B—6—2 In Depth Profiles of Oxide Films on GaAs Studied by XPS

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With increasing use of GaAs devices, surface passivation technique has long been sought. The thermal and the anodic oxidation of GaAs have recently been investigated[1-3]. The purpose of the present investigation is to study the quantitative chemical depth profiles of the oxide films produced by the thermal and the anodic oxidation of GaAs by means of X-ray photoelectron spectroscopy (XPS) in conjuction with argon ion sputtering. The XPS experiments were performed in the pressure of $\sim 8\times10^{-8}$ Torr by using Dupont-ESCA 650B system with MgK_α radiation of 9 KV x 28 mA. The binding energy of the oxide products were referenced to the $Au4f_{7/2}$ level of thin Au film evaporated on the sample at 84.0 eV. Argon ion sputtering was performed with ion current of $\sim$0.5 μA at 5 KeV and incident angle of 75°. The (110) and ($\bar{1}\bar{1}\bar{1}$) GaAs of chemical etched wafers were used for the thermal and the anodic oxidation, respectively. The samples used in this study are summarized in Table 1. The samples were sputtered step by step at a rate of $\sim$20 Å/min. Fig. 1 shows a typical photoelectron spectra of As3d and Ga3d from GaAs and oxidized GaAs. The spectra (a)-(e) in Fig. 1 originated from the sample (a)-(e) in Table 1, respectively. The broken lines (1), (2), (3), (4) and (5) show the position of the peaks from a cleaved GaAs, sputtered GaAs, Ga_2O_3, As_2O_3 and As_2O_5, respectively[3]. A spectrum was decomposed to the basic spectra from a clean GaAs and a gallium (or arsenic) oxide. Then we obtained the chemical concentration depth profiles of the oxidized GaAs by using the relative atomic sensitivity k_i ($k_{Ga3d}=1$, $k_{As3d}=1.5\pm0.1$ and $k_{O1s}=1.9\pm0.2$). The typical chemical depth profiles of the sample (a), (c), (d) and (e) are shown in Fig. 2. The Ga3d spectra in Fig. 1 show that the gallium oxide in both the thermally and the anodically oxidized GaAs is Ga_2O_3 throughout the oxide films. The O/Ga ratio of $\sim$1.5 in the oxide (Fig. 2(a)) also supports above assignment. The O1s spectra from those oxidized GaAs have a peak at a binding energy of 531.2-531.3 eV, which is interpreted as due to the lattice oxygen in Ga_2O_3 and/or As_2O_3. In the case of thermal oxidation below 530°C,

Table 1 Oxidized GaAs samples

Sample	Oxidation condition
(a)	thermal: at 530°C in air for 1/2 hour
(b)	thermal: at 900°C in air for 1/3 hour
(c)	thermal: at 530°C in 100 atm. O_2 with As for 1 hour
(d)	anodic:: AGW method, as grown
(e)	anodic : AGW method, annealed at 350°C in H_2 for 3 hour

Fig. 1. Photoelectron spectra from variously oxidized GaAs

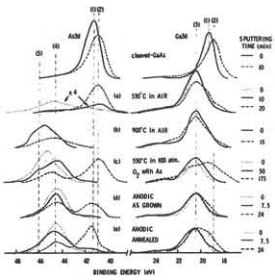
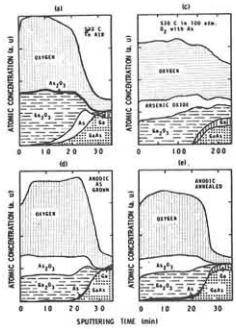


Fig. 2. Chemical depth profiles through thermally and anodically grown oxide on GaAs



as the thickness of the oxide increased the amount of arsenic oxide in the products became smaller and the elemental As accumulated at the oxide-GaAs interface increased as shown in Fig. 1-(a) and Fig. 2-(a). When GaAs was heated at 900°C (sample-(b)), the As/Ga ratio of the oxide film became larger than that of the sample-(a) as shown in Fig. 1-(b). In order to prevent the evaporation of arsenic oxide, sample-(c) was heated with As in 100 atm. O_2. Fig. 1-(c) and Fig. 2-(c) show that the evaporation of arsenic oxide is inhibited considerably. The binding energies of the As3d lines from the thermally grown oxide contained significant amount of arsenic oxide (sample-(b) and (c)) are 45.4±0.1 eV (probably due to $GaAsO_4$ and/or As_2O_5-As_2O_3) for the spectra of virgin samples and 44.6±0.2 eV (due to As_2O_3) for the spectra after argon sputtering. The spectra of Fig. 1-(d) and (e) show that the products of the anodic oxidation of GaAs are essentially Ga_2O_3 and As_2O_3 throughout the oxide films. The fact that the atomic ratio of O/(Ga+As) in the oxide is about 1.5 (see Fig. 2-(d) and (e)) supports above identification. The annealing of the anodically oxidized GaAs changed the ratio of (Ga/As/O) in the oxide film from (1/0.61/2.8) to (1/0.55/2.4) as shown in Fig. 2-(d) and (e). The elemental As was scarcely detected for the anodically oxidized GaAs. The oxide-GaAs interface widths for about 500 Å thick oxide were ∿200 Å (sample-(a)), ∿95 Å (sample-(d)) and ∿70 Å (sample-(e)), respectively.

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