Research Group for Nanoscale Structure and Function of Advanced Materials

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The research objective of Nanoscale Structure and Function of Advanced Materials group is to study nanoscale structures of functional devices and materials under external fields by using high-intensity quantum beams of muons, positrons, neutrons, and synchrotron light. As a highlighted result in our group, an interface height between graphene and metal substrate is experimentally revealed to change depending on the metal elements by Total-Reflection High-Energy Positron Diffraction method [1]. In this activity report, following two topics are introduced. Quadrupole fluctuation is detected via a coupling between muon and praseodymium (Pr) nuclear spin in PrV_2Al_{20} by muon spin relaxation (μSR) technique. Surface stress of Si(111) 7×7 reconstruction is successfully measured by using the surface-curvature and the reflection high-energy electron-diffraction (RHEED) apparatuses simultaneously.

Perturbation on hyperfine-enhanced ^{141}Pr nuclear spin dynamics associated with quadrupolar order in PrV_2Al_{20} [2]

Recent discoveries of heavy fermion superconductivity in quadrupolar phases of 4*f* electrons in some Pr-based compounds have stimulated renewed attention on quadrupolar quantum criticality [3,4]. However, an experimental investigation of quadrupolar correlations is difficult because experimental techniques sensitive to quadrupolar moments are still quite limited. Thus, it is important to develop new methodologies to probe quadrupolar properties.

We have studied the influence of 4*f* quadrupolar correlations on hyperfine-enhanced (HE) ^{141}Pr nuclear magnetism by using the μSR method. μSR is sensitive to slow spin dynamics and thus is suitable for probing HE ^{141}Pr nuclear spin fluctuations in a MHz scale.

μSR experiment has been performed on PrV_2Al_{20} which shows antiferroquadrupolar (AFQ) ordering at T_Q ~ 0.6 K [2]. As shown in Fig. 1, we observed an increase in the muon spin-lattice relaxation rate $1/T_{1,\mu}$ below 1 K, slightly above T_Q, with decreasing temperature. This increase can be attributed to the perturbation on the strength of HE ^{141}Pr nuclear spin-spin interactions associated with the development of AFQ correlation. This paves the way for a new microscopic approach to investigate quadrupolar correlations in Pr-based compounds using local spin probes.

In situ stress measurement of Si(111) 7×7 reconstruction during atomic hydrogen adsorption [5]

Surface stress of Si(111) 7×7 reconstruction has been theoretically studied but not been demonstrated experimentally[6]. We have measured the surface stress of the Si(111) 7×7 reconstruction by comparison with the hydrogen (H-) terminated Si(111) 1×1 surface.

The Si(111) 7×7 reconstruction surface was prepared by heating Si(111) wafer in a ultrahigh vacuum system after wet etching process. To obtain information on both the stress and the surface structure simultaneously, we have combined the surface-curvature and the RHEED apparatus during atomic hydrogen adsorption at 380˚C and room temperature (RT).

Atomic hydrogen exposure of Si(111) 7×7 results in rapid stress relaxation in the surface (Fig. 2). At the same time, the surface structure is transformed from Si(111) 7×7 to H-Si(111) 1×1. From the stress relaxation, the surface stress change is estimated to be 1.7 N/m at 5000 Langumuir (1 Langumuir = 1.33×10^{-4} Pa・s) at 380˚C [5], whereas it is 2.1 N/m at RT. H-Si (111) 1×1 surface forms a high-quality surface structure at 5000 Langumuir at 380˚C. On the other hand, it has many defects (holes, stacking fault, and islands) at RT. In conclusion, we have succeeded in the surface stress measurement of Si(111) 7×7 reconstruction during atomic hydrogen adsorption.

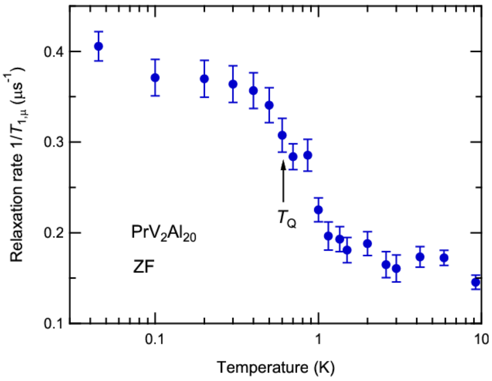

Fig. 1. Temperature dependence of $1/T_{1,\mu}$ in PrV_2Al_{20} under zero magnetic field (ZF).

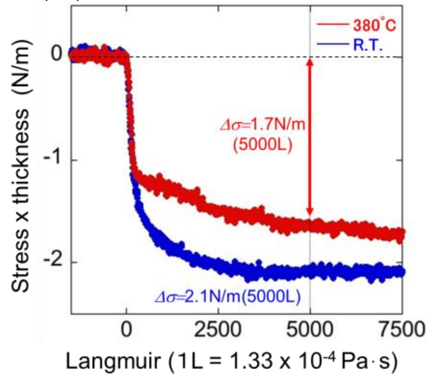

Fig. 2. Evolution of surface stresses during atomic hydrogen exposure of Si(111) 7×7 surfaces at two substrate temperatures of 380 ˚C (red line) and room temperature (blue line).

References

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