放射光による表面電子分光と陽電子回折
Studies on surface systems by using electron spectroscopy with synchrotron radiation and positron diffraction

松田巌
Iwao Matsuda
The Institute for Solid State Physics, the University of Tokyo, Japan
*e-mail: imatsuda(at)issp.u-tokyo.ac.jp

To comprehensively understand physical properties of materials, information on electronic states and atomic structure is fundamental and significant. Surface systems, formed by adsorptions of metal atoms on semiconductor crystals, have been prototype types of metal/semiconductor interfaces in electronics devices and, nowadays, it has become important playgrounds for low-dimensional physics. Systematic experiments of photoelectron spectroscopy and positron diffraction have revealed detailed physical properties of surface superstructures [1-6]. In the presentation, 1) I introduce one of the examples, the two-dimensional metallic surface phase on a Si surface[1-5], and 2) I discuss the future prospects for a combinational research with these surface analysis methods.

1) **Electron compound nature in a surface atomic layer of a two-dimensional hexagonal lattice [1]**

The two-dimensional (2D) ordered phase of monovalent metal alloy, $\sqrt{21}\times\sqrt{21}$, is formed on the Si(111) surface with the constant electron/atom ratio, indicating electron compound nature. Two conventional theories of the Hume-Rothery compounds, Jones model (nearly-free-electron model), and pseudopotential model (interionic interaction model), were applied to examine stability of the 2D phase. We found breakdown of the former and confirmation of the latter approaches with importance of medium-range interatomic interaction, mediated by the 2D surface-state electrons, in the latter approach.

2) **Toward the time-resolved experiments to study dynamics at surface systems [7]**

We have developed time-resolved photoemission spectroscopy system using synchrotron radiation (SR) at SPring-8 BL07LSU and an ultrashort pulse laser system. The performance of the instrument is demonstrated by mapping the band structure of a Si(111) crystal over the surface Brillouin zones and observing relaxation of the surface photo-voltage effect using the pump (laser) and probe (SR) method. The high-resolution and stable time-resolved photoemission experiments have observed detailed variation of the electronic structure during the relaxation. Systematic information of the *real time* electron spectroscopy and diffraction measurements would reveal natures of non-equillibrium process of various dynamic phenomena, such as surface phase transitions.

References:

1. Electron compound nature in a surface atomic layer of two-dimensional hexagonal lattice, I. Matsuda, F. Nakamura, K. Kubo, T. Hirahara, S. Yamazaki, W. H. Choi, H. W. Yeom, H. Narita, Y. Fukaya, M. Hashimoto, A. Kawasuso, S. Hasegawa, and K. Kobayashi, Phys. Rev. B 82, 165330-1, 165330-6 (2010).
2. Metal Co-Adsorption Induced R21xR21 Superstructure on Si(111) Surface Studied by Reflection High-Energy Positron Diffraction, Y. Fukaya,I. Matsuda,M. Hashimoto,H. Narita,A. Kawasuso, and A. Ichimiya, e-J. Surf. Sci. Nanotechnology, 7, 432-435 (2009).
3. Atomic structure of two-dimensional binary surface alloys: Si(111)-√21×√21 superstructure, Y. Fukaya, I. Matsuda, M. Hashimoto, K. Kubo, T. Hirahara, S. Yamazaki, W. H. Choi, H. W. Yeom, S. Hasegawa, A. Kawasuso, and A. Ichimiya, Surf. Sci. accepted.
4. Atomic and electronic structures of Si(111)-√21×√21 superstructure, Y. Fukaya, K. Kubo, T. Hirahara, S. Yamazaki, W. H. Choi, H. W. Yeom, S. Hasegawa, A. Kawasuso, and I. Matsuda, e-J. Surf. Sci. Nanotechnology, accepted.
5. Structure analysis of Si(111)-√21×√21-(Ag, Cs) surface by reflection high-energy positron diffraction, Y. Fukaya, I. Matsuda, R. Yukawa, and A. Kawasuso, Surf. Sci. accepted.
6. Atomic configuration and phase transition of Pt-induced nanowire on Ge(001) surface studied by

scanning tunneling microscopy, reflection high-energy positron diffraction and angle resolved photo-emission spectroscopy, Izumi Mochizuki, Yuki Fukaya, Atsuo Kawasuso, Ken Wada, Toshio Hyodo, Koichiro Yaji, Ayumi Harasawa, and Iwao Matsuda, Phys. Rev. B, accepted.
7. Development of soft X-ray time-resolved photoemission spectroscopy systemwith a two-dimensional angle-resolved time-of-flight analyzer at SPring-8 BL07LSU, Manami Ogawa, Susumu Yamamoto, Yuka Kousa, Fumitaka Nakamura, Ryu Yukawa, Akiko Fukushima, Ayumi Harasawa, Hiroshi Kondo, Yoshihito Tanaka, Akito Kakizaki, and Iwao Matsuda, Rev. Sci. Instrum. 83, 023109-1, 023109-7 (2012).