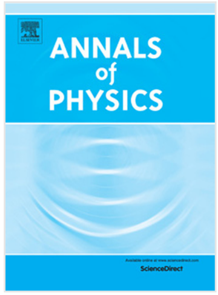
Accepted Manuscript



Ferromagnetic clusters induced by a nonmagnetic random disorder in diluted magnetic semiconductors

Dinh-Hoi Bui, Van-Nham Phan

PII: S0003-4916(16)30205-6
DOI: http://dx.doi.org/10.1016/j.aop.2016.10.004
Reference: YAPHY 67222

To appear in: *Annals of Physics*

Received date: 27 April 2016
Accepted date: 2 October 2016

Please cite this article as: D.-H. Bui, V.-N. Phan, Ferromagnetic clusters induced by a nonmagnetic random disorder in diluted magnetic semiconductors, *Annals of Physics* (2016), http://dx.doi.org/10.1016/j.aop.2016.10.004

Ferromagnetic clusters induced by a nonmagnetic random disorder in diluted magnetic semiconductors

Dinh-Hoi Bui[1,2] and Van-Nham Phan[1]

[1] *Institute of Research and Development, Duy Tan University, K7/25 Quang Trung, Danang, Vietnam*
[2] *Physics Department, Hue University's college of Education, 34 Le Loi, Hue, Vietnam*

Abstract

In this work, we analyze the nonmagnetic random disorder leading to a formation of ferromagnetic clusters in diluted magnetic semiconductors. The nonmagnetic random disorder arises from randomness in the host lattice. Including the disorder to the Kondo lattice model with random distribution of magnetic dopants, the ferromagnetic-paramagnetic transition in the system is investigated in the framework of dynamical mean-field theory. At a certain low temperature one finds a fraction of ferromagnetic sites transiting to the paramagnetic state. Enlarging the nonmagnetic random disorder strength, the paramagnetic regimes expand resulting a formation of the ferromagnetic clusters.

Keywords: Ferromagnetic-paramagnetic transition, diluted magnetic semiconductors, Dynamical mean field theory
PACS: 71.27.+a, 75.20.-g, 75.50.Pp, 85.75.-d

1. Introduction

Recently, the magnetic properties affected by disorders in diluted magnetic semiconductors (DMSs) have attracted much attention because of their importance to applications of DMSs in spintronics [1, 2]. In DMSs, magnetic ions are lightly doped into a semiconducting host. They play dual roles of both an acceptor and localized magnetic moment due to their partially filled *d*-shell [3]. At low temperature, DMSs have been found to be ferromagnetic (FM) [4, 5]. In DMSs, the FM state is a long ranged ordering of randomly distributed magnetic impurity moments. The local spin exchange between the magnetic ions and the holes (main carriers) is the essential ingredient of the magnetic properties of DMSs [5, 6]. At low temperature, this exchange coupling produces a long-range effective ferromagnetic interaction between the impurity local moments [7]. However, due to the doping, disorders are non-neglectable in DMSs [7, 8, 9, 10]. In contrast to the local exchange coupling, disorder always suppresses their ferromagnetic-paramagnetic (FM-PM) transition temperature [7]. In DMSs like in magnetic doping systems, magnetic disorder naturally arises from the random magnetic dopants [11, 12, 13]. Moreover, because of a heavy compensation, other kind of disorder so called nonmagnetic random disorder must be important in DMSs. For example, due to doping (e.g., Mn^{2+} in the semiconducting host $Ga_{1-x}Mn_xAs$) the radius of the anti-site (As) is varied and as a consequence defects might form a nonmagnetic randomness disorder of the host lattice sites. The nonmagnetic disorder generally reduces the hopping of the carriers therefore might play a significant role influencing the magnetic properties of the systems. In studying the magnetic properties of DMSs, this kind of disorder is often left out (see Ref [5] and Refs there in). Our present work therefore is devoted to examine the influence of the nonmagnetic disorder to the magnetic properties, in particular, the FM clustered formation in DMSs.

The FM clustered formation in DMSs generally is explained by the polaron percolation theory in which localized holes produce magnetic clusters of bound magnetic polarons [7]. Decreasing the temperature enlarges the polaron size. If the temperature is smaller than a critical value, the magnetic clusters overlap then the system stabilizes in the FM state. In the polaron percolation theory, the disorder is modeled by the mean inter-impurity separation [7, 14]. In their experiment, Guo and coworkers have made manifest the percolative magnetic transition [15]. Due to disorders (arising by doping), the authors observed a coexistence of the nonmagnetic ground state and the magnetic ordered state that leads to the FM clustered formation in the itinerant magnetic semiconductors. In our study, we explicitly consider the FM clustered formation in DMSs induced by the nonmagnetic random disorder. The nonmagnetic random disorder is modeled by a random variable indicating the randomness potential of the host lattice (e.g. As anti-site defects) [5]. It differs from site to site, directly effecting the conduction band [16]. The nonmagnetic random disorder is thereby included in the Kondo lattice model containing random distribution of magnetic dopants. The latter has been successfully investigated in the framework of dynamical mean-field theory (DMFT) to study the spin dynamics in DMSs [11]. DMFT has been extensively used for investigating strongly correlated electron systems [17]. It is based on the fact that the self-energy depends only on frequency in the infinite dimensional limit. In the presence of the nonmagnetic random disorder, we extend the DMFT to the disordered one, so called DMFT with disorder [16, 18, 19]. The DMFT with disorder approach has been applied to the disordered Kondo model to interpret the competi-