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Angle dependence of the elastic constant of $SmRu_4P_{12}$ in magnetic field

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$SmRu_4P_{12}$ shows a Metal-Insulator (M-I) transition at $T_{MI} = 16.5$ K and a successive magnetic phase transition at $T_N = 14$ K [1,2]. Breakdown of time reversal symmetry has been detected by μSR, NMR and nuclear resonant forward scattering measurements, so far [3-5]. On the origin of this M-I transition, several authors have proposed octupolar ordering scenarios on the basis of their experimental results. We have proposed T^{β} scenario from the elastic constant measurements [6]. T_{xyz} scenario was suggested from the isotropic behavior in T_{MI} [7]. A possibility of T^{α} scenario was proposed by Tsutsui] [5] and by Aoki from the specific heat measurement [8]. Type of the order parameter is still an enigma.

In order to investigate type of the order parameter of phase II, we have measured the angle dependence of the elastic constant in the magnetic field. Recently, we have found remarkable angle dependence of the elastic constant in the magnetic field [9]. The elastic constant C_{44} with the propagation direction $x = [100]$ and the displacement direction $z = [001]$ shows a characteristic field-angle dependence below T_N, when the magnetic field is rotated in xy plane. A two-fold pattern is observed in low field. And a four-fold pattern is added to the two-fold one with increasing field. It should be particularly remarked that the two-fold pattern is not sinusoidal but kink-like. There are some possible origins for this peculiar field-angle dependence in the elastic constant. This kink-like behavior evokes some imaginations that domains plays an important role [10], where the switching of the order parameter occurs at every 90 ° like the case of $PrPb_3$ [11]. Another origin for the four-fold pattern is deduced by a three-body coupling between quadrupoles q and elastic strain e, such as $q \times q \times e$. Other forms of the coupling terms cannot produce the four-fold angle dependence. In this study, we have measured C_{44} with various experimental configurations with respect to the displacement direction. In the case of C_{44} with the propagation direction x and the displacement y, when the field is rotated in xy plane, we observed only two-fold pattern without four-fold pattern, although the experiments are preliminary. We will discuss our results based on the quadrupole-stain coupling.

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