Abstract of Presentation

Self-assembled Nanostructured Superconductors for Energy-efficient Cryomagnetics and **Abnormal Vortex Matter in New Superconductors**

Abstract :

(a) For power applications of superconducting films, the critical current density (J_c) and the thickness of the film (d) should be as high as possible. Jc decreases with both thickness (for films thicker than about 200 nm) and magnetic field, so artificial pinning centres in addition to natural ones are required, especially for high-field applications. The earliest cost-effective method used for introducing artificial pinning centres was the so-called substrate decoration, i.e., growing nanoscale islands (nano-dots) of certain materials on the substrate prior to the deposition of the superconducting thin film [1], used first for Thalium-based films [1-3], then on YBCO [4,5]. Later on other two approaches proved to be successful: bulding up a layered distribution of a second phase using a multilayer deposition (quasi-superlattices) [6], and, respectively, by distribution of a secondary phase as a result of a compositional change in the target [7]. Several materials have been used till now for the creation of artificial pinning centres. Here we report on the artificial pinning centres induced in $YBa_2Cu_3O_7$ (YBCO) thick films by substrate decoration and quasi-superlattices approach using Au, Ag, Pd, $LaNiO_3$, $PrBa_2Cu_3O_7$ and non-superconducting YBCO, on the properties of thick superconducting films grown from a nano-crystalline YBCO target doped with 4 wt.% $BaZrO_3$ (BZO) and of films containing both BZO nano-inclusions and Ag nano-dots. The films were characterized by frequency-dependent AC susceptibility, DC magnetization, field-orientation-dependent transport measurements, XRD, SEM (EDX) and TEM. The effect of film thickness and nano-dots induced pinning centres on the critical current density, pinning force and pinning potential will be discussed.

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(b) The discovery of superconductivity in MgB_2 and, more recently, in iron pnictides, revived the interest in two-component and other exotic superconductors, including in the

Abstract of Presentation

field of vortex matter, as was shown recently by the discovery of "type 1.5" superconductivity [1]. However, even some exotic cuprates grown by high-pressure technique showed interesting anomalies related to the interplay between Josephson and magnetic coupling and/or two-gap superconductivity [2-3]. Here we will present two such examples of exotic vortex matter: magnetically-coupled pancake-vortex molecules in super-multi-layered cuprates, and vortex molecules composed of fractional flux quanta glued by an interband phase difference soliton. It was recently shown that in $HgBa_2Ca_{n-1}Cu_nO_y$ (Hg:12(*n*-1)*n*), vortex melting lines are the same for all Hg:12(*n*-1)*n* phases (n = 6-14). By comparing with melting lines of Hg:1234 and Hg1245, the fact that the addition of an extra CuO_2 Inner Plane (IP) does not change the melting line means that, for n=6 already, the short-range Josephson coupling becomes negligible compared to the (usually weaker) long-range magnetic coupling. In this scenario, there are two types of pancake vortex pairs in the CuO_2 Outer Plane: those separated by the thick block of (n-2) IPs, which are weakly coupled by the magnetic interaction, and, respectively, those separated by the thin $HgBa_2O_x$ charge reservoir layer, which are much stronger coupled by the Josephson coupling. The melting line common to all Hg:12(*n*-1)*n* phases ($n \geq 6$), separates two new vortex phases, pancake-molecule-solid, and pancake-molecule-liquid. Multilayer cuprate superconductors with CuO_2 layers ≥ 3 can also be considered as novel multi-band superconductor. It is theoretically proposed that there is a soliton in a superconductor having two bands, when the inter-band interaction is much smaller than intra-band interaction. The relative phase difference between two components can grow up to 2π and makes a stable soliton. This is the inter-component phase difference soliton (*i* - soliton). Gurevich and Vinokur [3] proposed possible ways to seek the *i*-soliton experimentally. Recently we have observed a lower temperature second peak in the out of phase *ac* magnetic susceptibility of multi-component cuprate superconductors, which we attributed to the dissipation due to rotation of a vortex molecule, composed of fractional vortices due to the two components, glued by an *i*-soliton bond. Basic properties of vortex molecule and *i*-soliton in multilayer cuprates, and their phase diagram will be discussed.

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