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
investigated1-3. The purpose of the present investigation is to study the quan-
titative 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
conjunction with argon ion sputtering. The XPS experiments were performed in the
pressure of 8x10^{-8} Torr by using Dupont-ESCA 650B system with MgKα 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 sput-
tering was performed with ion current of \sim0.5 nA at 5 KeV and incident angle of
75°. The (110) and (111) GaAs of chemical etched wafers were used for the thermal
and the anodic oxidation, respectively. The samples used in this study are sum-
marized in Table 1. The samples were sputtered step by step at a rate of \sim20 Å/min.

Fig. 1 shows a typical photoelectron spectra of As3d and Ga3d from GaAs and ox-
idized 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 posi-
tion of the peaks from a cleaved GaAs, sputtered GaAs, Ga2O3, As2O3 and As2O5,
respectively5. 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 (k_{Ga3d}=1, k_{As3d}=1.5±0.1 and k_{O3s}=1.9±0.2). 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 Ga2O3 throughout the oxide films. The O/Ga ratio of \sim1.5 in the oxide (Fig. 2(a)
) also supports above assignment. The Ols 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 Ga2O3 and/or As2O3. In the case of thermal oxidation below 530°C,

<table>
<thead>
<tr>
<th>Sample</th>
<th>Oxidation condition</th>
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<tbody>
<tr>
<td>(a)</td>
<td>thermal: at 530°C in air for 1/2 hour</td>
</tr>
<tr>
<td>(b)</td>
<td>thermal: at 900°C in air for 1/3 hour</td>
</tr>
<tr>
<td>(c)</td>
<td>thermal: at 530°C in 100 atm. O2 with As for 1 hour</td>
</tr>
<tr>
<td>(d)</td>
<td>anodic: AGW method, as grown</td>
</tr>
<tr>
<td>(e)</td>
<td>anodic: AGW method, annealed at 350°C in H2 for 3 hour</td>
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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. O₂. 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 GaAsO₄ and/or As₂O₅-As₂O₃) for the spectra of virgin samples and 44.6±0.2 eV (due to As₂O₃) 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 Ga₂O₃ and As₂O₃ 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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References