Investigation of Conduction Band Offset at *n*-Si/*n*-Ga_2O_3 Heterojunction Fabricated by Surface-Activated Bonding

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Introduction

For Ga_2O_3 power devices, fabricating heterojunctions with other materials is one of the possible solutions to compensate for shortcomings of the absence of *p*-type conductivity. Si/Ga_2O_3 heterojunctions are of special interest, owing to their complementary material properties. However, it is difficult to form high-quality heterojunctions between them by conventional epitaxial growth due to large mismatches in their lattice constants and thermal expansion coefficients. Surface-activated bonding (SAB) can be expected as an alternative method since it is room-temperature processable and thus has a high tolerance for the mismatches. At the last JSAP Autumn Meeting, *n*-Si/*n*-Ga_2O_3 heterojunctions fabricated by SAB were reported [1]. In this presentation, we report on investigation of the conduction band offset (ΔE_C) at the heterointerface based on the electrical properties.

Results

A schematic of the *n*-Si/*n*-Ga_2O_3 heterostructure is depicted in Fig. 1(a). Net donor densities of the Si and Ga_2O_3 layers were 2.0×10^{18} and 2.0×10^{17} cm^{-3}, respectively. Rectifying current density–voltage (*J*–*V*) characteristics were obtained, suggesting an existence of an energy barrier in the electron transport path. The barrier height ($q\phi_b$) was analyzed based on reverse-bias *J*–*V* characteristics in the measurement temperature range of 23°C–200°C. Note that in this study, only the thermionic emission process was considered for the $q\phi_b$ extraction since the tunneling process should be negligible due to thick depletion regions formed at both Si and Ga_2O_3 sides, which were associated with negatively charged interface states. Figure 1(b) plots estimated $q\phi_b$ as a function of reverse voltage (V_{rev}). The $q\phi_b$ decreased with decreasing V_{rev} and saturated at around 0.25 eV for $V_{rev} < -9$ V.

The $q\phi_b$ saturation can be explained as follows. The $q\phi_b$ consists of ΔE_C, the built-in potential in Si ($qV_{bi,Si}$), and an energy difference between the Fermi level and the conduction band minimum of Si (δ_{Si}) as shown in Figs. 2(a) and 2(b). The ΔE_C and δ_{Si} are constant, while the $qV_{bi,Si}$ depends on V_{rev}. In the range of -9 V $< V_{rev} < 0$ V, the $qV_{bi,Si}$ gradually decreased with decreasing V_{rev} and became zero at $V_{rev} \sim -9$ V, indicating that the flat-band condition was obtained in the Si at the $V_{rev} \sim -9$ V [Fig. 2(b)]. For further decreasing V_{rev} from –9 V, two-dimensional electron gas could be formed at the heterointerface; as a result, the $q\phi_b$ stayed almost unchanged at $\Delta E_C + \delta_{Si}$. From the discussion, the ΔE_C was estimated to be 0.18 eV, considering $\delta_{Si} = 0.07$ eV.

Acknowledgment

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[1] Z. Wang, D. Takatsuki, J. Liang, N. Shigekawa, and M. Higashiwaki, the 82nd JSAP Autumn Meeting 2021, 13p-S201-5.

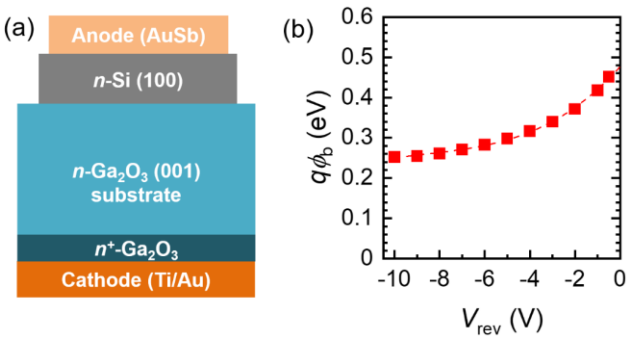

FIG. 1. (a) Schematic of *n*-Si/*n*-Ga_2O_3 heterostructure and (b) estimated $q\phi_b$ at its heterointerface as a function of V_{rev}.

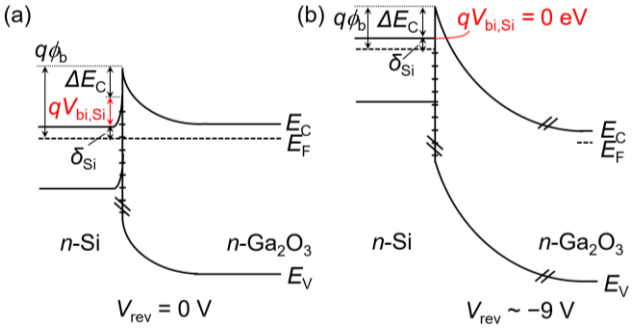

FIG. 2. Schematic energy band diagrams of *n*-Si/*n*-Ga_2O_3 heterostructure at (a) $V_{rev} = 0$ V and (b) ~ –9 V.