Dynamic cluster magnetic subsystems in diluted magnetic semiconductor $Ge_{1-x-y}Sn_xMn_yTe$

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Diluted magnetic semiconductors (DMS) based on $A^{IV}B^{VI}$ compounds doped with magnetic impurities are of considerable scientific and practical interest [1]. They are promising materials for spin electronics and convenient objects for fundamental research in the field of magnetism.

We synthesized a series of $Ge_{1-x-y}Sn_xMn_yTe$ samples of various compositions. Detailed studies of their magnetic properties have been carried out. The temperature dependences of the dynamic magnetic susceptibility $Re(\chi_{AC})(T)$ of some samples contain two peaks: the left (lower temperature) and the right (higher temperature) (Fig.1).

When the frequency of the external magnetic field H_{AC} changes, the right peak in the $Re(\chi_{AC})(T)$ dependences shifts, while the left one remains stationary. Fitting the experimental $Re(\chi_{AC})(T)$ dependences with Gaussian curves revealed four types of dynamic cluster magnetic subsystems of different spatial dimensions (0D, 1D, 2D, 3D). Dynamic (vibrating) magnetic clusters arise due to thermal vibrations of the crystal lattice containing ions of magnetic impurities and can be likened to standing waves, the size and structure of which provide long-range RKKY interaction (Ruderman–Kittel–Kasuya–Yosida) via charge carriers [2].

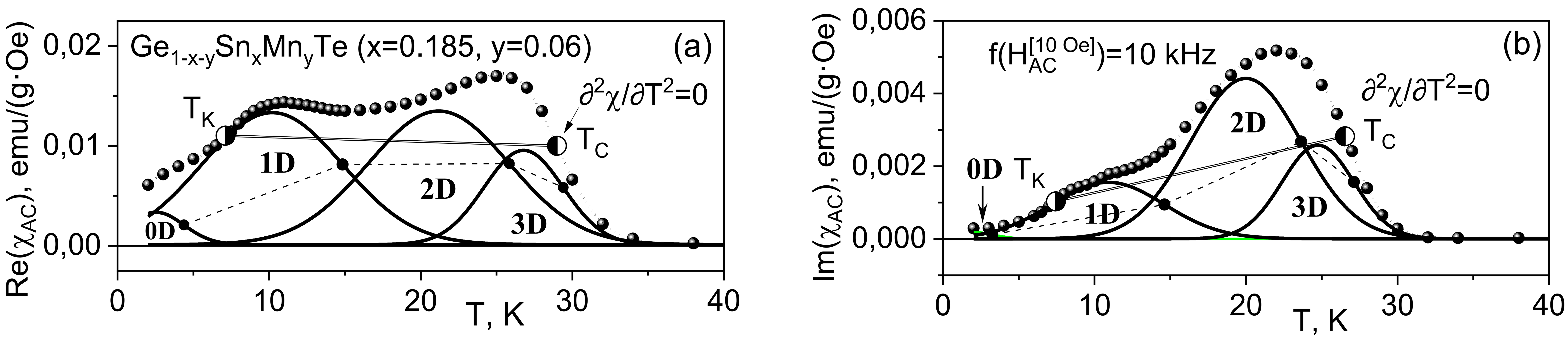

Fig. 1 – Contribution of 0D-3D magnetic clusters to the real and imaginary components of the dynamic magnetic susceptibility of the $Ge_{1-x-y}Sn_xMn_yTe$ sample

It was found that in $Ge_{1-x-y}Sn_xMn_yTe$ the phases of spin glass (SG) and cluster glass (CG) always coexist with the ferromagnetic (FM) phase, which is proved by the presence of magnetic hysteresis loops down to the lowest measurement temperatures of ~2 K. By analogy with the *Curie temperature* $\mathbf{T_C}$ (which is determined at the inflection point on the right wing of the $Re(\chi_{AC})(T)$, where $\partial^2\chi/\partial T^2=0$), the concept of the *Kilanski temperature* $\mathbf{T_K}$ is introduced, for which the same condition ($\partial^2\chi/\partial T^2=0$) is satisfied on the left wing of the $Re(\chi_{AC})(T)$ dependence. The distance between $\mathbf{T_K}$ and $\mathbf{T_C}$ is a convenient measure for determining the temperature range of magnetic transformations accompanied by the presence of magnetic hysteresis loops. Thanks to it, the symmetry between the two types of magnetic disordering becomes obvious: low-temperature (spin-glass) and high-temperature (paramagnetic) [3]. The symmetrical analogue of the *Curie-Weiss* temperature (**Θ**) for each magnetic subsystem is indicated in Fig. 2 by the letter **β** (*Kilansky-Slynko* temperature). $\mathbf{T_F}$ is the temperature at which spins begin to freeze during the formation of the spin glass phase.

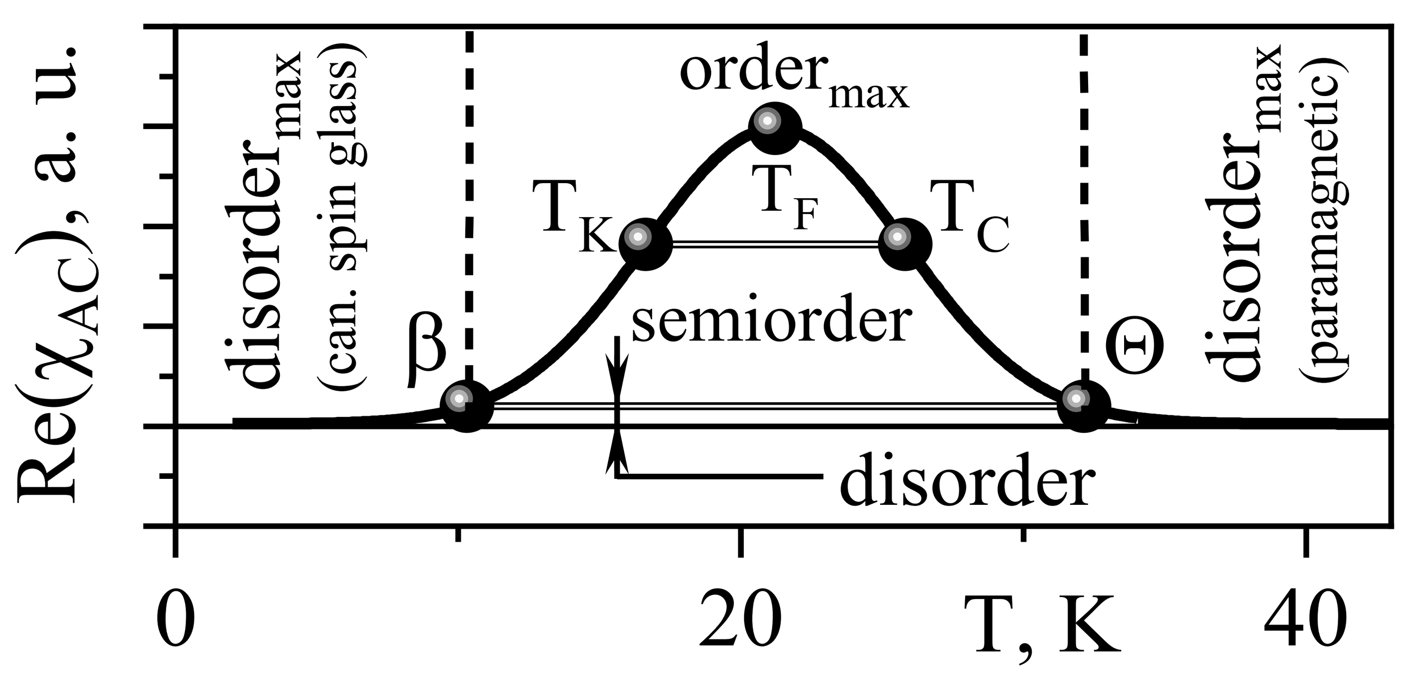

Fig. 2 – Five critical temperatures of a Gaussian magnetic subsystem: Θ, T_C, T_F, T_K, β.

References

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