Thermal Oxidation of III-V Materials and Heterostructures

R.J. Hussey, R. Driad*, G.I.Sproule, S. Moisa, J.W. Fraser, Z.R. Wasilewski, J.P. McCaffrey[+], D. Landheer and M.J. Graham
Institute for Microstructural Sciences
National Research Council of Canada
Ottawa, Canada K1A 0R6

*Current address:
Nortel Networks
3500 Carling Avenue
Ottawa, Canada K2H 8E9

[+]Current address:
Institute for National Measurement Standards
National Research Council of Canada
Ottawa, Canada K1A 0R6

III-V materials, unlike silicon, do not form high-quality native oxides and in some ways, this has hampered the development of optoelectronic technology. The oxidation of III-V compounds, particularly of GaAs, has been studied extensively in the past, however, in efforts to try to produce successful metal-oxide-semiconductor field-effect transistors (MOSFETs). Emphasis was placed on anodic oxidation. More recently, both anodic and thermal oxidation data for AlGaAs and quaternary systems have been reported (1-7) and the Al-containing oxides have been found to possess good insulating characteristics (3,4). The oxidation methodology can also be extended to InP-based devices where, e.g., InAlAs could serve as the oxidation layer (8). Thus, Al_2O_3-containing layers offer promise as insulators in III-V technology.

This paper focuses on the characterization of thermal oxides on GaAs and heterostructures for GaAs- and InP-based devices, for example, those used in vertical cavity surface emitting lasers (VCSELS) or heterojunction bipolar transistors (HBTs) which are comprised of AlGaAs sandwiched between GaAs layers or InAlAs sandwiched between InGaAs and/or InP layers. The relative oxidation rates of planar surfaces of GaAs and AlGaAs, as well as the relative lateral oxidation rates in GaAs- and InP-based heterostructures have been determined. The objective is to preferentially oxidize AlGaAs or InAlAs to produce an insulating alumina layer in device structures in an attempt to improve device performance.

GaAs (100), ~ 2.5 μm-thick layers of $Al_{0.8}Ga_{0.2}As$, GaAs-based heterostructures (GaAs/$Al_xGa_{1-x}As$/GaAs, with x values of 0.25 and 0.75), and InP-based heterostructures (InGaAs/InAlAs/InGaAs/InP) were thermally oxidized over the temperature range 300-500°C in a variety of environments - pure oxygen and moist air (air bubbled through H_2O at 25° or 95°C) and moist nitrogen (N_2 bubbled through H_2O at 95°C).

Results will be presented on the chemical characterization of the films, and the relative oxidation rates of GaAs and AlGaAs, and of GaAs- and InP-based heterostructures. The kinetics and mechanism of oxidation depend on the particular oxidant. Selective oxidation of Al-containing layers is optimized by oxidation in moist nitrogen. Oxide compositions and morphology of the various layers have been determined by Auger, XPS, SEM and TEM. Electrical measurements will be presented on oxidized InAlAs/InGaAs heterostructure diodes.

REFERENCES

1. K. Smekalin, G. Zhang and J. Lammasniemi, J. Electrochem. Soc., **141**, L97 (1994).
2. P. Schmuki, R.J. Hussey, G.I. Sproule, Y. Tao, Z.R. Wasilewski, J.P. McCaffrey and M.J. Graham, Corros. Sci., **41**, 1467 (1999).
3. F.A. Kish, S.J. Caracci, N. Holonyak, Jr., K.C. Hsieh, J.E. Baker, S.A. Maranowski, A.R. Sugg, J.M. Dallesasse, R.M. Fletcher, C.P. Huo, T.D. Osentowski and M.G. Crawford, J. Electron. Mat., **21**, 1133 (1992).
4. U.K. Mishra, P. Parikh, P. Chavarkar, J. Yen, J. Champlain, B. Thibeault, H. Reese, S.S. Shi, E. Hu, L. Zhu and J. Speck, **IEDM'97**, 21.1.1.
5. R.S. Burton and T.E. Schlesinger, J. Appl. Phys., **76**, 5503 (1994).
6. H. Nickel, J. Appl. Phys., **78**, 5201 (1995).
7. C.I.H. Ashby, J.P. Sullivan, K.D. Choquette, K.M. Gerb and H.Q. Hou, J. Appl. Phys., **82**, 3134 (1997).
8. H. Gebretsadik, K. Kamath, W-D. Zhou, P. Bhattacharya, C. Caneau and R. Bhat, Appl. Phys. Lett., **72**, 135 (1998).