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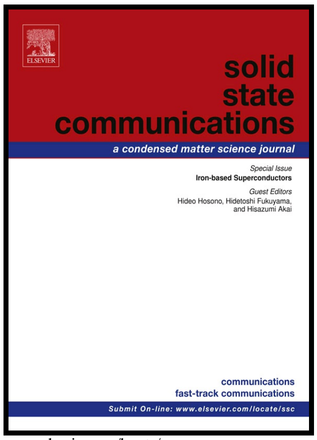

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Antiferromagnetic Phase Diagram of the Cuprate Superconductors

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Abstract

Taking the spin-fermion model as the starting point for describing the cuprate superconductors, we obtain an effective nonlinear sigma-field hamiltonian, which takes into account the effect of doping in the system. We obtain an expression for the spin-wave velocity as a function of the chemical potential. For appropriate values of the parameters we determine the antiferromagnetic phase diagram for the $YBa_2Cu_3O_{6+x}$ compound as a function of the dopant concentration in good agreement with the experimental data. Furthermore, our approach provides a unified description for the phase diagrams of the hole-doped and the electron doped compounds, which is consistent with the remarkable similarity between the phase diagrams of these compounds, since we have obtained the suppression of the antiferromagnetic phase as the modulus of the chemical potential increases. The aforementioned result then follows by considering positive values of the chemical potential related to the addition of holes to the system, while negative values correspond to the addition of electrons.

Keywords: high-Tc superconductors, phase transitions
PACS: 74.72.-h, 74.20.-z, 74.62.-c,, 74.62.Dh

1. Introduction

Cuprates are puzzling materials; the undoped parent compounds are Mott insulators presenting an antiferromagnetic (AF) arrangement at a finite Néel temperature. As the system is doped, either with electron acceptors or donors, which, in any case would simply mean an increase of the amount of charge carriers to the system, it develops high-temperature superconductivity. The superconducting (SC) critical temperature presents a characteristic dome-shaped dependence on dopant concentration, reaching a maximum value at an optimal doping and vanishing as the system is doped even further, becoming a normal metal. So far, there is no consensus regarding the microscopic mechanism which is responsible for the appearance of superconductivity in those systems. However, it is widely accepted that some sort of AF spin fluctuations are the interaction responsible for the Cooper pairs formation.

Recently, starting from a spin-fermion model, which has been employed previously to describe the cuprate superconductors [1] we have derived an effective model for the charge carriers [2] and the superconductivity in our model arises from a novel mechanism, that yields a high critical temperature which is comparable to the experimental values. Moreover, by including doping effects a dome-shaped dependence of the critical temperature is found as charge carriers are added to the system, in agreement with the experimental phase diagram [3]. Presently instead of focusing on the SC phase, we investigate the magnetic order, by calculating the doping dependence of the Néel temperature, which is calculated providing the AF phase diagram that can be compared with experimental results. As shall be seen below, our results are in good agreement with the data for the $YBa_2Cu_3O_{6+x}$ (YBCO) system [4, 5]. This calculation is an alternative to the one performed before [6], which was based on the fact that a skyrmion topological excitation is created in association to a doped charge, being actually attached to it.

Our approach provides a unified description for the phase diagrams of the hole-doped and the electron doped compounds, which is consistent with the experimental results [7]. As the dopant concentration increases, a dome-shaped SC phase appears adjacent to the AF order, both for electron-doped and hole-doped cuprate compounds as well. Our calculations present

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