Talk 2: 11:45–

EPR in doped AF $S = 1/2$ quantum spin chains: quantum critical phenomena, Oshikawa-Affleck theory and new magnetic oscillations

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We report results of high frequency (60-360 GHz) EPR study of the quasi one-dimensional magnet CuGeO3 doped with magnetic impurities Co, Fe, Mn, which substitute cooper in $S = 1/2$ AF Cu^{2+} chains. In all cases studied a magnetic impurity modifies the collective EPR line whereas no specific impurity resonances related with the doping spins $S = 3/2$ (Co^{2+}), $S = 2$ (Fe^{2+}) or $S = 5/2$ (Mn^{2+}) are observed. The first effect of doping consists in separation of the quantum spin chains in two kinds. In the first group all types of the long-range magnetic order (spin-Peierls or Neel) are suppressed down to the lowest temperatures studied and the ground state is the Griffiths phase. In the second group the dimerization with the same (or slightly reduced) temperature as in pure single crystal is conserved. It is worth noting that a relatively low concentration of a magnetic impurity, namely $x = 0.01$ (Fe) or $x = 0.02$ (Co), is sufficient for the complete damping of dimerization. In this case the magnetic system consists of the spin clusters having different coupling constants J and low temperature magnetic susceptibility follows power law $\chi \sim 1/T^{\xi}$ with the exponent $\xi < 1$. For the quantitative description of the Griffiths phase magnetic properties we have suggested a simple model with a dispersion of Neel temperatures $T_N \sim J \leq T_{\max}$ in clusters with the probability $w(T_N) \sim T_N^{-\xi}$. In this approach the calculation of $\xi(T)$ at arbitrary temperature is possible, which leads to a correct determination of ξ and $T_{\max}$ from the experimental data. It is found that for all impurities studied $T_{\max} \sim 120$ K is about exchange integral along Cu^{2+} chains in undoped case, whereas critical exponent strongly depends on dopants and equals $\xi = 0.3$ (Fe), $\xi = 0.7$ (Mn) and $\xi = 0.8$ (Mn). The second effect of doping can be understood in the framework of the Oshikawa-Affleck theory describing ESR in $S = 1/2$ AF quantum spin chains. Doping of $CuGeO_3$ with magnetic impurities leads to onset of the staggered field in the sample, which together with exchange anisotropy controls the EPR line width. As long as in presence of the staggered field the line width W and g-factor are connected by the universal relation [1], the quantitative analysis of the ESR can be done by computing the Oshikawa-Affleck function [2]: $f_{\mathrm{OA}} = W(T)/\Delta g(T)\dot{T}$ (here Δg denotes the g-factor shift). It is found that the temperature dependences of the line width and g-factor are formed as a result of the competition between interchain antiferromagnetic interactions and staggered Zeeman energy. We argue that the b axis, which corresponds to the strongest interchain exchange direction, is an " easy direction " for the staggered field, i.e. the alignment of the external field B along b increases the magnitude of the staggered magnetization. Experimental data also suggest that in doped $CuGeO_3$ antiferromagnetic interaction increases with magnetic field. The third recently observed effect of doping have been deduced from the anomalous polarization characteristics of the magnetic resonance in $CuGeO_3$ doped with 2% of Co impurity, which accompanies in this system the collective EPR on Cu^{2+} chains [3]. For the Faraday geometry the new mode is damped for the microwave field $\mathbf{B}_\omega$ aligned along a certain crystallographic direction showing that the character of magnetic oscillation differs from the standard spin precession and can be described by linear oscillation of the magnetization. This effect seems to be closely connected with the impurity driven staggered magnetization and argued to correspond to an unknown before, collective mode of magnetic oscillations in an $S = 1/2$ AF quantum spin chain. This work is supported by the Programme " Strongly Correlated Electrons " of Russian Academy of Sciences.

[1] S.V. Demishev et al., Europhys. Lett., 63, 446 (2003)
[2] S. Demishev et al., Progress of Theoretical Physics Supplement No. 159, 387 (2005)
[3] S.V. Demishev et al., Pis'ma v ZhETF, 84, 305 (2006)