MAGNETIC PHASE TRANSITION IN $Y_{1-x}Tb_xMn_6Sn_6$ COMPOUNDS

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The magnetic structure of $Y_{1-x}Tb_xMn_6Sn_6$ compounds (x = 0.0, 0.10, 0.25) was studied using small-angle neutron scattering (SANS) in the temperature range from 260 to 400 K, above and below the critical temperature T_C. The dependences of the SANS intensity on the momentum transfer demonstrate the presence of three contributions to the scattering, which differ in the scattering function (Q-dependence of the intensity) and in the evolution of these dependences with temperature. Scattering by large-scale magnetization domains is observed below T_C and is described by the Porod law Q^n. The Bragg peak from the incommensurate magnetic structure is also observed below T_C in the region of large Q. Ornstein-Zernike scattering by critical magnetization fluctuations is most pronounced at high temperatures. The order-disorder transition temperature, determined from the maximum scattering by critical fluctuations, increases with concentration: T_C = 300 ± 2 K, 325± 2 K, 353±3 K for compounds with concentrations x = 0, 0.1, 0.25. An incommensurate magnetic structure with a complex temperature behavior is observed in all compounds, with the period of the structure increasing with concentration x. The ferromagnetic component of magnetization was detected only in Tb-doped compounds at $T < T_C$. Above T_C, the magnetic structure disintegrates into fluctuating ferromagnetic planes, giving the occurring magnetic phase transition a quasi-two-dimensional character.

Critical fluctuations, according to the Mermin-Wagner theorem [1], demonstrate the instability of ferromagnetic order in two-dimensional systems and can be described by a new, nonmagnetic order parameter along the c-axis [2]. We argue that slowly fluctuating ferromagnetic planes are capable of ordering into a variety of spin structures: a complex double helix (x = 0), a conical helix, and a ferrimagnet (x = 0.1, 0.25). The phase transition from the fluctuating phase to the ordered one in YMn_6Sn_6 occurs in a complex manner through a system of crossovers, implying that on the basis of fluctuating ferromagnetic planes with a decrease in temperature in the range [300 - 340] K, it is possible to form first an antiferromagnetic commensurate (but fluctuating) phase, then a spiral (but fluctuating) phase, and, finally, a stable spiral phase at $T \approx 300$ K. Doping with a rare earth element simplifies the phase transition and the fluctuating Mn planes are immediately ordered into a collinear magnetic (ferrimagnetic for the Mn-Re plane system) structure. The ferromagnetic component of this ferrimagnetic structure increases with decreasing temperature from T_C to $T \approx 300$ K, and then “freezes”, thereby confirming the hypothesis of a phase transition from a two-dimensional magnetic system to its three-dimensional analogue.

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[2] P. Chandra, et al, (1990). Ising transition in frustrated Heisenberg models. Phys. Rev.Lett. 64, 88–91.