Synopsis

Thesis title: *Studies on the dependence of current-voltage characteristics on carrier concentration and granularity in several superconducting systems.*

Name: Tasaul Sk

Supervisor: Prof. Ajay Kumar Ghosh

Department: Department of Physics, Jadavpur University, Kolkata 700032

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Presence of different vortex phases described in the framework of the Berezinskii – Kosterlitz - Thouless (BKT) and Abrikosov (A) affect several properties in different ways and magnitudes in a superconducting system. Vortices generated by thermal fluctuations control both the transport and magnetic properties in superconductors with even strong pinning. Depending on the superconducting system we may control the current-voltage (*IV*) characteristics. We have explored several such superconducting systems in which the vortex phases can be controlled differently. In the present thesis, we have investigated how controlling vortices from two different regions the current-voltage (*IV*) and related features can be altered. We have studied controlling vortices both from the lattice sites and inter-granular sites in superconductors. We have chosen several superconducting systems for having several types of vortices below the critical temperature. In the inter-granular sites compound having magnetic control over the vortices has been chosen. In addition, the usual change in carrier doping level has been used. Superconducting samples with a wide range of pinning strength have been synthesized and characterised. Below we have outlined several specific studies directed towards aforementioned directions relating to the enhancement of critical current density.

We observed that below the critical temperature (T_c) several Ce substituted in lattice sites of $YBa_2Cu_3O_{7-\delta}$ (YBCO) superconductors exhibit nonlinear *IV* characteristics. We have extracted an exponent (η) following the idea of the Berezinskii – Kosterlitz –Thouless (BKT) transition using *IV* over a wide range of temperatures around the critical temperature. The superfluid phase stiffness (SPS) has been extracted within the framework of the Ambegaokar–Halperin–Nelson–Siggia (AHNS) theory. In a combined plot of the SPS and resistivity as a function of *T*, we observe that the superfluid density which is proportional to the SPS varies widely corresponding to the zero resistive states. The shift of the temperature corresponding to the crossing point with the electron doping level has been found to be very strong **[T. Sk, Ajay Kumar Ghosh, AIP Adv. 10 (2020) 065117]**.

The resistive properties of (1) pure YBCO superconductors and (2) composite systems consisting of YBCO and the low-density multiferroic component of

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Y_2CoMnO_6 (YCMO) have been studied. *IV* characteristics of underdoped YBCO superconductors have been studied by adding low-density multiferroic YCMO as an intergranular network. The nonlinear nature of *IV* below the critical temperature has been used to extract η related to the superfluid stiffness. Variations of the exponent with temperature have been studied within the framework of the BKT transition. Within the framework of the AHNS theory, we have discussed controlling the SPS as a function of T in different composite systems. The magnetic nature of the intergranular networks in YBCO strongly influences the SPS. **[T. Sk, Ajay Kumar Ghosh, J. Low Temp. Phys. 198 (2020) 224].**

A highly anisotropic superconducting sample Bi-2212 exhibits pancake vortices in presence of magnetic field. However, at the zero magnetic field the BKT vortices are formed in layers in which Cooper pairs are originated. Nonlinear *IV* characteristics of Bi-2212 observed in the presence of the nonmagnetic impurity have been explained incorporating the idea of the BKT phase transition **[T. Sk, D. Rakshit, Ajay Kumar Ghosh, Phys. Scr. 97 (2022) 025704]**. An exponent (η) is extracted as a function of T for several $Bi_2Sr_2CaCu_{2-x}Zn_xO_{8+\delta}$ (Bi-2212) superconducting samples. Within the framework of the AHNS theory, we have extracted the superfluid phase stiffness (SPS) as a function of T. A scaling between the SPS and critical temperature is observed. Strong suppression by the nonmagnetic impurity has been explained using the idea of localized phase fluctuations in the superconducting planes.

An understanding of the (Abrikosov) vortex phase diagram and how the pinning scenario in superconductors exhibiting nonlinear *IV* at the zero magnetic field (BKT) affects magnetic critical current density is an important direction of research to correlate transport and magnetic properties. We have studied M (H, T) of several representative superconducting systems which show nonlinear *IV*. In addition, nonmagnetic doping in superconducting planes changes the pinning scenario in a complex way. At several T we have studied magnetization (M) as a function of magnetic field (H) in (1) the pure Bi-2212 and (2) the Zn doped ($x = 0.15$) Bi-2212 below respective critical temperatures, T_c using a vibrating sample magnetometer (VSM). An enhancement in $\Delta M(H)$ in Zn-doped Bi-2212 has been observed. Based on the criterion, ΔM = constant the *HT* diagram is found. Shifting in the irreversibility line (IL) has also been investigated. An enormous enhancement of magnetic critical current density (J_{cm}) in the Zn-doped Bi-2212 superconductor is observed. We have analysed $J_{cm}(H)$ to understand the microscopic nature of vortex pinning. A possible crossover from the collective pinning regime at lower magnetic field to a single vortex pinning with the increase in H at several T is observed in both samples having almost similar granular nature. Pinning of pancake vortices is strongly affected by the localised magnetic moment induced by nonmagnetic Zn in Cu sites. Change in the pinning force density in doped Bi-2212 has been explained **[T. Sk, P. Mandal, D. Rakshit, Ajay Kumar Ghosh, Physica C 603 (2022) 1354152].**

Ajay Kumar Ghosh
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Professor (Dr.) Ajay Kumar Ghosh
Department of Physics
Jadavpur University
Kolkata - 700032

Tapaul SK
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