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Characterization of the Oxide Film Obtained by Wet Oxidation of $Al_xGa_{1-x}As$ with x=0.55-0.99

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Introduction

Wet oxidation of Al-rich AlGaAs is a well-established technique for its application of semiconductor optical devices especially for vertical cavity surface emitting laser.[1,2] The large selectivity between AlGaAs and GaAs provides an discretely controlled insulating film monolithically multilayered with GaAs. Further, the large refractive index contrast between GaAs realizes strong optical confinement with the multilayer structure. Recently, we proposed a laser structure embedded in 2-dimensional photonic crystal slab.[3] We employed AlO_x for the clad layer in contrast to the dominantly employed air-bridge, expecting the greater mechanical robustness and thermal conductivity. To design those device structures, the utilization of accurate physical parameters is indispensable. It is accepted that the behavior of oxidation as well as the properties of the resulting layers strongly depend on the Al concentration of initial $Al_xGa_{1-x}As$.[1,4] However, detailed investigation of the Al concentration dependence of the properties of wet oxidized AlGaAs have not carried out up to now.[1,4] In this report, we make a direct investigation on the characteristics of oxide film obtained by the wet oxidation of $Al_xGa_{1-x}As$ precisely varying its x between 0.55-0.99.

Experimental

Samples used for this study were grown on undoped GaAs substrate by molecule beam epitaxy. First, 250 nm GaAs buffer layer was grown. Subsequently, 300 nm $Al_xGa_{1-x}As$ was grown on the top of the structure. The Al composition was varied between 55 % and 99 %. The samples were wet oxidized in a furnace at 410 ℃ for 120 min. Note that the oxidation was carried out mainly from the surface because of the sample structure having the AlGaAs layer on the top without cap layer. The layers can hence be easily fully oxidized, which is suitable for the investigation of its native characteristics proceeded in this study. Water in a bubbler was kept at 90 ℃ and steam was carried into the furnace by N_2 gas. Structural characteristics of the samples were examined by x-ray diffraction (XRD), cross-sectional scanning electron microscope (SEM), and atomic force microscope (AFM). The optical characteristics of the samples were investigated by spectroscopic ellipsometry (SE).[4] SE measurements were carried out at wavelengths in the range between 400 nm and 900 nm with the incident angle of 70^{O}. Cauchy model was applied to determine the refractive index assuming the single oxide layer structure on the top of the thick GaAs substrate.[5] The absorption by the oxide film was ignored considering the measurement wavelengths. Surface roughness of the samples was ignored because of the smooth surface examined by AFM. The thickness extracted from the SE measurement was compared with the values obtained by SEM observation.

Result and Discussion

Figure 1 shows an appearance of the samples after the wet oxidation. As clearly seen in the figure, the appearance gradually changes probably reflecting the differences of the refractive indexes between samples.

Figure 2 shows the XRD curve for samples having its Al concentration x of 0.55 and 0.86 before and after oxidation. For the sample having x=0.55, we observe a main peak related to GaAs associated with a peak stemmed from AlGaAs. The curve shows no deviation before and after oxidation, indicating the negligible progress of the oxidation for this sample. In contrast, for the sample x = 0.86, the peak related to AlGaAs becomes undetectable after oxidation. This indicates the $Al_xGa_{1-x}As$ lost its crystalline structure, predicting the efficient formation of oxides. The similar behavior was confirmed for the samples having it's Al concentration x greater than 0.80, agreeing well with the reported border of 0.85.[1]

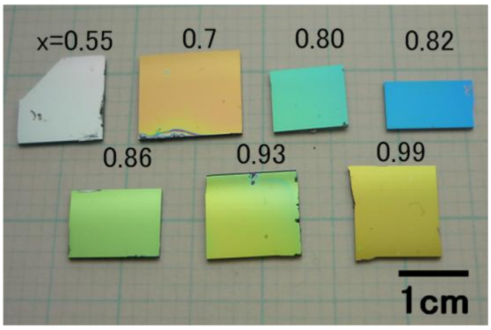

Fig. 1. Appearance of the samples after oxidation.

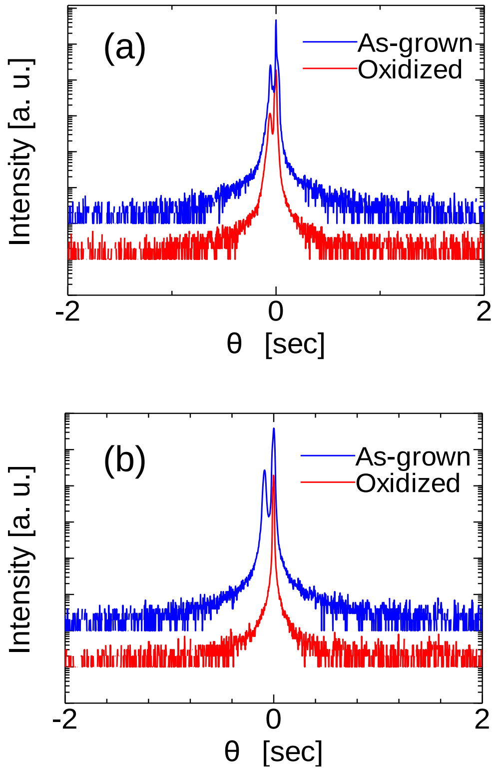

Fig. 2. XRD θ–2θ scans for the $Al_xGa_{1-x}As$ samples of (a) x = 0.55 and (b) 0.86 before and after oxidation.

Figure 3 shows wavelength dispersions of the refractive index of the oxide layer for the samples having x larger than 0.80. The values were systematically changed between 1.59 and 1.68 depending on the Al concentration and wavelengths, agreeing well with the previous reports for a specific Al concentration.[4] The refractive indexes decreased with increasing Al composition.[6,7]

Figure 4 shows thickness of oxidized samples measured by SE and SEM. The samples shows mostly identical

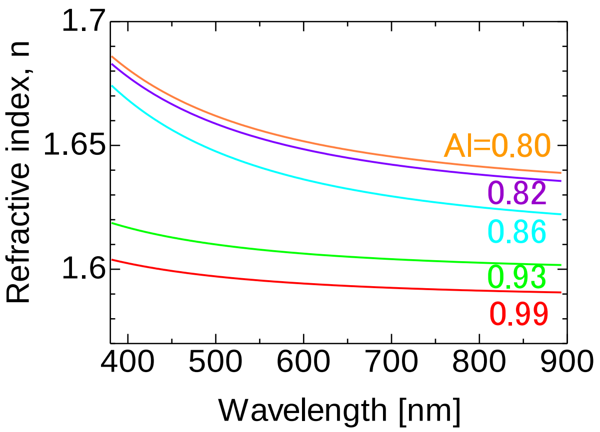

Fig. 3. Wavelength dispersions of the refractive index for the oxide layers investigated. The initial Al concentration were indicated in the figure.

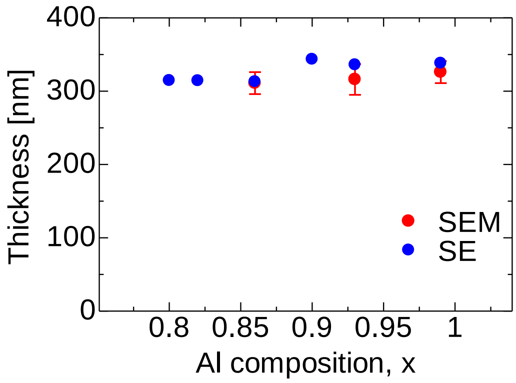

Fig.4. Thickness of oxidized samples.

thickness between x=0.8 and 0.99, suggesting the small deviation of the strain conditions between those even after oxidation.[1]

Summary

We have investigated the characteristics of oxide films obtained by the wet oxidation of Al-rich $Al_xGa_{1-x}As$ with x= 0.5 - 0.99. The efficient oxidation was observed for the samples having the Al concentration x greater than 0.8, examined by the appearance and XRD curve. The oxidized layer showed clear changes of their refractive indexes between 1.59 and 1.68, depending on the wavelengths and Al concentration. Further, the layers show small deviations of their thicknesses, certificating the similar strain conditions between those. The results provide the applicability of those layers for the optical devices, enabling the designing of the device structure with the obtained parameters.

Acknowledgement

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