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Kondo screening across a metal-insulator transition

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Disorder is always present in real materials, and it may lead to inserting new physics as we break translational invariance. We are motivated by the phosphorous doped silicon (Si:P) semiconductor in this work. Each phosphorus atom contributes one extra electron to the conduction band, which moves to an impurity band close to the bottom of the conduction band. As the density of dopants increases, we observe a metal-insulator transition (MIT). Interestingly, this MIT coexists with the formation of local magnetic moments, leading to a non-trivial thermodynamic response. (1) In this work, we model this impurity band by a tight-binding model with randomly placed sites on a cubic lattice, with the hopping mediated by the insulating silicon background. We characterize the non-interacting MIT via a finite size scaling of the two-point conductance. Then, we add diluted local moments to the problem and investigate their contribution to the thermodynamics as we cross the MIT. The coupling between these magnetic moments and the impurity electrons screen these moments below the Kondo temperature TK. Due to disorder, TK is distributed according to a power-law at low energies, and this power law does not depend on the interaction strength between the bath and the local moments, nor on the impurity concentration. Then, we investigate the screening of two impurities, which also have a direct coupling, via the RKKY interaction and how the random singlet formation competes with the Kondo effect. We notice that the RKKY interaction modifies the power-law, attenuating the divergence as we go to larger concentrations of impurities. We construct a $T = 0$ phase diagram as a function of the magnetic couplings, Kondo and RKKY. We follow the thermodynamic responses across the MIT, connecting our results to the phenomenology of Si:P.

Palavras-chave: Efeito Kondo. Desordem. Transição metal-isolante.

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