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Development of reflection high-energy positron diffraction (RHEPD) apparatus at KEK

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Introduction

Reflection high-energy positron diffraction (RHEPD) is a surface-sensitive tool owing to the positive charge of positrons. When the high-energy (10-20 keV) positron beam is incident on the crystal surface at grazing angle, the total reflection takes place below the critical angle. The critical angle is derived from the Snell's law. For example, the critical angle is estimated to be 2.0° when the positron beam accelerated at 10 kV is incident on the Si crystal. Under the total reflection condition, the penetration depth of the positron into the crystal surface is quite low, which is less than approximately 2 Å. In order to investigate the topmost surface structure and dynamics at the topmost surface, we developed RHEPD apparatus by using a ^{22}Na source at JAEA [1, 2].

In the present study, we developed new RHEPD apparatus using a intense positron beam created from a linac at Slow Positron Facility of Institute of Materials Structure Science, KEK. We succeeded in the observation of the fractional spots in the RHEPD pattern from the Si(111)-7×7 surface.

Experimental

We connected a ultra-high vacuum (UHV) chamber composed of the einzel lens, microchannel plate with a phosphor screen, and manipulator to the positron beam line at the Slow Positron Facility. The repetition frequency of linac was set at 50 Hz. The positron beam was accelerated to 10 kV.

The samples (5×25×0.5 mm^3) were cut from a mirror-polished *n*-type Si(111) wafer with a resistivity of 1-10 Ωcm. The samples were flashed at 1200°C for a few seconds several times in the UHV chamber with a base pressure lower than 9×10^{-8} Pa to produce the well-ordered 7×7 superstructure. In order to measure the rocking curves, the glancing angle was varied from 0.8° to 6° with a step of 0.1°.

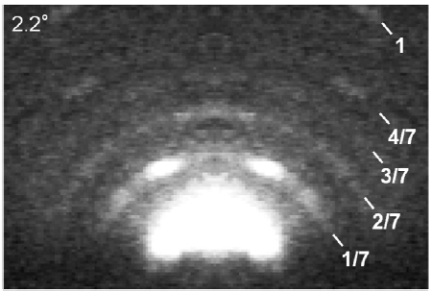

Fig. 1 RHEPD pattern from the Si(111)-7×7 surface at room temperature. The glancing angle and incident azimuth correspond to 2.2° and [$11\bar{2}$] direction, respectively.

Results

Figure 1 shows an example of the RHEPD pattern from the Si(111)-7×7 surface. We can clearly see the fractional spots resulting from the formation of the 7×7 superstructure. We also measured the RHEPD rocking curve of specular spots from the Si(111)-7×7 surface, as shown in Fig. 2. In addition to the intense total reflection and the (111) Bragg reflection peaks, the (333), (444), and (555) Bragg reflection peaks are clearly observable, indicating that the experiment was successful. The reflected intensity is 5-15 times as large as the ^{22}Na source method. In near future, we will apply new RHEPD developed at Slow Positron Facility of KEK to the determination of the atomic positions at low-dimensional surfaces. We will try to investigate the formation of charge density waves at the surface phase transition and the spin splitting at the Rashba surface.

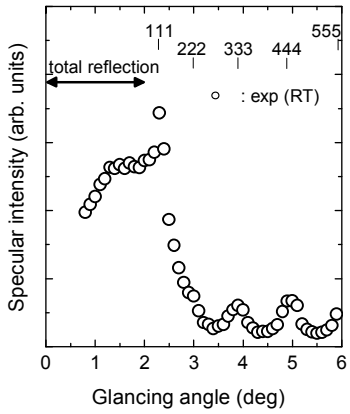

Fig. 2 RHEPD rocking curve of specular spots from the Si(111)-7×7 surface at room temperature. The incident azimuth is set at the [$11\bar{2}$] direction.

References

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