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結晶性 AlO_x 層上への GaAs の再成長

Epitaxial regrowth of GaAs layer on crystalline AlO_x thin films

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We have studied the preparation and characterization of a crystalline AlO_x tunnel barrier with the aim to develop a suitable insulating oxide layer for devices based on III-V compound semiconductors. The key point to access this problem is suppression of As vacancy generation and dangling bonds caused by the oxidation process. We have reported the preparation and characterization of a high quality, crystalline AlO_x ultra-thin layer (x-AlO_x) on a GaAs surface [1]. Our approach consists of two steps: epitaxial growth of an Al layer with carefully controlling the layer thickness, and post-oxidation of the Al epilayer at room temperature. Reported in this paper is the epitaxial growth of GaAs layer on a clean surface x-AlO_x

Process for the preparation of an x-AlO_x layer with molecular beam epitaxy (MBE) is shown schematically in Fig. 1(a): it consists of four steps: (i) epitaxial growth of a 5.5-Å thick Al layer on GaAs at RT in a MBE growth chamber, (ii) oxidation of the first Al layer in dry air for over 10 hours at atmospheric pressure in an entry chamber, and (iii) deposition of a second, 2.3-Å thick Al layer in a growth chamber, and (iv) final oxidation under the same condition as the preceding oxidation. The RHEED patterns are shown in Fig. 1(b) in accordance with those four steps. Despite of the oxidation process, crystalline feature has been preserved throughout the entire process. Cross sectional TEM images and EELS depth profile analyses both confirm the formation of a crystalline γ–AlO_x layer. The *C-V* characteristics of the structure consisting of 100-nm Al / 1-nm x-AlO_x / 300-nm *n*-GaAs / *n*-GaAs(001) exhibit the behavior which is typical for MIS structure. Using admittance spectra obtained by the *C-V* measurements, the interface trap density is estimated to be $D_{it} \sim 3 \times 10^{11}$ $cm^{-2}eV^{-1}$[2]. The large barrier height and low D_{it} both indicate the realization of high quality an x-AlO_x layer and clean interface.

Epitaxial regrowth of GaAs layer on a surface x-AlO_x through the in-situ UHV process has also been studied. RHEED pattern are shown in Fig.1 (d). When the substrate temperature increased up to 510 °C after the formation of an x-AlO_x layer at RT, RHEED patterns become brighter with a clear diffraction pattern. Spatial separation between streaks preserves that of the AlO_x. When the GaAs growth is started, a clear GaAs β(2×4) streak patterns appears immediately. These results strongly suggest that a thin x-AlO_x layer can be buried into fully-epitaxial III-V semiconductor structures.

[1] N. Nishizawa *et al.*, J. Appl. Phys. **114,** 033507 (2013).　[2] N. Nishizawa *et al.*, 61st JSAP Spring meeting, 18p-PG6-9 (2014).

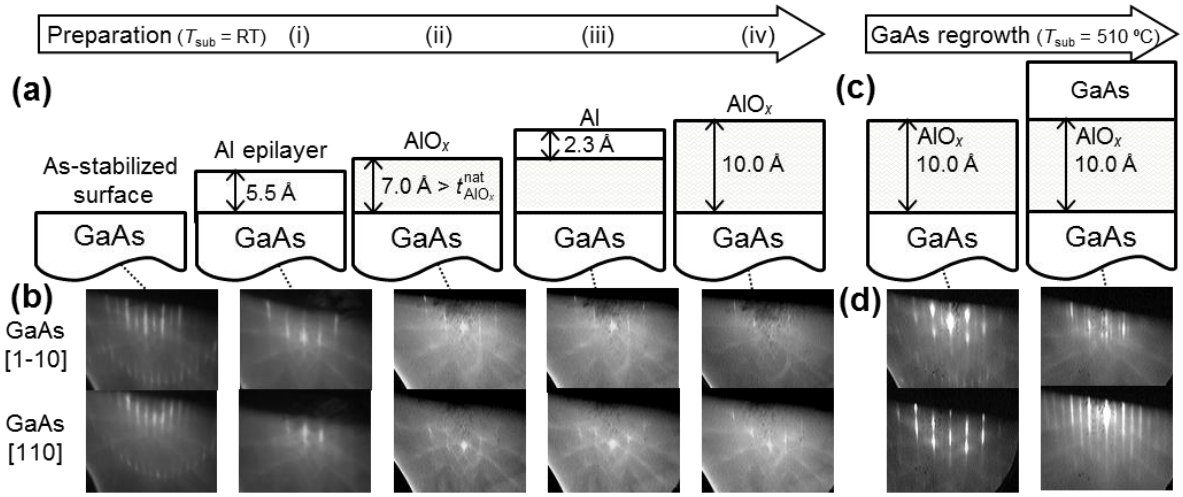

Fig.1 (a),(c) Schematic process flow to form a x-AlO_x and to re-grow GaAs layer on x-AlO_x. (b),(d) RHEED patterns observed along two orthogonal azimuths, GaAs [110] and [110] in accordance with process steps.

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