Observation of the Quantum Tunnelling of hydrogen in Pd ultrathin film

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The diffusion of light interstitials such as positive muon and hydrogen has been studied experimentally and theoretically. Whereas the diffusion follows the Arrhenius law at high temperature, the quantum tunnelling takes place dominantly without thermal activation at low temperatures. According to the theory by Kondo, the hopping rate of particles in the quantum regime is proportional to T^{2K-1}, where T and K are the temperature and the coupling constant with conduction electrons [1]. This means that the diffusion rate has a minimum around the cross-over from the thermal diffusion to the quantum tunnelling. Concerning the hydrogen quantum tunnelling, few experimental studies have been reported because of the difficulty in detecting hydrogen atoms directly. In this research, focusing on the relaxation of a metastable state of a hydrogenated Pd film formed at low temperature, we report the quantum tunnelling of hydrogen atoms through the measurement of the in-plane electrical resistivity.

A Pd 10-nm-thick ultrathin film was deposited on a glass substrate by magnetron sputtering at room temperature. A metastable state of Pd-hydride was formed by hydrogen ion implantation with 0.5 keV at 35 K in a UHV chamber. The resistivity of the film was measured for 4 hours by incrementally heating the sample from 6 K with an interval of about 5 K. Because the transition from the metastable state to another stable state by hydrogen diffusion reveals a change of the resistivity, the hydrogen diffusion was monitored through the resistivity measurement. Figure1 showes the resistivity change observed at each temperature, which is related to the hopping rate of hydrogen atoms in Pd. The resistivity change was found to have a minimum around 30 K. This indicates that the H diffusion undergoes a transition from thermal to quantum regimes. We discuss the temperature dependence of the hopping rate on the basis of the Kondo theory.

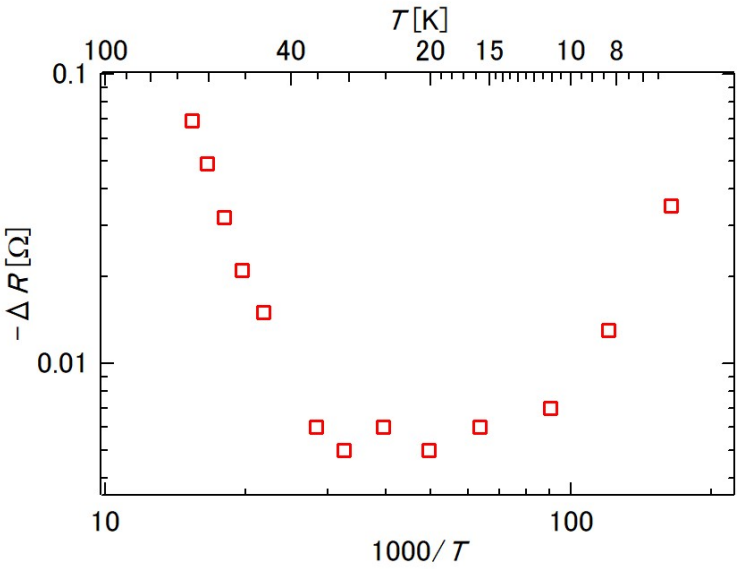

Figure1: Resistivity change of Pd-hydride at different temperatures during heating from 6 K.

References:
[1] J. Kondo, *Physica B+C* **125B** (1984) 279.