Development of Distinction and Excellence at NCKU

Work Report Form for Distinguished Scholars

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<tr>
<th>Name of the Employee</th>
<th>E. V Charnaya</th>
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<td>Period of Employment</td>
<td>from 1999-06-01 to 2000-01-30</td>
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一、研究、教学、科技研發與管理工作全程經過概述。（由受聘人填写）

Please summarize the entire research, teaching, or science and technology R&D and management work process (To be completed by the employee)

1. Introduction

Magnetic instabilities or flux jumps observed in some type-II superconductors are of great interest for applied and fundamental physics and therefore they were extensively studied for more than 40 years (see reviews [1,2]). Flux jumps were first found in metallic low-temperature superconducting materials and later in high-temperature and other unconventional superconductors. The most studied bulk superconductors with magnetic instabilities are the conventional low-temperature superconducting Nb and its alloys (see [1,3-6] and references therein), YBaCuO and some other high-Tc superconductors (see [7,8] and references therein), and MgB2 (see [9,10] and references therein), which have rather low heat capacity and possibility to transport high enough Jc. It is generally assumed that the occurrence of magnetic instabilities is caused by abrupt redistribution of Abrikosov vortices triggered by thermomagnetic fluctuations [4,11]. When type-II superconductors are submitted to an external magnetic field higher than the lower critical field $H_{c1}$, flux-bearing vortices enter inward through the sample borders until they are captured by pinning centers. This process results in inhomogeneous flux distribution over the sample volume. The spatial variation of magnetic field gives rise to supercurrents in the sample which accommodated to be exactly the critical current $J_c$. The achieved self-organized state is called the critical state. Under small perturbations, for instance, local temperature fluctuations, vortices move to adjust a new critical current relevant to the altered temperature. The energy dissipation produced by moving flux lines leads to a local increase in temperature. If the latter is smaller than the initial fluctuation, the critical state remains stable. Otherwise, the positive feedback gives rise to vortex avalanches and pronounced flux jumps. The flux avalanche patterns depend also on the sample geometry (see [12] and references therein). In particular, recent studies of magnetic instabilities in thin superconducting films revealed dendrite and branched fingerlike patterns as well as feather-shaped flux fronts [2,12-15].

The flux jumps in type-II superconductors are often experimentally observed by measuring the magnetization at sweeping external magnetic field $H_e$ [7,8,10,16]. In this case, the initial rise in the local temperature emerges due to small flux changes provoked by increasing or decreasing $H_e$. On hysteresis loops $M(H_e)$ the flux jumps, when they occur, are seen as abrupt decreases in magnetization followed by gradual recovering. Depending on ambient conditions and particular superconductor features, the magnetization jumps can be tiny and hardly recognized or giant. Basic concepts on superconductivity and model theories predict strong dependence of magnetic instability on temperature which agrees with known experimental results [1,4,5,11]. For many superconductors, magnetization jumps can be observed only within some temperature and field ranges in the superconducting state [1,16,17]. A drastic influence of the field sweep rate on magnetization jumps is also expected but only few experimental observations were reported till recently [8,18-21].

Here we present results of experimental observations of magnetic instability variations with the field sweep rate and temperature...
for a lead-porous glass nanocomposite. The flux jumps are detected by magnetization measurements upon sweeping the external magnetic field. At present, composites with nano-size metallic inclusions [22] attract the increased attention because of their perspective technological applications in superconducting and other nanodevices. As far as we know, no studies of magnetic instabilities were carried out for a nanocomposite consisted of lead nanoparticles embedded into porous glass and they were never seen in granular or textured lead while dendrite flux avalanches were observed in thin Pb films [23], small magnetization jumps were reported for a Pb film with a square antidote array [24], and weak flux jumps were found in a lead inverse opal [25].

2. Samples and experiment

The sample of porous glass was made from phase separated soda borosilicate glass with pore structure produced by acid leaching. After acid leaching, an interconnected network of fine pores was formed with an average pore diameter of 7 nm as determined by mercury intrusion porosimetry which also showed that 80% of pore volume corresponded to the size range from 6.8 to 7.4 nm. The volume fraction of pores was about 24%. The liquid lead was embedded into the porous glass under high pressure up to 10 kbar. The filling of the total pore volume near 85% was evaluated by weighing the sample. The specimen for magnetization measurements had the form of a slab with dimensions of 1.4x2.1x3.7 mm. The surface of this specimen was thoroughly cleaned to remove traces of bulk lead.

Magnetic properties were studied using a Quantum Design SQUID (superconducting quantum interference device) magnetometer with a 7-T solenoid in the temperature range 1.7 to 20 K. The temperature during measurements was stabilized within 0.01 K. The zero-field-cooled (ZFC) and field-cooled (FC) magnetizations were measured using the conventional procedure of cooling the sample at zero field till minimal temperature, switching on magnetic field, warming up to 20 K and subsequent cooling at a constant applied field. The hysteresis loops were monitored upon sweeping the external field with sweep rate ranged from 0.25 to 700 Oe/s. The resistance was measured by a four-probe method using a Quantum Design PPMS (physical property measurement system) at zero magnetic field upon cooling.

3. Experimental results

The temperature dependences of the ZFC and FC magnetization obtained for the sample under study at magnetic field 1 Oe and ZFC magnetization at 10 Oe are shown in Fig. 1. The magnetization was calculated without taking into account the demagnetizing factor. The onset of diamagnetism is seen at 7.22 K with near complete diamagnetic shielding at lower temperatures. As can be seen from Fig. 1, the FC magnetization is weak compared to the ZFC magnetization at low temperature. The dependence of resistance on temperature is shown in the inset to Fig.1. The resistive transition is very sharp with the transition temperature quite similar to that in bulk lead (7.19 K [26]).

The magnetization versus field loops obtained at different temperatures upon the same sweep rate 20 Oe/s are shown in Fig.2. Pronounced magnetic instabilities are seen only below 6 K. At 6 K some tiny flux jumps can be still observed but at 6.5 K and above the hysteresis loops do not show any signs of instabilities. Note, that at a temperature of 6.5 K and higher temperatures up to the superconducting transition the hysteresis loops feature the distinct fish-tail shape. Below 5.5 K and till 3 K the magnetization jumps are full or almost near full. The number of magnetization jumps decreases with increasing temperature and they are concentrated closer to the center of the loops. At 5.5 K no jump event is seen on the virgin magnetization curve while a jump is observed in every quadrant for the secondary magnetization. Generally, the M(H) loops in the temperature range from 5.5 to 3 K are rather similar to instability patterns often seen for typical type-II superconductors of different nature [3,7,10,11,16,19,20]. At 2.5 K one can see alterations in the vortex behavior: incomplete and frequent jumps occur at low fields in the central part of the hysteresis loop. This trend develops to lower temperatures leading to a complex loop at 1.8 K.

Magnetization pattern variations with sweep rate were studied here at two temperatures, 1.8 and 5.0 K. Fig.3 shows some examples of the hysteresis loops at 5 K. Magnetic instabilities gradually disappear when the sweep rate decreases from 20 to 1 Oe/s, flux jumps remaining full at any sweep rate. However, the number of magnetization jumps reduces with decreasing sweep rate in a non-monotone way as can be seen from patterns obtained at 10 and 5 Oe/s. At a rate of 1 Oe/s the magnetization versus field loop becomes...
stable and remains unchanged when the sweep rate was equal to 0.5 and 0.25 Oe/s.

The case of the magnetization pattern alterations with increasing the sweep rate at 1.8 K is presented on Fig.4. Starting from a rate of 50 Oe/s some jumps on the higher field parts of the hysteresis loops are getting incomplete and the amplitude of magnetization jumps decreases. Such trends become pronounced at 200 Oe/s. At a rate of 300 Oe/s one can observe only individual incomplete jumps which smeared eventually at higher sweep rates. The hysteresis loop at 700 Oe/s corresponds to the averaged central part of loops at lower sweep rates.

According to Figs.2-4, the magnetic instability patterns in the first and third as well as second and fourth quadrants on the hysteresis loops are quite symmetric in pairs but they are somewhat less symmetric with respect to the field axis. Such binary symmetry was also seen in measurements performed with high temperature superconducting materials [7,9,10,27].

4. References

5. Figure captions
Fig.1. Temperature dependences of the magnetization divided by field. Open symbols show the ZFC magnetization observed at field 1 Oe (circles) and 10 Oe (diamonds), closed symbols show the FC magnetization at 1 Oe. The inset shows the temperature dependence of the
sample resistance at zero field.

Fig.2. Magnetization versus field hysteresis loops at different temperatures obtained at the sweep rate 20 Oe/s.

Fig.3. Magnetization versus field hysteresis loops at 5 K observed at different sweep rates below 20 Oe/s.

Fig.4. Magnetization versus field hysteresis loops at 1.8 K observed at different sweep rates below 20 Oe/s.

Fig.5. Temperature variations of the field $H_f$ of the first full jump on the virgin magnetization at the sweep rate 20 Oe/s (closed symbols). An open symbol shows the field of the first incomplete jump at 2.5 K. The inset shows variations of the field $H_j$ of the first jump on the secondary magnetization with changing the sweep rate SR at 5 K.
Fig. 2.
Fig. 3.
Fig. 4.
二、研究或教學或科技研發與管理成效評估（由計畫主持人或單位主管填寫）
Please evaluate the performance of research, teaching or science and technology R&D and management Work: (To be completed by Project Investigator or Head of Department/Center)

(1)是否達到延攬預期目標？
Has the expected goal of recruitment been achieved?
Yes, Our expected goals of recruitment had been completely achieved.

(2)研究或教學或科技研發與管理的方法、專業知識及進度如何？
What are the methods, professional knowledge, and progress of the research, teaching, or R&D and management work?
The progress of our research was fulfilled as our schedule.

(3)受延攬人之研究或教學或科技研發與管理成果對該計畫(或貴單位)助益如何？
How have the research, teaching, or R&D and management results of the employed person given benefit to the project (or your unit)?
Professor Charnaya massively increased our scientific results.

(4)受延攬人於補助期間對貴單位或國內相關學術科技領域助益如何？
How has the employed person, during his or her term of employment, benefited your unit or the relevant domestic academic field?
Professor Charnaya has benefited our unit a lot by introducing world leading topic to us.

(5)具體工作績效或研究或教學或科技研發與管理成果:
Please describe the specific work performance, or the results of research, teaching, or R&D and management work:
Our results have been published in many leading scientific journals.

(6)是否續聘受聘人？ Will you continue hiring the employed person? □續聘 Yes □不續聘 No

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