A low-energy positron diffraction (LEPD) experiment station for a linac-based slow-positron beam

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Low-energy positron diffraction (LEPD), which is the positron counterpart of low-energy electron diffraction (LEED), has been evaluated by a LEED theorist as an ideal surface structure analysis method [1]. In 1979, the first LEPD was observed by the Brandeis Univ. group with a channel electron multiplier using a slow-positron beam from a radioisotope (RI) source [2]. Subsequently they developed a system for observing a LEPD pattern with multiple spots and demonstrated that LEPD experimental results are more closely reproduced by a dynamical diffraction theory than in LEED [3]. Unfortunately, however, LEPD experimental research has been discontinued for about last two decades because of the difficulty in obtaining a low-energy positron beam with sufficient intensity and quality.

We have utilized a high-intensity slow-positron beam generated by a linear-electron-accelerator (linac) and succeeded in observing diffraction patterns of a Ge(001)-2×1 surface structure [4]. This is the first LEPD observation with a linac-based slow-positron beam and expected to open the way to provide a fundamental tool for surface structure analysis along with total-reflection high-energy positron diffraction (TRHEPD) [5].

There are a number of differences between an RI-based LEPD system and a linac-based one. One difference is the time structure of the beam. While an RI-based system provides a continuous beam, a slow-positron beam generated with a normal-conducting linac has a pulsed time-structure reflecting that of the linac beam. A high-intensity pulsed slow-positron beam could cause a multi-hit problem in the detection system with a position sensitive detector. To address this problem, a pulse stretcher for ∼ 5 keV beam with an approximately 6-m long Penning-Malmberg trap has been developed [4].

Another difference is the beam transportation methods. The RI-based LEPD system employed electrostatic lenses along the whole beam-line, while linac-based systems transport the beam from a remote positron production unit along the beam-line with a magnetic field. A transmission-type brightness-enhancement system with a 150-nm-thick Ni foil and electrostatic optics have been developed to allow low-energy positron beams interacting with a sample in a non-magnetic field region with a sufficient beam intensity and quality.

References

[1] S. Y. Tong, *Surf. Sci.*, **457**, L432 (2000).
[2] I. J. Rosenberg *et al.*, *Phys. Rev. Lett.*, **44**, 1139 (1980).
[3] C. B. Duke, in: A. Dupasquier, A. P. Mills Jr. (Eds.), *Positron Spectroscopy of Solids*, IOS, Amsterdam, 1995, p. 317.
[4] K. Wada *et al.*, *e-J. Surf. Sci. Nanotech.*, **16**, 313 (2018).
[5] Y. Fukaya *et al.*, *J. Phys. D: Appl. Phys.*, **52**, 013002 (2019).

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