Abstract—$^{57}$Fe Mössbauer studies of $\text{MnP}_{0.995}^{57}\text{Fe}_{0.005}P$ monophosphide have been performed in a wide temperature range including magnetic transitions at the points $T_\text{C} = 292\text{ K}$ and $T_\text{N} = 60\text{ K}$, the former of which (at $T_\text{C}$) is a transition from the paramagnetic to ferromagnetic phase and the latter (at $T_\text{N}$) is a transition with the formation of a helical magnetic structure. The model interpretation of the Mössbauer spectra within the full hyperfine interaction Hamiltonian involves the features of the magnetic structure of undoped MnP phosphide. The analysis of spectra at $T < T_\text{N}$ has shown that it is necessary to take into account the magnetocrystalline anisotropy of the helical structure of MnP and the anisotropy of the hyperfine magnetic field $H_{hf}$ on $^{57}\text{Fe}$ nuclei. It has been found that a Bloch-type domain structure is formed in a ferromagnetic phase in the temperature range $T_\text{N} < T < T_\text{C}$ ($T_\text{N} = 119\text{ K}$) and that two magnetic structures coexist in the temperature range of $T_\text{N} < T < T_\text{B}$. The analysis of the temperature dependence $H_{hf}(T)$ within the molecular field theory including magnetostriction effects (Bean–Rodbell model) has indicated that the phase transitions at $T_\text{N}$ and $T_\text{C}$ are of the first and second orders, respectively. It has been established that the magnetic moments $\mu_\text{Fe}$ undergo strong thermal fluctuations in the wide temperature range of $T^* < T < T_\text{C}$ ($T^* = 190\text{ K}$).

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1. INTRODUCTION

Phosphide MnP is of great interest because it undergoes magnetic phase transitions induced by the temperature, external magnetic field, or pressure [1–7]. Furthermore, it has been recently found that MnP at external pressure (about 8 GPa) and low temperatures ($T < 5\text{ K}$) undergoes a transition to a superconducting state, changing a helical magnetic order in the manganese sublattice [5–7]. Although the superconducting state becomes possible only at the suppression of the magnetic order, the effect of the specificity of the magnetic order on the possibility of its transformation to superconductivity is still under discussion [5, 7]. The reduction of the temperature in the absence of external fields induces three successive transitions in MnP [3]. The first paramagnetic $\leftrightarrow$ ferromagnetic high-temperature (HT) transition with the magnetization along the $c$ axis of an orthorhombic unit cell of phosphide (space group $Pbnm$) occurs at $T < T_\text{C} \approx 292\text{ K}$. The second, intermediate-temperature (IT), transition occurring at $T < T^* \approx 190\text{ K}$ holds the ferromagnetic collinear structure, but the magnetization component $M_{\text{||}}$ along the $b$ axis appears. The third, low-temperature (LT), magnetic transition occurs at $T < T_\text{N} = 47\text{ K}$ to a state with the incommensurate helical antiferromagnetic structure, where the magnetic moments of manganese “rotate” in the $(bc)$ plane and the modulation vector $q = (0.117, 0, 0)$ is directed along the $a$ axis [3]. It was shown that just the LT phase is transformed to a superconducting state at the external pressure on MnP [5–7].

The magnetic measurements of MnP single crystals reported in [3, 8] showed that the magnetic component $M_{\text{||}}$ of the IT phase demonstrates a noticeable hysteresis upon cooling (HT $\rightarrow$ IT) and heating (LT $\rightarrow$ IT) of samples, as well as at the application of a magnetic field. In view of the data obtained, it was assumed that the IT phase consists of extended ferromagnetic domains, which are identical in structure to the HT phase and are separated by walls whose helical structure is very similar to the LT phase [3]. It is assumed that change in the direction of the process (heating/cooling) at the transition to the IT phase affects both the length of ferromagnetic domains and the width of “helical” domain walls separating these domains. The application of the external magnetic field along the $b$ axis of the crystal changes the direction of the rotation (chirality) of magnetic moments in

ORDER, DISORDER, AND PHASE TRANSITION

IN CONDENSED SYSTEM

$^{57}$Fe Probe Mössbauer Study of Magnetic Phase Transitions in MnP Phosphide


* Moscow State University, Moscow, 119992 Russia
* e-mail: salex12@rambler.ru
** e-mail: janglaz@bk.ru

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