TRICRITICAL POINT MODIFICATIONS BY MAGNETIC IMPURITIES IN AN ITINERANT ELECTRON SDW SYSTEM

M. Antonoff

To cite this version:
M. Antonoff. TRICRITICAL POINT MODIFICATIONS BY MAGNETIC IMPURITIES IN AN ITINERANT ELECTRON SDW SYSTEM. Journal de Physique Colloques, 1988, 49 (C8), pp.C8-85-C8-86. <10.1051/jphyscol:1988829>. <jpa-00228461>

HAL Id: jpa-00228461
https://hal.archives-ouvertes.fr/jpa-00228461

Submitted on 1 Jan 1988

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
TRICRITICAL POINT MODIFICATIONS BY MAGNETIC IMPURITIES IN AN ITINERANT ELECTRON SDW SYSTEM

M. M. Antonoff

Department of Physics, University of Massachusetts at Boston, Boston, Massachusetts 02125, U.S.A.

Abstract. – The polarization of magnetic impurities by a spin-density-wave tends to stabilize the commensurate SDW phase and to modify the coordinates of the tricritical point. A numerical calculation has been performed to obtain the impurity concentration dependence of the tricritical point coordinates and the associated discontinuity in the SDW wave-vector.

1. Introduction

It has previously been shown that polarizable magnetic impurities affect the Néel temperature [1, 2] and furthermore can induce a first-order phase transition on the boundary between the commensurate (C) and the incommensurate (I) phases [3, 4]. The first-order transition is associated with a discontinuity in the wave-vector at the C-I boundary which includes the tricritical point, the point at which the phases meet and which we designate by \((H^*, T^*)\). The phase diagram of the system is shown in figure 1. \(H^*\) is the critical value of the imperfect nesting parameter \(H\). In this paper we present the results of a numerical calculation to determine the coordinates of the tricritical point and the wave-vector discontinuity as functions of the concentration of polarizable magnetic impurities.

The fundamental physical concept is that magnetic impurities, polarized by the effective magnetic field of the SDW, lead to an increase in the transition temperature of the SDW state since the free energy of the system is lowered by the alignment of impurity magnetic moments. The commensurate phase is favored in this situation since the SDW peaks coincide with lattice sites in the C-phase. In the I-phase, the coincidence of the SDW peaks and the lattice sites is destroyed so that randomly distributed impurities will experience various phases of SDW. The result is that the average interaction between magnetic impurities and the SDW has a singularity at \(q = 0\). The C-I boundary, determined by the equality of the free energies of the C and I phases, will be shifted towards larger values of \(H\), reflecting the increase in stability of the C-phase. In addition, a discontinuity in the SDW wave-vector will appear along the boundary.

2. Mathematical formulation

A mathematical formulation of the problem was made previously [1-3] using a matrix Green's function approach to obtain a self-consistent expression for the SDW order parameter. Assuming that the transitions from the paramagnetic state into both the CSDW and the ISDW to be second-order, expressions were obtained for \(T_C(H)\) and \(T_I(H)\), the transition temperatures for the C and I phases, respectively. The tricritical point is determined by equating the transition temperatures. Using the octahedral band model proposed by Shibatani, Motizuki and Nagamiya [4], the following equation is obtained for the Néel temperature of a second-order phase transition:

\[
\ln \left( \frac{T_N}{T_{00}} \right) = \frac{\lambda n/N(0) V}{\lambda n + T_N} + \text{Re} \sum_{n=0}^{\infty} \left\{ \frac{x_n}{\lambda_n^2 - \rho x_n/6 + \zeta^2} - \frac{1}{n + 1/2} \right\}
\]

(1)

where \(n\) is an integer, Re denotes the real part of the sum and

\[
\rho = \gamma/2\pi T_N, \quad \zeta = H/2\pi T_N, \quad \xi = q^*/4\pi T_N,
\]

\[
x_n = n + 1/2 + \rho/2 + i\zeta.
\]

(2)
The factor \( \lambda \eta \) is proportional to the impurity polarization by the SDW, with \( \eta = 1, 1/2 \) for the C, I phases. \( N(0) \) is the density of states at the Fermi surface, \( V \) is the exchange interaction between conduction electrons, \( \gamma \) is the band width of collisional broadening of band states by magnetic impurities, \( q \) is the SDW wave-vector (measured from one-half a reciprocal lattice vector) and \( v \) is the Fermi velocity. \( T_0 \) is the value of \( T_N \) for the special case of perfect nesting \( (H = 0) \) and impurity concentration \( C = 0 \).

For \( H > H^* \), equation (1) must be solved simultaneously with the equation which determines the maximum of \( T_1(q, H) \) with respect to the wavevector \( q \). The equation for this condition is

\[
\sum_{n=0}^{\infty} \text{Re} \left\{ \frac{\lambda_n}{[\chi_n^2 - \rho \chi_n/6 + \xi_0^2]} \right\} = 0. \quad (3)
\]

3. Results and conclusions

We have obtained numerical results for the critical point coordinates and the discontinuity in the wave-vector as functions of magnetic impurity concentration by solving equations (1) and (3) simultaneously. The values \( \eta = 1, 1/2 \) were selected for scaling the average interaction energies of the magnetic impurities with the CSDW and ISDW, respectively. The results are shown in figure 2 where \( \lambda_0 \) is proportional to the magnetic impurity concentration. The figure displays two sets of solutions for the normalized critical temperature \( t^* = t_N/T_00 \), critical value of \( \zeta_0^* = H^*/2\pi T_00 \) and the discontinuity in the wave-vector at the critical point \( \xi_0^* = q^* v/4\pi T_00 \).

The solutions in figure 2 correspond to values of \( K = 0.2 \) and 0.5 where \( K = 2\pi (JS)^2 / 6V_0 \), and \( \gamma_0 \) is the collisional broadening per impurity and \( J \) is the exchange energy of spin \( S \) with the SDW. \( K \) is a dimensionless constant which measures strength of the impurity-SDW interaction relative to the collisional broadening. Throughout the calculations the value \( N(0)V = 0.25 \) was used.

Figure 2 shows that the critical temperature \( t^* \) is greater over the entire range of impurity concentration for the larger value of \( K \). For low impurity concentration we find that the wave-vector discontinuity is proportional to the square-root of the impurity concentration, \( \xi_0^* \sim \lambda_0^{1/2} \), for both values of \( K \). This result has been independently confirmed by making an expansion of equations (1) and (3) about the zero concentration critical point. We note also the close association of the values of the imperfect nesting parameter \( \xi_0^* \) with the wave-vector \( \xi_0^* \). We expect this work to be applicable to experimental studies of thin films of Cr containing magnetic impurities (e.g. Cr-Co) since samples can be fabricated to provide a wide range of impurity concentration.


Fig. 2. - Numerical results for the normalized values of critical temperature \( t^* \), imperfect nesting parameter \( \xi_0^* \) and the wave-vector discontinuity \( \xi_0^* \) as functions of the impurity concentration. \( \lambda_0 \) is proportional impurity concentration. The numerical labels on the curves refer to values of \( K. N(0)V = 0.25 \) was used throughout the calculation.