Low-Dimensional V-based Complex Oxides: an NMR Study

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Abstract

We performed 31P and 51V NMR study of low-dimensional isostructural vanadylvanadate Sr2V3O9 (T_{AF} = 5 K) and vanadylphosphate Sr2VP2O9 (T_{AF} = 2.8 K). Large negative shift of the whole 51V spectrum in comparison with Sr2VP2O9 is an evidence of a strong correlation (coupling) between all three 51V nuclei mediated by electron system. The striking feature of 31P relaxation in Sr2VP2O9 is an existence of two characteristic relaxation rates (R_{1short} and R_{1long}) with more than three orders difference between them. Moreover, the "long" relaxation curve drastically decreases below 15 K. Another result is high value of "short" relaxation which exceeds in two orders of magnitude the 51V relaxation rate in Sr2VP2O9. Therefore P-ions are involved in magnetic hyperfine exchange process via the path V-O-P-O-V.

Key words: spin-lattice relaxation; 31P NMR; 51V NMR

1. Introduction

The crystal structure of Sr2V3O9 compound contains three types of V site: V^{4+} in VO_6 octahedra forming chains along the c-direction and two V^{5+} in VO_4 tetrahedra which form a connection bridges of two types between VO_6 [1]. In Sr2VP2O9 the V^{4+} ions are substituted by P ions which enable us to study the role of non-magnetic cations in magnetic interactions in these low-dimensional V-based oxides [2]. According to magnetic susceptibility and specific heat measurements, Sr2V3O9 exhibit the transition to antiferromagnetic (AF) state at T_{AF} = 5 K, whereas for Sr2VP2O9 the transition is found at T_{AF} = 2.8 K [3].

2. Results and discussion

An example of 51V NMR spectra measured in both samples at 295 K and 4 K is shown in Fig.1 and 2. Large negative shift of the whole spectrum (V^{4+} and V^{5+}), in comparison with Sr2VP2O9, could be considered as an evidence of a strong correlation (coupling) between all three 51V nuclei mediated by electron system. 51V NMR spectrum at 4 K in Sr2VP2O9 has been successfully simulated assuming an existence of one V site and in the presence of following interactions: anisotropic chemical shift; quadrupole 1-st order interaction and indirect 51V-31P coupling. Nuclear spin-lattice relaxation rate R_1 = 1/T_1 of 31P and 51V nuclei in Sr2VP2O9 has been measured in the temperature range 4 - 300 K by saturation recovery method using integration of spin-echo in the time domain. The resulting R_1 curves in dependence on temperature are presented in Fig.3. The striking feature of 31P relaxation is an existence of two characteristic relaxation rates (R_{1short} and R_{1long}) with more than three orders difference between them. Moreover, the "long" relax-
Fig. 1. $^{51}$V NMR spectra at 4 K in Sr$_2$V$_3$O$_9$ and Sr$_2$VP$_2$O$_9$. $F_0$ is the Larmor frequency of $^{51}$V in the magnetic field of 7.014 T [4].

Vo$_6$ octahedra. This coincides with the fact that above 40 K $^{31}$P "fast" relaxation rate is almost independent on temperature. Similar behavior is observed in 1D Heisenberg spin chain [5]. In the case of more temperature dependent $^{51}$V spin-lattice relaxation, one should add in the analysis quadrupolar mechanism which is proportional to $T^2$ at $T > \theta_D$ and falls down as $T^7$ at $T < 0.02 \theta_D$, where $\theta_D$ is the Debye temperature [6].

3. Conclusion

Our preliminary NMR results show that unique crystal structure of the V-based oxides Sr$_2$V$_3$O$_9$ and Sr$_2$VP$_2$O$_9$ leads to complicity of magnetic exchange processes reflected in unusual $^{31}$P and $^{51}$V spin-lattice relaxation behavior.

References

[3] E. Kaul et al., MSU-HTSC VI, Moscow, June 2001; E. Kaul et al., to be published.