PCP1-1

Spatiotemporal Dynamics of Driven Josephson Junction Networks

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Spatiotemporal dynamics of phases in Josephson junction networks (JJNs) is studied using a computer simulation based on a phase model which is related to the resistively shunted junction model. We consider JJNs which consist of a two-dimensional array of superconducting grains where each pair of the nearest-neighbor sites is connected by a Josephson junction. The JJNs are driven by external currents with spatiotemporal modulation. We investigate the current-voltage characteristics of the driven JJNs for some types of the spatiotemporal modulation of external currents. The dynamics of JJNs shows complicated behaviors in the current-voltage characteristics. There exist a sort of collective phenomena in the dynamics of JJNs under certain conditions on some controllable parameters of the present system. The collective dynamics is affected significantly by the spatiotemporal modulation of external currents. We clarify the novel collective effects on the dynamics of JJNs.

Keywords: Josephson Junction Network

PCP1-2

Vortex lattice melting transition : Effects of artificial nanorods

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It is known that vortices in a mesoscopic superconductor show peculiar structures, which depend on the shape of the superconductor. Ooi et al [1] found that melting transition temperatures of vortex lattices in a square superconducting plate become maximum when the vortex number is a square number. Then using the molecular dynamics method (MD), Kato and Kitago [2] investigated the vortex lattice melting transition in a pure superconductor. They showed standard deviation of vortex position increases rapidly with increasing temperature.

We investigated this melting of vortex lattice in a dirty square mesoscopic superconductor, using MD. We found when the vortex number is a multiple of 4, the vortex lattice becomes rather stable. [Fig.1:The standard deviations of 4 to 101 vortices in the square superconductin plate including 100 impurities as a function of the number of vortices.] So we consider other shape superconductors because of stable vortex state in the superconducting plate.
It is known that the superconducting properties are improved by adding nanorods to superconductor [3]. We investigate the melting transition of the vortex lattice in a square superconductor with nanorods, or nanorods array.

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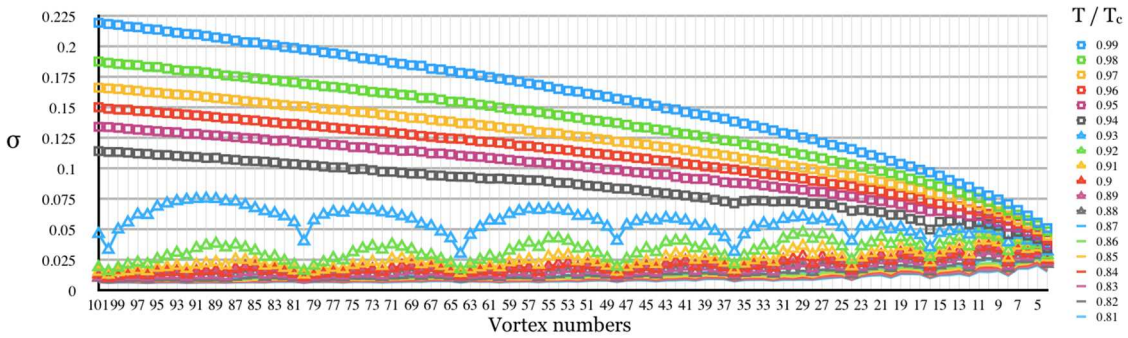

PCP1-3

Peculiar vortex states in mesoscopic superconductors with antidots

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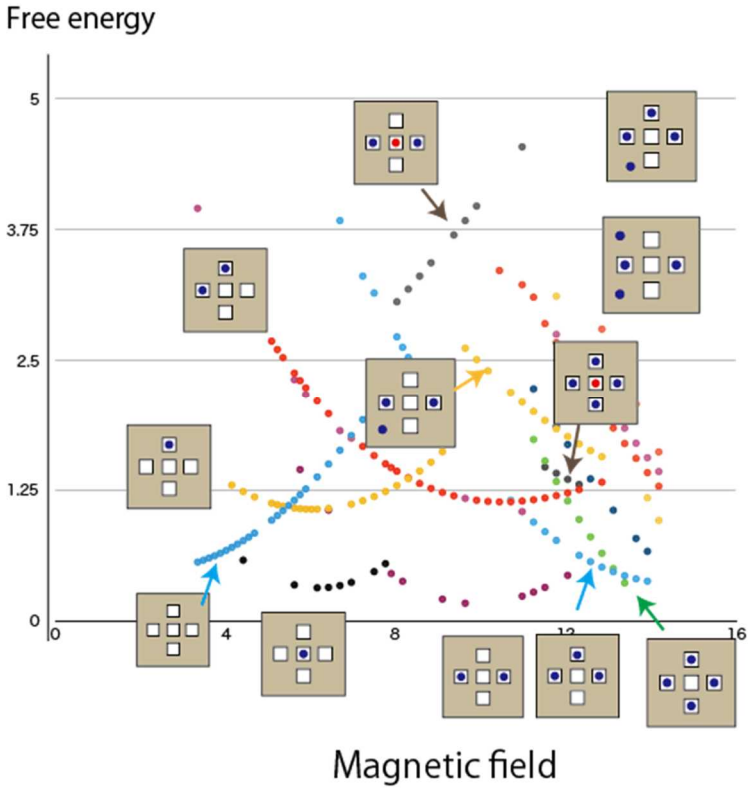
The vortex configurations in a mesoscopic superconducting square plate with antidots under uniform magnetic fields are obtained by solving the Ginzburg-Landau(GL) equation using the finite element method(FEM). In this study, dimensions of the samples are $30\xi_0 \times 30\xi_0$, where ξ_0 is the coherence length at zero temperature, and the Ginzburg Landau parameter and temperature set to $\kappa=10$ and $T=0.8Tc$ where Tc is the superconducting transition temperature. The sample has 5 antidots, one is located at the center of the sample, and the other four antidots are located away from the center point in the directions parallel to the four sides of the square sample. Generally, the GL equation has not only the most stable state solution but also metastable state solutions. In the most stable states in each magnetic field, the number of vortices that pass through the sample n increases monotonically as increasing the field H. The most stable states where $n=3$ is realized in very narrow field region, this is because the sample has four-fold rotational symmetry. It is predicted theoretically anti-vortex can appears in the most stable state near below transition temperature from the discussion of the symmetry. We found metastable states where anti-vortex appears in a certain magnetic field region even in rather low temperature condition.



Keywords: Ginzburg-Landau equation, mesoscopic superconductor, antidot, anti-vortex

PCP1-4

Structures of vortices in a superconductor under spatially varying fields

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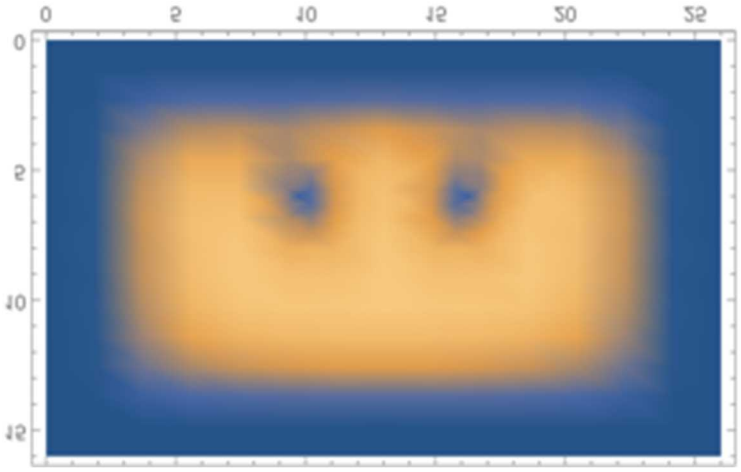
We study behavior of vortices in a type II superconductor under spatially varying fields. Because in application of superconductors, such as an electromagnet, spatially varying fields appear. In previous study, we found directions of vortices are not parallel to the field in a chiral helimagnet /superconductor bilayer structure [1,2]. The origin of this behavior may come from interaction between vortices or screening current at edges of the superconductor.
In this study, we investigate structures of vortices in a superconductor under spatially varying fields by solving the Ginzburg-Landau equation, in order to clarify the origin of previous results. First, we obtain structures of vortices under a constant field tilted π/4 from z-axis to investigate influences of edge currents [Fig.1]. In this case, vortices are parallel to the field, therefore, edges of the superconductor do not affect the vortex structures. We conclude previous results may come from interaction between two vortices that are not parallel. We will show structures of vortices under various fields.



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Keywords: Vortex, Ginzburg-Landau Equation, Vortex-votex interaction, Finite Element Method

PCP1-5

Transition temperature in a dirty mesoscopic superconductor: Transition from localized superconductivity to extended superconductivity

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Transition temperature (Tc) of a mesoscopic superconductor is enhanced [1]. This is because superconducting electrons are confined in a small space, an effective density of states is enhanced. This phenomenon is clearly appeared as gigantic enhancement of Tc in a dirty nano-size superconductor. (Fig.1) In this case, superconducting electrons are localized in a small region, and effective density of states is enhanced [2]. (Fig.2)

However, just below this transition temperature, superconductivity remains localized. If we defined true Tc as the temperature when zero resistivity occurs, true Tc is lower than the enhanced Tc. In order to find this true Tc, we must solve the full Bogoliubov-de Gennes (BdG) equations, instead of the linearized BdG equations [2].

In this study, we investigate how localized superconductivity in a dirty mesoscopic superconductor extend to whole superconductor, with decreasing the temperature. Also, we investigate how Tc depends on the size and structure of the superconductor.

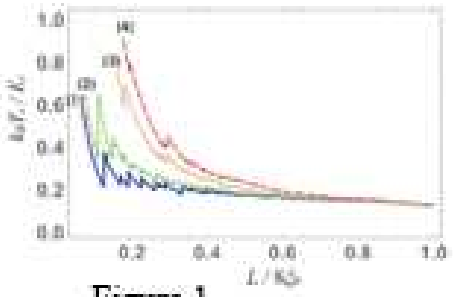

Figure 1

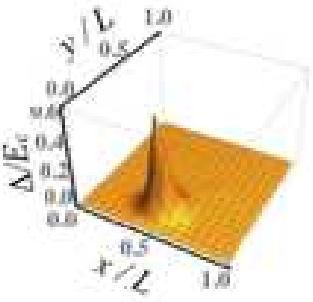

Figure 2

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Keywords: Transition temperature, Dirty mesoscopic superconductor, Bogoliubov-de Gennes equations, Localization

PCP1-6

Magneto-optical imaging of field profile on niobium surface with microstructures of niobium hydrides and a single grain boundary

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Improvement of the quality factor (Q-factor) of superconducting radio-frequency (SRF) cavities, usually made from Nb, for the acceleration of charged particles is desired practically, because the energy consumption by the dissipation in SRF cavities leads to the increase of the cooling cost. Since the dissipation by a motion of vortex (quantized magnetic flux) cause a residual surface resistance even at very low temperatures (~ 2 K), removal of vortices from a SRF cavity may make Q-factor better. However, there remain small amount of vortices even in the cooling with a magnetic shield, because the expulsion of vortices from superconducting Nb is not perfect due to unintended pinning. Therefore, exploration of the origins of the pinning is important. To study what kind of defects or microstructures influence on the pinning of vortices, we have observed magnetic-field profiles by a magneto-optical imaging technique on a Nb surface with microstructures, formed by the precipitation of niobium hydrides during a cooling into cryogenic temperatures, and with a single grain boundary. In the presentation, experimental results indicating that the grain boundary works as a guide for the vortex motion in some conditions and the surface microstructures trap vortices considerably.

Keywords: vortex, Niobium, Grain boundary, Magneto-optical imaging

PCP1-7

Reversible-Irreversible Transition Induced by Increased Shear Amplitude and Vortex Density

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When a periodic ac shear is applied to many-particle assemblies with disordered configuration, the particles gradually self-organize to avoid future collisions and transform into an organized configuration. For a small shear amplitude d, the particles finally settle into a reversible state where all the particles return to their initial position after each shear cycle, while they reach an irreversible state for d larger than a threshold amplitude d_c [1]. Using periodically sheared vortices in amorphous Mo_xGe_{1-x} films with random pinning, we have studied the critical behavior of the reversible-to-irreversible transition (RIT). From the time-dependent voltage generated by vortex motion, we have observed organization of vortex configuration called random organization [2,3]. The relaxation time for the system to reach the steady state, plotted against d, shows a power-law divergence at the threshold amplitude d_c, indicative of a nonequilibrium RIT. The critical exponent is in agreement with the value expected for an absorbing phase transition in the two-dimensional directed-percolation universality class [4,5]. In our previous experiments, RIT was induced by increasing d at a fixed vortex density n, that is, at a fixed magnetic field B. This situation is qualitatively equivalent or similar to the one where n (i.e., B) is increased at fixed d. However, it is not evident whether the same critical behavior of RIT is observed irrespective of the parameters (d or n [6]) used in the experiment. This is an important issue in examining the universality of RIT. We will present the data in favor of the notion.

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Keywords: Vortex, Nonequilibrium phenomenon

PCP1-9

Observation of Flux States and Vortex Penetration in Perforated Square Loops of Superconducting Amorphous MoGe Films

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We report the magnetic visualizations of flux states in perforated square loops of superconducting amorphous MoGe films cooled in magnetic fields. Scanning superconducting quantum interference device microscopy measurements clearly revealed how the magnetic field is distributed in the loops at different magnetic fields. We found various flux states with different configurations, including vortices trapped in between holes and/or sample edges. Counting the number of trapped vortices for each image, we found that the vortices are completely excluded from the loop when the applied field is below a threshold field. We also found that the threshold field depends not only on the sample size, but also the arrangements of holes. These findings are useful for trapping or eliminating vortices in square loops, which can be crucial elements for designing various devices for quantum information processing, memory, and metrology.

Keywords: Mesoscopic superconductors, Flux States, Scanning SQUID microscope

PCP1-10

Vortex penetration and expulsion in $NbSe_2$ mesoscopic superconductors detected by small tunnel junction method

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University of Tsukuba[1]

By using the mechanical exfoliation method developed in the graphene research, one can obtain exfoliated films with atomically flat and defect-free surfaces. Such high uniformity is advantageous for researches of physical phenomena that are easily hindered by defects or surface roughness. Here, we use exfoliated films of a layered superconductor to investigate vortices in mesoscopic superconductors.
To electrically detect vortex penetration, expulsion, and positional change in a mesoscopic superconductor, we attached a superconductor/insulator/normal metal (SIN) junction to the superconductor (small tunnel junction method). In this structure, the junction voltage under a small current is sensitive to the supercurrent underneath the junction, which is changed by the behavior of vortices. In this study, $NbSe_2$ is used as the layered superconductor, a cleaved film of MoS_2 is used as the tunnel barrier, and Cr/Au electrodes are used as the normal metal. In the sample fabrication, we first formed a stacked structure $NbSe_2/MoS_2$, and then a Cr/Au electrode was connected to the stacked structure to form a tunnel junction with area of about 1 mm^2, and a current lead was directly connected to the $NbSe_2$ flake. Finally, the sample was etched into a rectangular shape with size of ~ 4 mm^2 by reactive ion etching.
In the magnetic field dependence of the voltage of the SIN junction under a constant small biasing current, for small and increasing magnetic fields, almost periodic voltage jumps were observed, corresponding to one-by-one single vortex penetration. On the other hand, highly irregular voltage jumps were observed in other magnetic field regions. In the presentation, we will discuss these experimental results and their interpretation in detail.

Keywords: Vortex, NbSe2