Non-chiral spin frustration versus local unfrustrated spin chirality in an exactly solvable spin-electron planar model of inter-connected trigonal bipyramids

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In this work, an interplay between a non-chiral spin frustration and unfrustrated spin arrangement with sings of local chirality in a mixed spin-electron model on a regular two-dimensional lattice constituted of identical inter-connected bipyramidal units is rigorously examined within the dos Santos and Lyra's concept of the spin frustration [1]. The model is designed to belong to a class of bond-decorated lattices, which are exactly solvable by means of the decoration-iteration mapping transformation [2]: the common vertices of the plaquettes are occupied by the Ising spins of the magnitude 1/2, the rest ones, forming triangular clusters oriented perpendicularly to plaquette's axes, are available for mobile electrons (each cluster for 2 electrons), and the exchange interactions merely between the nearest lattice sites are allowed.

The analysis of obtained numerical results shows that the ground-state phase diagram of the considered spin-electron model contains two different macroscopically degenerate quantum phases, namely the spontaneously ordered ferro- or ferrimagnetic phase (FM) with signs of local chirality (left- and right-handed) in each one-third-filled electron triangle and the disordered frustrated (FRU) one. While the sponateously ordered FM phase is completely unfrustrated, both the Ising and electron sub-lattices are frustrated within the FRU phase. Specifically, the Ising spins at nodal lattice sites are completely free to flip between up and down states, while the electron pairs delocalized over triangular cluster of each bipyramidal unit underlie a quantum superposition of six intrinsic antiferromagnetic and three non-magnetic ionic states, which implies the spin frustration of the electron sub-lattice in terms of dos Santos and Lyra's concept [2]. The observed non-chiral spin frustration in electron sub-lattice and the spontaneous arrangement ordering with local chiral features persist also at finite temperatures. Of course, both they are gradually vanishing with increasing temperature. The spin frustration of mobile electrons is always completely suppressed by strong thermal fluctuations after exceeding a certain frustration temperature. The reverse trend can be observed only near the ground state boundary FM–FRU. In this region, up to three consecutive frustration temperatures indicating the thermally induced destruction, re-creation and definitive destruction of the non-chiral spin frustration in electron sub-lattice can be found.

References:

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[2] M.E. Fisher, Phys. Rev. **113** 969 (1959)

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