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ULTRASONIC ANOMALY AT NEEL POINT AT T=2.23 K IN $GdBa_2Cu_3O_{6.4}$ SINGLE CRYSTAL

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Results of ultrasound velocity measurements for $GdBa_2Cu_3O_{7-x}$ single crystal (x=0.6) at 2-300 K are presented. It is found that this system is undergoing the antiferromagnetic (AF) ordering of the rare earth (RE) ions Gd at T_N = 2.23 K. This transition corresponds to the relative variation of the longitudinal velocity $\Delta S_l/S_l \sim 2\text{-}3\%$ and sound attenuation increase about ten times. We suppose that the AF ordering of Gd ions is due to the superexchange (SE) between Gd^{3+} ions via oxygen ones. The second anomaly detected at ~200 K appears as a kink on temperature dependence of ultrasound velocity and as a footstep on attenuation curve.

1. INTRODUCTION

The 1-2-3 compounds are systems showing the coexistence of superconductivity (SC) and the RE sublattice AF order. For both SC $GdBa_2Cu_3O_{7-x}$ (x=0-0.6) and nonSC (x=0.6-1) compounds AF ordering has been observed at T_N=2.23 ±0.02 K[1,2]. Transition temperature T_N is unchanged for both insulating and SC phases. The important problem is to determine a dominant mechanism of the RE AF ordering in Gd123. It is interesting to compare the recently obtained heat capacity results with the behaviour of other thermodynamic parameters at T_N, such as ultrasound velocity and attenuation.

2. EXPERIMENT

The temperature dependences of the ultrasound velocity and the attenuation at 2-300 K for 1 MHz longitudinal and transversal acoustic waves propagated along c-axis in the $GdBa_2Cu_3O_{6.4}$ single crystal with SC transition near 30 K (T_c is obtained from the ac magnetic susceptibility) were investigated. The electromagnetoacoustic (EMA) method was used[3]. The transition from a normal to the SC phase is not accompanied by a kink on the temperature dependence of the ultrasound velocity. A weak kink on the temperature dependence of the EMA signal amplitude A (see fig.1) at T_c is likely to deal with the variation of the EMA transformation coefficient near T_c due to the magnetic field penetration depth increase near T_c. Test measurements on the tin samples near T_c confirm this assumption. In measurements of the ultrasound velocity and efficiency of the transformation on tin single crystal an increase around T_c was also observed. The absence of acoustic anomaly near T_c for 123 single crystals is connected with (calculated from the BCS theory) a weak effect $\Delta S_l/S_l \sim 10^{-5}$ which is less than the experimental error bar $\sim 10^{-4}$.

3. RESULTS

We have detected for the $GdBa_2Cu_3O_{6.4}$ single crystal anomalies on the temperature dependence of the

ultrasound velocity (2.5%) and attenuation (10 times) in region near T_N=2.23 K (see fig.1). We suppose that these anomalies are caused by the AF ordering of gadolinium ions at T_N= 2.23 K. Previously the Gd ions AF rearrangement at T_N for Gd123 was detected by heat capacity technique, neutron diffraction, Moessbauer and NMR studies[1,2,7].

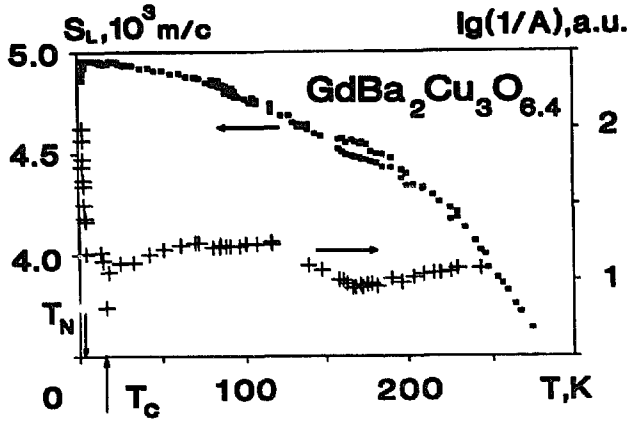

FIGURE 1
Temperature dependence of the longitudinal ultrasound velocity [▪] and attenuation [+] in $GdBa_2Cu_3O_{6.4}$ single crystal.

4. DISCUSSIONS

The main problem of the RE AF ordering is to determine the dominant mechanism of the RE ions interaction. The standard RKKY interaction seems not to be related because the RE moments do not interact with electrons at the Fermi level[4] while the modified RKKY[5] gives the value of T_N which is too low. The contribution of the dipolar interaction between the RE ions is not dominant for Gd123[7]. The T_N estimation[6] based on this mechanism leads to the value about 0.5 K. It is clear that the SE is one of the most probable way to couple the magnetic moments of Gd ions.

The nature of the SE is closely connected with crystal structure. Gd123 has the perovskite-like structure ($ABO_{2,3}$) which differs from the perovskite (ABO_3) type by the oxygen deficiency. The latter reduces the coordinate numbers of cations. The molecular field theory gives the main features of the SE. We can use the known for our system values of the asymptotic Curie-Weiss temperature θ_A[1,7] to calculate the ratio θ_A/T_N. In the framework of the Van Vleck theory one can deduce from this ratio for our Gd123 system the following results: a) moments of the next nearest neighbor magnetic ions are antiparallel; b) the 90° SE via oxygen ions is as strong as the 180° SE. Thus we have an opportunity to estimate the contribution of a multistep long-range SE in the RE AF ordering for Gd123. These estimations obtained from this model are in a good agreement with our ultrasonic results[8].

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