Ultrasonic Study of Magnetoelastic Effects in the Spin-Peierls State of CuGeO₃

M. Saint-Paul, G. Reményi, N. Hegmann, P. Monceau, G. Dhalenne, A. Revcolevschi

► To cite this version:

M. Saint-Paul, G. Reményi, N. Hegmann, P. Monceau, G. Dhalenne, et al.. Ultrasonic Study of Magnetoelastic Effects in the Spin-Peierls State of CuGeO₃. Journal de Physique IV Proceedings, 1996, 06 (C8), pp.C8-539-C8-540. 10.1051/jp4:19968117 . jpa-00254547

HAL Id: jpa-00254547

<https://hal.science/jpa-00254547>

Submitted on 1 Jan 1996

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Ultrasonic Study of Magnetoelastic Effects in the Spin-Peierls State of CuGeO_3

M. Saint-Paul, G. Reményi, N. Hegmann, P. Monceau, G. Dhalenne* and A. Revcolevschi*

CRTBT, Centre National de la Recherche Scientifique, BP. 166, 38042 Grenoble cedex 9, France

**Laboratoire de Chimie des Solides, Université Paris-Sud, Bâtiment 414, 91405 Orsay cedex, France*

Abstract The quasi-one-dimensional CuGeO_3 compound is the first inorganic material to exhibit a spin-Peierls transition driven by the magnetoelastic interaction between antiferromagnetic chains and the phonon field which opens a finite energy gap in the spin excitation spectrum by the dimerization of the lattice. The anomalous elastic character of the spin-Peierls system is established by studying in a high magnetic field the propagation of longitudinal ultrasonic waves along the three crystalline axes. We have measured the longitudinal elastic constants C_{11} , C_{22} and C_{33} of CuGeO_3 in magnetic fields up to 20 Teslas. The phase boundaries between the uniform (U), modulated (M) and dimerized (D) phases are associated to large anisotropic variations of the elastic constants. The temperature dependence of the three elastic constants exhibits a minimum at the U-D and U-M phase boundaries. The field dependences of C_{22} and C_{33} are reported.

INTRODUCTION

The spin-Peierls (SP) transition is driven by the magnetoelastic interaction between the 1D antiferromagnetic chains and the 3D phonon field in the lattice which opens a finite gap in the spin excitation spectrum by the dimerization of the lattice [1]. CuGeO_3 has been intensively studied and we present ultrasound measurements performed under high magnetic field up to 20 Teslas.

Experimental results

The CuGeO_3 single crystalline samples were cut from a large crystal several cm long grown from the melt by a floating zone method associated with an image furnace[2]. The magnetic field was provided by a resistive Bitter coil which could be swept continuously from 0 to 20 Teslas. The magnetic field was parallel to the direction of the sound propagation. The standard pulse echo technique was used with LiNbO_3 transducers and the sound velocity was measured by the phase coherent detection technique. The elastic constant C is related to the sound velocity by the relation $C=dV^2$ where d is the mass density equal to 5.1 g/cm^3 . At room temperature C_{11} , C_{22} and C_{33} are equal to 7.2, 4 and $32 \times 10^{10} \text{ N/m}^2$ respectively corresponding to velocities of 3700, 2600 and 8000 m/s. The temperature and magnetic field dependences have been reported in reference [3]. The magnetic field dependences of C_{22} and C_{33} measured at 4 K are shown in figure 1. The D-M phase transition at 4K is characterized by a step-like decrease of C_{22} at the magnetic field $H_c=12\text{T}$, whereas C_{33} increases. The critical magnetic field H_c is slightly anisotropic because of the small g factor anisotropy, g is the electron gyromagnetic ratio[1]. The value $H_c=12 \text{ T}$, determined in figure 1a when magnetic field is applied along the crystallographic b axis, is in agreement with the x-ray experiments[4]. $H_c=13 \text{ T}$ obtained when magnetic field is applied along the c axis is in agreement with the susceptibility measurements [5]. The sharp transition of C_{22} (sharpness 0.2 T) is characteristic of a first order phase transition. Hysteresis in the variation of C_{33} when increasing and decreasing the magnetic field confirms the first order character of the transition. Theoretical approaches predict that, above the threshold field H_c , the periodicity of the lattice modulation deviates from the commensurate wavevector[1]. Incommensurate lattice modulation has been observed in CuGeO_3 in field exceeding H_c by a high resolution X ray diffraction experiment[4]. The chains are no longer dimerized but the interatomic spacing is modulated with a wavelength

determined by the magnetic field. The present work confirms that the elastic properties of the compound is very sensitive to this structural D-M phase transition and the ultrasound technique is very useful to probe the order parameter[3]. Nevertheless the large anomalies of C_{22} and C_{33} at this transition are not yet explained and further theoretical work is necessary to elucidate such a behaviour. An incommensurate phase is characterized by an order parameter that is modulated with a wavelength incommensurate with the lattice periodicity. At high magnetic fields this modulation is sinusoidal. Close to the critical H_c field the modulation is no longer described by a plane wave, but an alternating sequence of commensurate regions and discommensurations in which the order parameter phase changes rapidly with respect to the underlying lattice[1].

Figure 1: Magnetic field dependence of the elastic constants C_{22} (a) and C_{33} (b) at 4K: the magnetic field is along the b-axis (a) and the c-axis (b).

References

- [1] For a review see J.W. Bray, L.V. Interrante, I.S. Jacobs and J. Bonner in *Extended Linear Chain Compound* edited by J.S. Miller (Plenum New York, 1983) Vol3.
- [2] A. Revcolevschi and R. Collongues C.R. Acad. Sci **266** 1767(1969).
- [3] M. Saint-Paul, G. Rémynyi, N. Hegman, P. Monceau, G. Dhalenne, and A. Revcolevschi Phys.Rev.B **52** (1995) 15298.
- [4] V. Kiryukhin and B. Keimer, J.P. Hill and A. Vigliante Phys. Rev Lett **76** (1996) 4608.
- [5] M. Hase I. Terasaki and K. Uchinorakura Phys. Rev. Lett. **70** (1993) 9616.