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ABSTRACT

Quantum Diffusion of Hydrogen Isotopes as Probed by Nuclear Reaction Analysis and Resistivity Measurements

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Nuclear quantum effects have significant impact on the dynamics of light particles. Hydrogen diffusion in metals is one of the suitable platforms to study the quantum characters, and quantum tunneling is believed to be prominent at low temperatures. However, detailed experimental data of H diffusion at low temperatures remain scarce due to the difficulty of directly probing H hopping. Our focus is on the electronic modification of host metals by H. Hydrogen hopping from metastable to stable states is accompanied by changes in electrical resistance, enabling the measurement of H hopping rates through resistance measurements. The depth distribution and lattice location of H are analyzed using nuclear reaction analysis (NRA) to identify the hopping pathway.
We performed resistance measurements and NRA, and investigated the H hopping mechanism in Pd and V hydride films at low temperatures[1-3]. Metastable hydride states were synthesized by quenching and H ion implantation at low temperatures. The resistance changes due to the H distribution changes were observed, and the H hopping rates were successfully obtained from the resistance relaxation. Our findings revealed that the energy level matching is crucial for the quantum tunneling at low temperatures, and thus the tunneling rate is sensitively affected by isotope effects and lattice strain. Furthermore, nuclear quantum effects also play a significant role in determining the hopping behaviour around the crossover region between thermal and quantum hoppings.

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[2] T. Ozawa *et al.*, Vacuum and Surface Science 62, 8, 492 (2019). [3] S. S. Das, T. Ozawa *et al.*, in preparation.