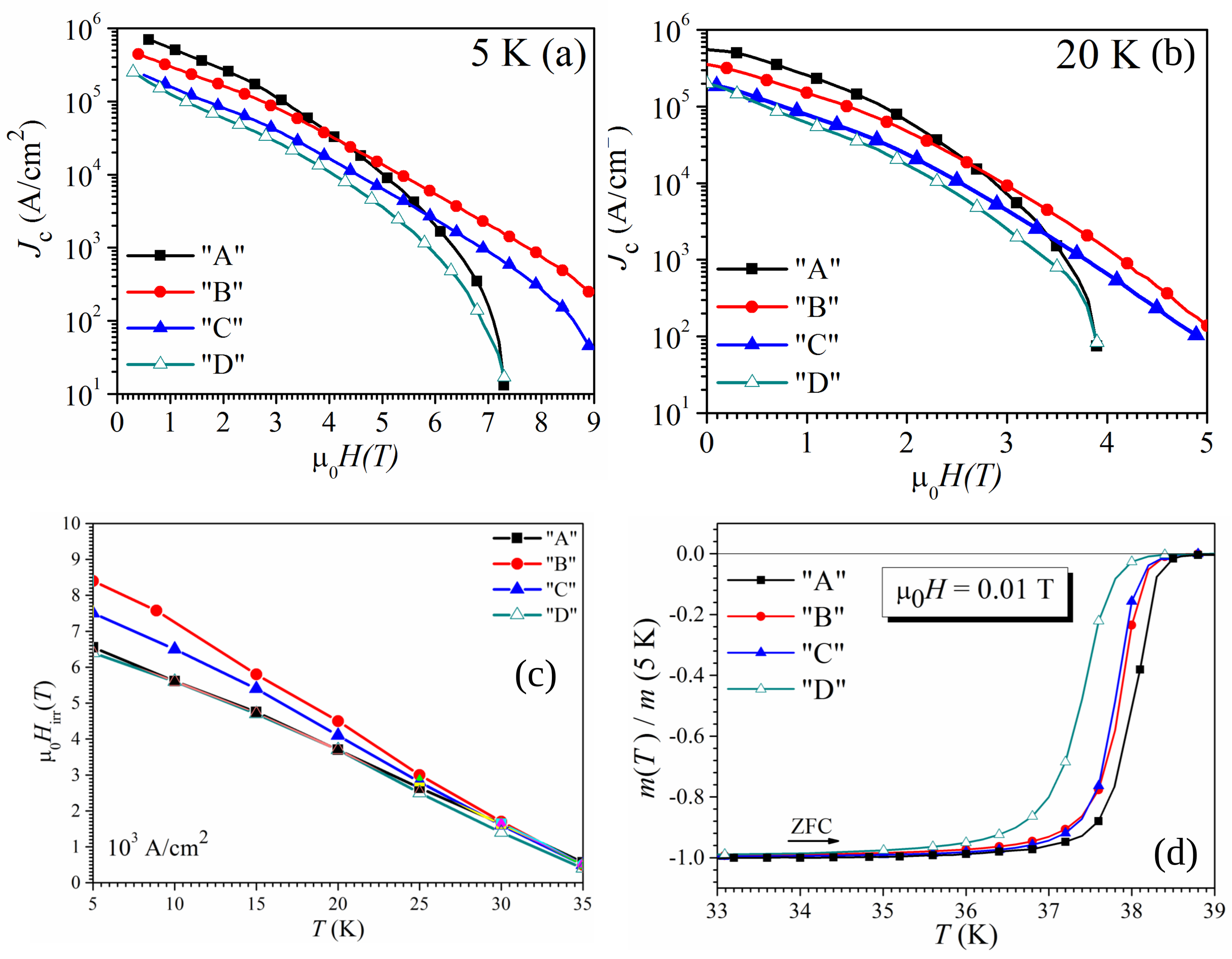

Fig. 2. Critical current density vs. magnetic field of SPSed samples at 5 K **(a)** and 20 K **(b)** , H_{irr} **(c)**, and ZFC *m*(T)/*m*(5K) **(d)** for **GeO_2** added MgB_2 (Alfa Aesar) [1, 3].

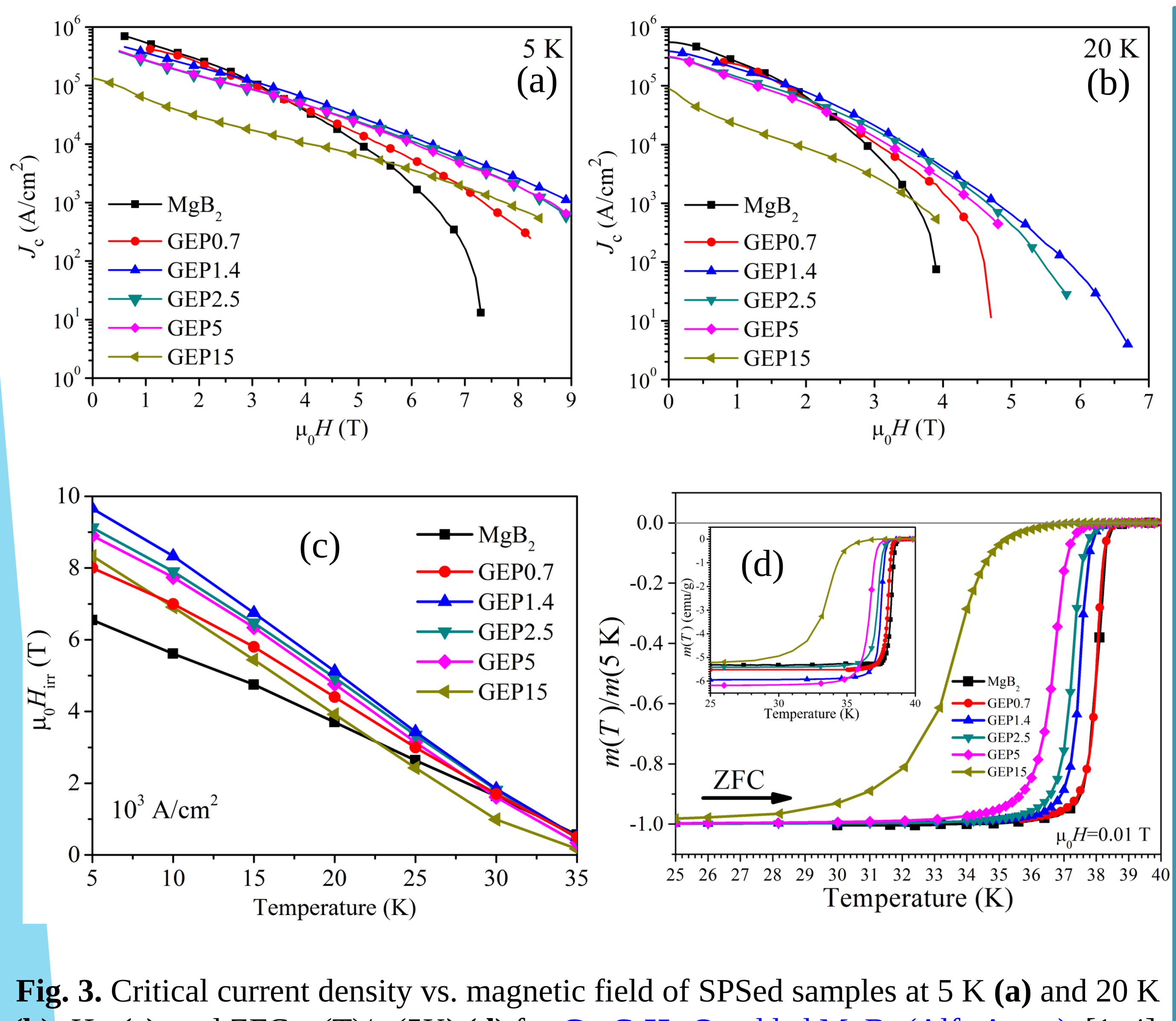

Fig. 3. Critical current density vs. magnetic field of SPSed samples at 5 K **(a)** and 20 K **(b)**, H_{irr} **(c)**, and ZFC *m*(T)/*m*(5K) **(d)** for **$Ge_2C_6H_{10}O_7$** added MgB_2 (Alfa Aesar) [1, 4].

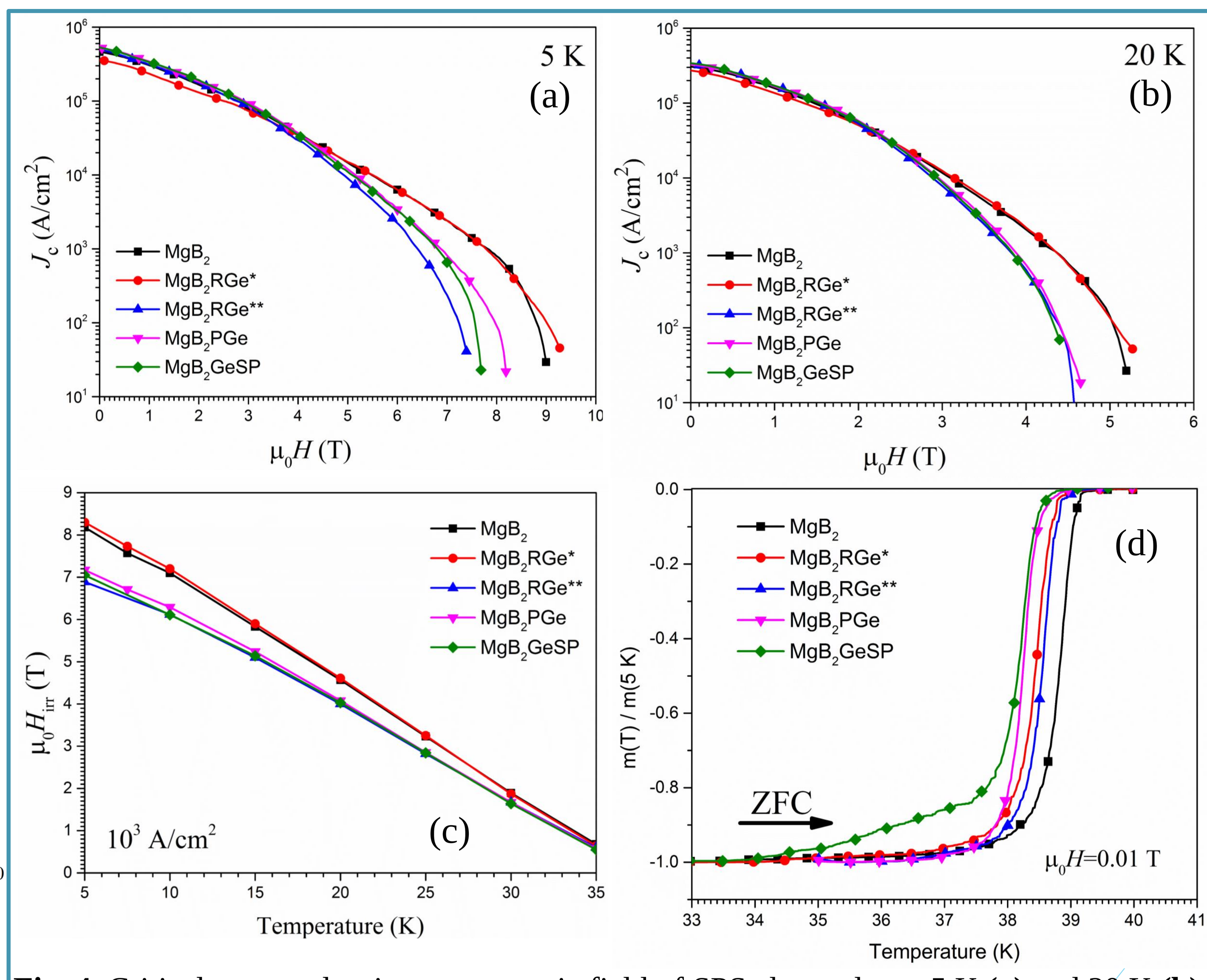

Fig. 4. Critical current density vs. magnetic field of SPSed samples at 5 K **(a)** and 20 K **(b)**, H_{irr} **(c)**, and ZFC *m*(T)/*m*(5K) **(d)** for **OM** added MgB_2 (Pavezyum).

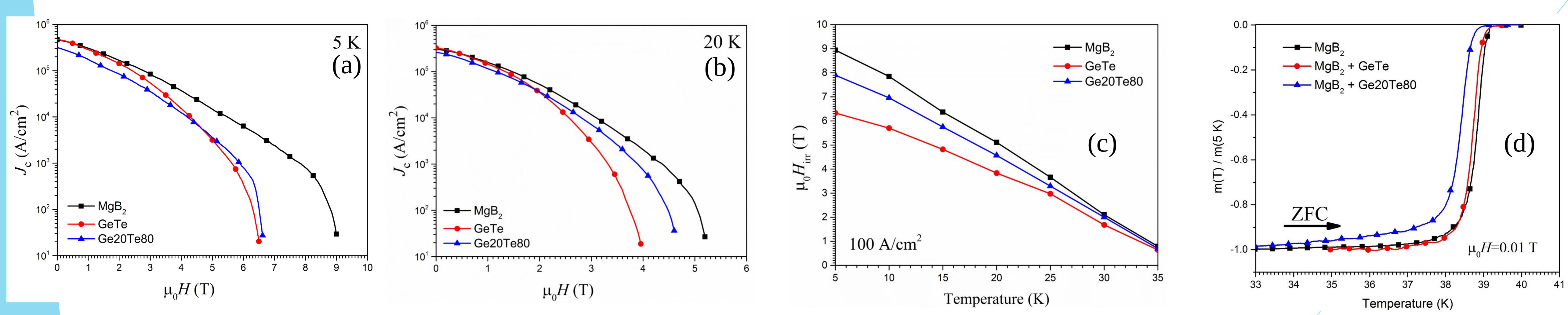

Fig. 5. Critical current density vs. magnetic field of SPSed samples at 5 K **(a)** and 20 K **(b)**, H_{irr} **(c)**, and ZFC *m*(T)/*m*(5K) **(d)** for **GeTe** added MgB_2 (Pavezyum).

C. Conclusions

1. Dense samples of MgB_2, with relative density higher than 91 % were obtained by *ex-situ* SPS using different Ge based additions.

2. The best J_c was obtained for GEP1.4 (Fig. 3. a, b), followed by GEP2.5, $MgB_2Ge_{0.005}$ (Fig. 1. a, b), and $MgB_2(GeO_2)_{0.005}$ (Fig. 2. a, b).

3. The quality of pristine MgB_2 raw powder strongly influences the addition effect. When using two types of MgB_2 powders (produced by different companies), the efficiency of the addition in enhancing Jc can strongly change. In fact the effect of the additive vanishes for a raw MgB_2 powder rich in carbon. Samples made from the C-rich MgB_2 raw powder show enhanced J_c. (Fig. 4, 5. a, b).

4. Considering the observations from 3, on the the influence of GeTe, Ge20Te80, and OM (Fig. 4, 5) we plan fabrication of added samples using a C-free raw powder.

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