行政院國家科學委員會專題研究計畫成果報告

國科會專題計畫成果報告撰寫格式說明

NSC Project Reports

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一、中文摘要

這項研究計劃包含三個主題:

1. "Dusty plasma"的相圖
2. 在 d, p wave 超導體中的 Ginzburg - Landau approach.
3. 高溫超導體中的 Abrikosov 晶格的溶化.

對第一,二個主題來講,所有重要的目的都被解決了，但是第三個子題,我只得到的部份結果和 negative 結果。第一,二個題目的結果已在下面所列的兩篇文章發表。我正在撰寫研究結果且計畫繼續研究晶格的融化。

Abstract

My proposal includes two projects:

1. Phase diagram of “dusty plasma”.
2. Ginzburg - Landau approach in d, p wave superconductors.
3. Abrikosov lattice melting in high Tc superconductors.

While all the goals of the first two parts were completely achieved, only negative and partial results were obtained as far as the third project is concerned. The results of the first two part were published in four papers cited below. I continue to study melting in my following proposal and only now am writing the first paper.

Keywords: dusty plasma, phase diagram, p,d wave, superconductors, melting.

二、緣由與目的

1. Phase diagram of dusty plasma.

In series of recent experiments regular lattices of charged "dust" particles (of about mikron size) have been observed. Although the system is thought to be similar to the Wigner crystal, various lattice structures different from the closely packed bcc (body centered cubic) and fcc (face centered cubic) typical to Wigner crystals have been clearly identified. I and my collaborator: Prof. H.C. Lee (Nat. Central University) used mean field approximation, Lindemann criterium and numerical calculation of lattice sums to map the phase diagram and the excitations (phonon) spectrum.

2. Ginzburg - Landau equations approach in nonconventional d and p wave superconductors.

Although the precise microscopic mechanism behind high Tc superconductivity is not known as yet, it became evident in view of several clean experiments, that the pairing mechanism should be of the d wave type with an admixture of s - wave coupling. This is different from the conventional superconductors (metals, alloys,…) in which it is purely s - wave. This view is supported by most successful microscopic models like t-J model or similar in which the d - wave pairing appears naturally. It is well known that these strongly coupled models are notoriously difficult to use. One therefore resorts to a well tested phenomenological technique: effective Ginzburg - Landau type theories. They are especially useful in cases of in homogeneities in space or time, as it is in the Abrikosov vortex case. One variant of such a theory for the d - a mixed superconductors was made last year by two groups, C. S.Ting et al and Berlinsky et al. They used two complex fields to describe different components. They obtained mostly numerically the one vortex solution and lattice close to the upper critical field. Independently, there has been growing interest in the p wave pairing in superconductors. It is well established by now that p pairing occurs in superfluid He3 and most probably in some so called “heavy fermion” superconductors like Upt3. Recently clear indications were reported on p wave pairing in UPt3 newly discovered superconductor Sr2RuO4. The order parameter in this case is a vector in spin space. It has an aditional spin coupling to magnetic field. This makes the phase diagram very unusual. In particular the usual Meissner phase disappears, one gets great variety of nonequal ground states. The phase diagram hasn’t been studied yet in detail. Objectives were: 1. To formulate one component effective Ginzburg - Landau theory for d wave superconductors and study its vortex and lattice solutions. 2. Using this calculate the nonlinear transport properties of the d wave superconductors using time dependent GL equations. 3. To determine the phase diagram of the p wave superconductor. 4. To determine the universality class of the superconducting phase transition.

3. Abrikosov lattice melting in high Tc superconductors.

The most remarkable characteristics of the type II superconductors are Abrikosov vortices. They form a lattice phase separating the Meissner phase and the normal phase. The transition between the mixed (lattice) phase and normal neglecting fluctuations is second order. These predictions were fully tested on old low Tc superconductors. Theoretically for them fluctuations are not important. The Ginzburg parameter indicating the importance of fluctuations does not exceed 10^-6. The fluctuation region around Tc for which fluctuations are important is immeasurably narrow. The situation changes dramatically for high Tc cuprates. As a result of large Ginzburg-Landau parameter and large anisotropy the Ginzburg number is about 1/100 and fluctuations become sizable on large portions of the phase diagram. Fluctuations drive melting to weakly first order ones. For vortex lattice it was conjectured that this take place too and lattice melts into vortex liquid. I was supposed to develop analytical methods to describe the melting.

三、研究報告應含的內容

1. Phase diagram of “dusty plasma”.

The results are comprehensibly described in two recently published papers [1] and [2].

2. Phase diagram of “dusty plasma”.

The results for d wave superconductors are comprehensibly described in two recently published papers [3] and [4] and number of communications in proceedings.
The p-wave project is also finished with reports in [5] and [6]. The later contains an unexpected discovery of Skyrmions in UPt3. I write now

with my student Y.Y. Chen an expanded version of the PRL letter.

3. Abrikosov lattice melting in high Tc superconductors

I finally developed a reliable calculational scheme which is described in a recent prepring "First principles calculation of fluctuation contribution in vortex solids and liquids (on the net, submitted to PRL) . The subject however is not closed and carries over in expanded version into the new NSC project.

五、參考文獻

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