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## **VORTEX FLOW IN MgB<sub>2</sub> FILMS IN DEFERENT MAGNETIC FIELD WITH ARTIFICIAL PINNING CENTERS ON THEIR SURFACE**

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### **Introduction**

The superconducting MgB<sub>2</sub> has a high critical current density up to  $j_c=1.6 \times 10^7$  A/cm at 15K [1] what makes it very attractive for technical applications. On the other hand, a broadening of the superconducting transition under applied magnetic, as found in resistivity measurements [2], would severely limit potential applications for MgB<sub>2</sub>. Magnesium diboride exhibits an anomalous magnetic behaviour with dendritic magnetic instabilities for vortex penetration [3] and “noise-like” jumps of the magnetization in an applied magnetic field [4], which should influence the resistive behaviour of this novel superconducting material.

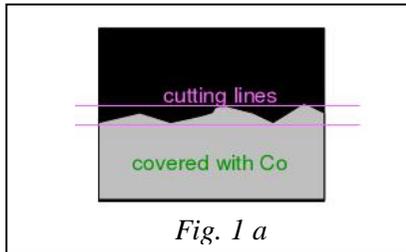
Recent experimentals have demonstrated that the dendritic instability is sensitive to external conditions [5-8]. Indeed it was shown that covering MgB<sub>2</sub> films with a layer of gold or aluminium suppresses the dendrite formation [7] or changes their propagation direction [8]. The embedding in MgB<sub>2</sub> film of a self-organized array of magnetic nanoparticles is expected to be strong stabilizing factor especially in applied magnetic fields matching with average distance between embedded magnetic nanoparticles. We investigated in present work an influence of self-organized array of Co nanoparticles which covered MgB<sub>2</sub> film.

### **Sample preperation and characterization**

The MgB<sub>2</sub> film with a thickness about 500 nm on Sapfire substrate was prepared using “two-step” synthesis technology described in details in [9].

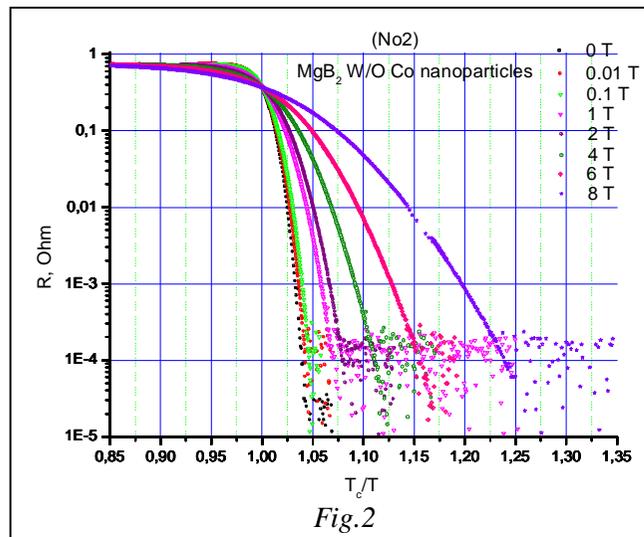
The specimen labeled No2 consisted of the MgB<sub>2</sub> thin film which was to one half of its area covered with Co nanoparticles. Two cuts with a diamond wheel saw

near the boundary of the covered area was performed so that we got two samples (Fig.1 a): first sample without any cover (No 2) , and second one fully covered with Co, (No2Co).



Aluminum wires of 50  $\mu\text{m}$  in diameter were attached to the samples by ultrasonic bonding for four-probe resistance measurements using AC Lock-In-technique. The common electrical current 10-100  $\mu\text{A}$  flown during measurements through both directly connected samples (Fig 1 b). The influence of the value of the current becomes invisible for  $I \leq 60 \mu\text{A}$ . All the presented on Figures 2,3 resistive measurements were performed with  $I = 50 \mu\text{A}$ . We used 'Oxford Instruments' He/He-cryostat and a Dewar containing superconducting solenoid which was "freshly" cooled from room temperature to 4.2 K without applied magnetic providing absence of remanence magnetization. The critical temperature  $T_c$  was determined from the mid-points of the  $R(T)_{B=\text{const}}$  curves.

## Results and discussion



The Figure 2 demonstrates that the uncovered sample (No2) did not show explicit linear dependence of  $\ln(R)$  on  $T_c/T$  at any  $H$  - applied external perpendicular magnetic. The dependencies are smooth, monotonous but without clear linear regions. We consider this fact as a sequence of an inhomogeneity of the sample. The quantitative behavior of  $\ln(R)$  on  $T_c/T$  with varied  $H$  is in good agreement with our work [2].

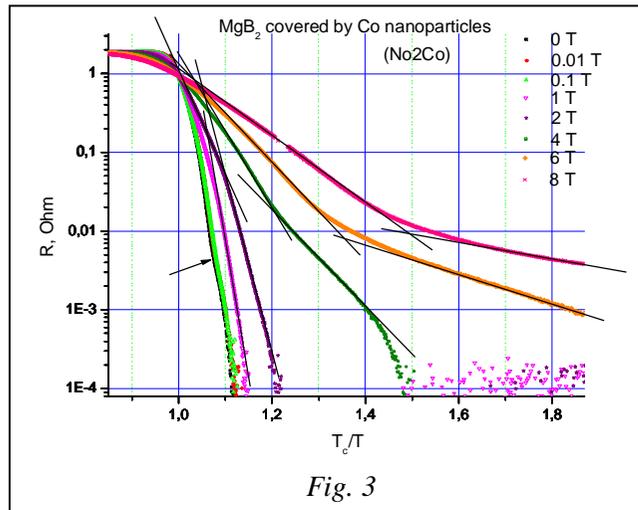


Fig. 3

Figure 3 demonstrates rather different type of dependencies of  $\ln(R)$  on  $T_c/T$  with varied  $H$  of the same sample with embedded Co nano-particles (No2Co). One can conclude that magnetic nano-particles result in magnetic field which led to arising of the bend pointed on by arrow in weak applied magnetic fields  $\leq 0.1$  Tesla and even without applied external magnetic field. The influence of self-organized array of magnetic nano-particles becomes more visible for fields  $\geq 1$  Tesla. The arising and increasing of linear regions of the dependency with magnetic field is the evidence of re-ordering of bundles of vortices in a state with higher homogeneity than in the sample without Co nano-particles. [10] The increasing of the slope for the linear ranges of the curves at 1 T and 2 T with  $T_c/T$  and vanishing of described above concavity is the evidence of enhancement of pinning force due to matching effect between short-distance order parameter of vortices and average distance between self-organized embedded Co nano-particles. With increasing of magnetic field the matching effect vanishes but influence of produced by magnetic nano-particles magnetic field becomes stronger. It led to arising of a linear region with fewer slopes and pinning force. At lowest temperatures occurs one more crossover in type of vortex flow which overrides the mentioned above effect and recovers usual dependence, qualitatively the same as for noncovered by magnetic nano-particles sample in the same range of applied external magnetic field.

To conclude we investigated influence of embedded self-organized array of Co nanoparticles on resistive transitions MgB<sub>2</sub> films. It was found rather strong influence of the nanoparticles in applied magnetic fields  $\geq 1$  Tesla. We believe that arising and increasing of linear regions of the dependency  $\ln(R)$  on  $T/T_c$  with magnetic field is the evidence of stabilizing of bundles of vortexes in a state with higher homogeneity which leads to increasing of pinning force especially in region where exists matching between average distance between vortexes and average distance between embedded self-organized array of Co nanoparticles. The further investigations with other magnetic material nanoparicles and better homogeneity of microstructure.

### Acknowledgments

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Abstract

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