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Photoemission Study on the Surface Photovoltage Effect For Si(111) Surface

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Introduction

Recently, the research on the surface photovoltage (SPV) has been performed at super-ACO in France using the FEL light [1]. In the study, it was observed that the band bending is decreased when the synchronized FEL light and SR are irradiated for Si(111) 2×1 and GaAs-Ag surface. At UVSOR, SPV for GaAs surface was also observed using synchronized laser light and SR [2]. In addition, we observed SPV for Si(111) surface using CW laser light [3]. In these cases, SPV is induced to decrease the band bending between semiconductiong surface and bulk. The mechanism of SPV is explained by a model that the carrier induced by laser light transfers to the surface. However, it is not clear whether SPV is associated with the surface state. Moreover, it is not clear whether the same senario is applied in the case of the metallic surface or in the case of the semiconducting surface. In order to investigate the relationship between SPV and the surface state, and between SPV and the carrier concentration, we have performed the photoemission study on the surface photovoltage for Si(111) surface.

Experimental

The detailed experimental setup including the optical alignment was described in Ref. 3. SPV was obtained by measuring the photoemission spectra at BL-16B and 18A. Total instrumental energy resolution at 90K was 0.1~0.3 eV, depending on the photon energy ($h\alpha$) in the energy range of 50~130 eV. The clean surface was obtained by annealing the sample at ~1473K using the laser light (Nd-YAG laser, $h\alpha$ = 1.165 eV) and checked by LEED. The base pressure was ~2×10^{-8} Pa.

Results and Discussion

Figure 1 shows the Si 2*p* core-level photoemission spectra (closed circle) for n- (P-doped, 9-14   cm) and p-type (B-doped, 10-20 cm) Si(111) surface at 90K, respectively. Under the laser light irradiation, the photoemission spectra (open circle) for the n-type (p-type) Si(111) surface shift to higher (lower) binding energy side. The shift direction for the n- and p-type Si(111) surface was opposite. It is considered that the observed rigid shift is caused by SPV induced by the laser light irradiation.

Figure 2 shows the valence band photoemission spectrum for $\sqrt{3}\times\sqrt{3}$ Si (111)-Bi surface (n-type, P-doped 9-14   cm) at room temperature. For the $\sqrt{3}\times\sqrt{3}$ Si(111)-Bi surface, it is known that the surface state near the Fermi level disappears and the band gap is open. Under the laser light irradiation, the photoemission spectrum for the $\sqrt{3}\times\sqrt{3}$ Si(111)-Bi surface shifts to higher binding energy side by ~0.2 eV. The shift is identical to that for the clean 7×7 Si(111) surface. This means that SPV is not associated with the surface state in this system.

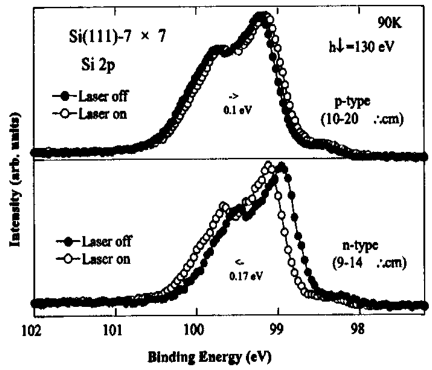

Fig. 1 Si 2*p* core-level photoemission spectra for the n- and p-type Si(111) surface with laser light irradiation and without laser light irradiation.

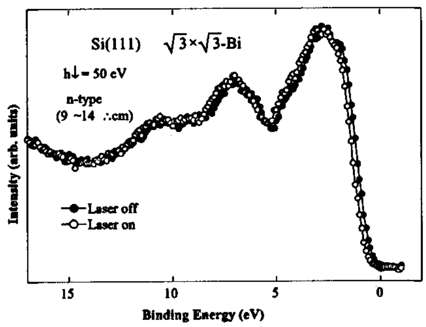

Fig. 2 Valence band photoemission spectra for Si(111) $\sqrt{3}\times\sqrt{3}$-Bi surface with laser light irradiation and without laser light irradiation.

References

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