Surface Studies at SPF, KEK: Positron Diffraction and Positronium TOF


1Institute of Materials Structure Science, KEK, Tsukuba, 305-0801, Japan
2Accelerator Laboratory, KEK, Tsukuba, 305-0801, Japan
3Advanced Science Research Center, JAEA, Tokai, 319-1195, Japan
4Quantum Beam Science Center, QST, Takasaki, 370-1292, Japan
5Department of Applied Chemistry, Chiba University, Chiba, 263-8522, Japan
6Research Institute for Material and Chemical Measurement, AIST, Tsukuba, 305-8569, Japan
7Tokyo Gakugei University, Koganei, 184-8501, Japan
8Institute of Catalysis, Hokkaido University, Sapporo, 305-8569, Japan
9Department of Physics, Tokyo University of Science, Tokyo 162-8601, Japan

* email: hyodot@post.kek.jp

Recent Surface studies at the Positron Facility (SPF) in IMSS, KEK are reported. The slow-positron beams of intensity $5 \times 10^{7}$/s in the long-pulse mode (width 1.2 μs) and $5 \times 10^{6}$/s in the short-pulse mode (1-10 ns, variable) are stably used.

1. Positron diffraction: Total-reflection high-energy positron diffraction (THREPD) is a unique method exceedingly sensitive to the atomic geometry of the topmost- and immediate sub-surface [1,2]. Recent results using the long-pulse mode positron beam are the determination of the graphene-substrate distance where the substrates are Cu(111) and Co(0001)[3], and the detection of an asymmetric buckling structure of germanene on Al(111)[4]. It also determined a surface atomic structure of rutile-TiO$_2$(110)(1×2), which had been debated for more than 30 years [5].

A low-energy positron diffraction (LEPD) station using the long-pulse mode positron beam has been constructed and a diffraction pattern from Ge(001)(2×1) surface was observed. The pattern is recorded by a delay-line detector (DLD). Since a DLD does not accept too many positrons in a short pulse, a technique has been developed to stretch the 1μs pulse to an appropriate width up to 20ms.

2. Positronium time-of-flight (Ps-TOF): Ps-TOF station is operated with the beam in the short pulse mode whose width is short enough for the measurement of TOF of the ortho-Ps whose lifetime is 142μs. For metals, in particular, the spectrum carries information on the electronic state of the surface exclusively, because Ps does not form in the bulk and thus it is certain that the Ps emitted is formed on the very surface. Recently it was observed that coating of W surface with alkali metals greatly enhanced the Ps emission from the surface [6]. The energy spectra show evidence of energy loss compared to that of the Ps emitted from a clean W surface.

This study was performed under the PF Proposal No.2016S2-006, 2014S2-004, 2013S2-005 and 2013U002, and the auspices of the JAEE-KEK Joint Development Research at KEK. It was partly supported by JSPS grants KAKENHI (S)24221006 and (S)24221007 and those for Young Scientists B) 25800182 and 26800170, Cabinet office Cross-ministerial Strategic Innovation Promotion Program (SIP, unit D66), and by Toray Science and Technology Grant from Toray Science Foundation.