# Surface-Site-Selective Study of Si(111)-7×7 Using Auger Photoelectron and Photoelectron Auger-Electron Coincidence Spectroscopy

Takuhiro Kakiuchi[*1], Narihiko Fujita[2], Shogo Hashimoto[2], Masatoshi Tanaka[2], and Kazuhiko Mase[3]

[1]Depatment of Chemistry, Faculty of Science, Ehime University, 2-5 Bunkyocho, Matsuyama, Ehime 790-8577, Japan

[2]Department of Physics, Faculty of Engineering, Yokohama National University, 79-5 Tokiwadai, Hodogaya-ku, Yokohama 240-8501, Japan

[3]KEK-PF, Tsukuba, Ibaraki 305-0801, Japan

## Introduction

Local valence electronic structures of specific sites of surfaces and interfaces of semiconductor are very important in fundamental surface science and semiconductor industry. Core-Valence-Valence Auger photoelectron coincidence spectroscopy (*CVV* APECS) provide us with information on the local valence electric structures at specific sites, when the energy resolution of analyzer for photoelectrons is better than the surface core-level shift [1]. On the other hand, photoelectron Auger-electron coincidence spectroscopy (PEACS), where the *CVV* Auger electrons with a specific kinetic energy are detected by an electron energy analyzer as trigger while photoelectrons in core photoelectron region are measured by another electron energy analyzer, provide us with very surface-sensitive photoelectron spectrum (PES) [2]. The escape depth ($ED_{PEACS}$) of electrons measured in PEACS is shorter than conventional synchrotron radiation photoelectron spectroscopy (SR-PES). The $ED_{APECS}$ is given by following equation;

$$\frac{1}{ED_{PEACS}} = \frac{1}{\mu_{Pe}} + \frac{1}{\mu_{Ae}}, \; \mu_{Pe} = \lambda_{Pe}\cos\theta, \; \mu_{Ae} = \lambda_{Ae}\cos\theta \; - (1),$$

where $\lambda$ and $\theta$ denote the inelastic mean free path (IMFP) and the emission angles of the detected electrons, respectively [3]. The $ED$ in APECS is also estimated by the same equation. In this study we investigated local valence electronic structures of a Si(111)-7×7 surface using APECS and PEACS.

## Results and discussion

Figure 1 (a) shows a Si-$L_{23}VV$-Si-2p APECS measured in coincidence with Si $2p_{3/2}$ photoelectron of relative binding energy of -0.45 eV, which emitted from the rest-atom sites on Si(111)-7×7 (filled squares with error bars). The width of the APECS in Fig. 1 (a) is much narrower than those of conventional Si-$L_{23}VV$ Auger electron spectrum (open circles, singles AES), indicating the high purity of the Si-$L_3VV$ AES component of the rest-atoms. The highest peak of Si-$L_3VV$ AES of the rest-atom is shifted by about 1 eV to the higher kinetic energy side relative to that of the singles AES. The results indicate that the binding energy of valence electron band with the highest density of the rest-atoms shifts by a several hundreds meV to lower binding energy side relative to those of the other surface sites.

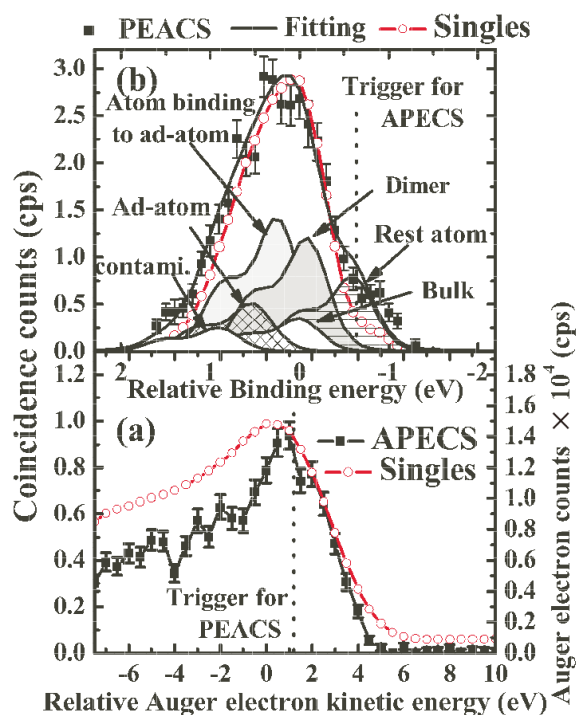Figure 1 (b) shows the Si-2p-Si-$L_{23}VV$ PEACS measured in coincidence with Si-$L_{23}VV$ AES of relative



**Fig. 1** (a) Si-$L_{23}VV$-Si-2p APECS and (b) Si-2p-Si-$L_{23}VV$ PEACS.

kinetic energy +1.1 eV (filled squares with error bars). The main peak of the PEACS shifts to higher binding energy side relative to that of conventional Si-2p PES (open circles, singles PES). As the result of a fitting procedure, the total area of surface components constituting Si-2p PES is observed to be increased by about 30%. Si-2p-Si-$L_{23}VV$ PEACS is also used to identify negatively or positively charged components..

## References

[1] R. A. Bartynski *et al.*, Phys. Rev. Lett. **68**, 2247 (1992).

[2] G. Stefani *et al.*, J. Electron Spectrosc. Relat. Phenom. **127**, 1 (2002).

[3] G. A. Sawatzky: in *Auger electron spectroscopy* eds. C. L. Briant and R. P. Messer (Academic Press, San Diago, 1988) Chap. 5, p. 167-243.

* tkakiuchi@chem.sci.ehime-u.ac.jp