ELASTIC TENSOR OF Gd$_5$(Si$_2$Ge$_2$)

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Gd$_5$(Si$_2$Ge$_2$) is famous for its unique properties associated with the magnetic-martensitic transition from a monoclinic to orthorhombic phase occurring close to room temperature. A giant magnetocaloric effect ($\Delta T / \Delta B \cong 8$ K / 2 T) makes Gd$_5$(Si$_2$Ge$_2$) promising for energy efficient refrigeration and a colossal strain (up to 10,000 ppm) gives it a potential for use as an actuator. We present the results of the first-ever study of the elastic properties of single crystal Gd$_5$(Si$_2$Ge$_2$). The crystals were grown by a tri-arc crystal pulling technique from a stoichiometric mixture of the components in an argon atmosphere under normal pressure using a tungsten rod as the seed material. Five oriented crystals were cut such that they had faces perpendicular to the [100], [010], [001], [110], [101], or [011] directions. Their surfaces were polished to optical quality. Velocities of all three sound modes (longitudinal and two transverse) were measured in each of the crystallographic directions mentioned above. Measurements were performed by the classical transmission pulse-echo-overlap method at room temperature in the monoclinic phase of the crystal. Pairs of identical lithium niobate 60 MHz or 40 MHz transducers were used for generation/detection of the longitudinal and transverse waves respectively.

The propagation of the sound wave in the crystal is governed by the system of Christoffel equations [1]. Their analysis allowed us to deduce the values of all elements of the elastic stiffness tensor $\hat{C}$, shown in Fig. 1. Sound speeds in arbitrary crystallographic directions were calculated by the backward substitution of these constants into Christoffel equations. The cross-sections of the sound wave velocity surfaces in the main crystallographic planes are shown in Fig. 2.

By knowing the velocities of the sound waves in all directions, the determination of the Debye temperature is straightforward [1]. According to our calculations its value is equal to 250 K, in agreement with specific heat data [2].

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References