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MBE による GaAs 上への極薄結晶性 AlO_x トンネルバリヤー層の形成

Formation of an ultra-thin, crystalline AlO_x tunnel layer on GaAs by MBE

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Being inspired by the development of the crystalline MgO tunnel barrier in spintronics [1, 2], we have studied the preparation and characterization of a crystalline AlO_x tunnel barrier with the aim to develop a sound oxide insulator 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. Reported in this paper is the preparation and characterization of a high quality, crystalline AlO_x ultra-thin layer on a GaAs surface [3]. Our approach consists of two steps: epitaxial growth of an Al layer with carefully controlled layer thickness and post-oxidation of the Al epilayer at room temperature.

The crystalline AlO_x (x-AlO_x) layer has been prepared by using a molecular beam epitaxy (MBE) system. As schematically shown in Fig. 1(a), formation of a x-AlO_x layer consists of four steps; (i) epitaxial growth of a 5.5-Å thick Al layer at RT in a MBE growth chamber, (ii) oxidation of the first Al layer in dry air for 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 most important parameter in this process is the thickness of epitaxial Al layer, being 5.5 Å. This value has been selected on the basis of the thickness of naturally oxidized layer at the surface of an Al single crystal [4]: the first Al epitaxial layer having 5.5-Å thickness will fully be oxidized whereas a GaAs surface is hardly oxidized. 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.

Carrier transport across the crystalline AlO_x layer was assessed by studying low-temperature *I*–*V* characteristics of a device consisting of 100-nm Al/1-nm x-AlO_x/300-nm *n*-GaAs/*n*-GaAs substrate, in comparison with that obtained from the Al/n^+-GaAs Schottky barrier. A rather symmetric *I*–*V* curves strongly suggests that the carrier transport is dominated by the tunneling through an x-AlO_x layer. Fitting with Simmons' equation [5] to the *I*–*V* curves of the forward bias region has yielded the barrier height of 2.8 eV with barrier thickness of 1.0 nm. These values indicate the realization of high quality an x-AlO_x layer.

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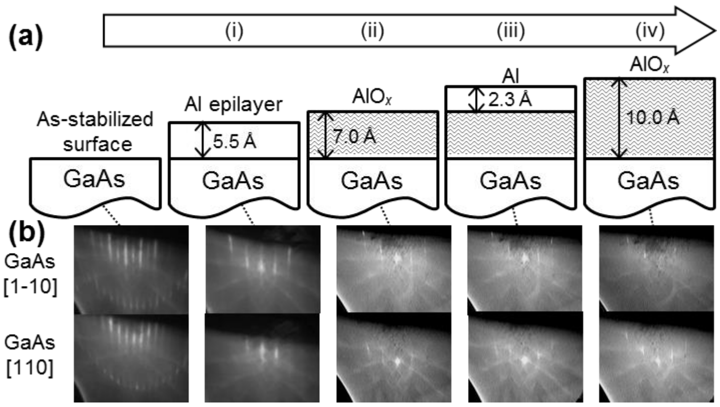

Fig.1 (a) Schematic process flow for the formation of a crystalline AlO*x*. (b) RHEED patterns for each step observed along two orthogonal azimuths, GaAs [$1\bar{1}0$] and [110] in accordance with process steps.

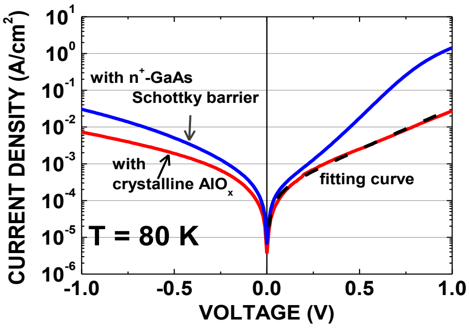

Fig.2: *I-V* characteristics of the devices with a crystalline AlO_x layer (red line) and n^+-GaAs Schottky barrier (blue line). A dashed black line represents the *I-V* curve obtained from model calculation based on Simmons' equation [5].