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Properties of InAlP Native Oxides Supporting MOS Inversion-layer Behavior

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GaAs remains the most widely employed semiconductor for high-speed electronic applications due to its crystal growth and processing maturity, and wide array of compatible, high electron mobility alloys of varying bandgap that can be grown epitaxially on its surface. However, its incapacity to produce a native oxide of electrical characteristics similar to those of SiO_2 on Si, has hindered its development in low-power applications. Native oxides produced by the wet oxidation of epitaxial AlGaAs suffer from high leakage currents and As-related traps. However, wet thermal native oxides of As-free $In_{0.485}Al_{0.515}P$ (lattice matched to GaAs) have been found to have excellent insulating properties and may provide a viable oxide for III-V MOS applications.[1],[2]

Two ~63 nm thick InAlP films, both with and without a 10 nm InGaP oxidation barrier, are grown by MOCVD on GaAs and surface-oxidized in water vapor (500 °C, 30-120 min). Fully oxidized (60 min), the films expand to 110 nm as revealed by transmission electron microscopy (TEM) and variable-angle spectroscopic ellipsometry (VASE) measurements. Upon etching the oxides back to 49 nm for more direct comparison to oxidized AlGaAs samples, the leakage increases only slightly (2-3X) to ~6e-10 A/cm^2 at 5 V, still about 4 orders of magnitude less than our best leakage current in comparable thickness $Al_{0.98}Ga_{0.02}As$ native oxides. Breakdown fields for these thin InAlP native oxides are in the 5 MV/cm range – more than 1.5 times higher than our AlGaAs oxides, and similar to those reported for $Ga_2O_3(Gd_2O_3)$.[3] However, leakage was found to increase significantly (to ~1.6e-2 A/cm^2) when the film was etched to ~25 nm, exposing a region which TEM imaging shows is filled with higher density precipitates.

We have reported[2] that high-frequency (1 MHz) and quasi-static C-V measurements on illuminated InAlP oxide MOS capacitors show clear signs of an inversion layer, dependent on oxidation time (optimal at 60 min), suggesting a relatively clean interface and possibly unpinned Fermi level. TEM studies show the oxidation front stopping within the InAlP just above the underlying interface in samples with or without an InGaP barrier, providing a clean semiconductor heterointerface at which the inversion layer likely forms. While unprotected GaAs oxidizes relatively quickly at these temperatures, its oxidation appears to be prevented (or greatly retarded) by the InAlP oxide “cap”. In contrast, the porous AlGaAs native oxides do not prevent GaAs oxidation. The InAlP oxide thus appears sufficiently dense (consistent with the observed diffusion-limited oxidation kinetics) to prevent the outdiffusion of Ga and As, as necessary for GaAs oxidation. Finally, TEM imaging shows that InAlP oxides on structures with the InGaP barrier layer have much smoother interfaces and greater thickness uniformity.

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[1] Adrian L. Holmes, Ph.D. Dissertation, The U. of Texas at Austin, December 1999.
[2] P. J. Barrios, D. C. Hall, G. L. Snider, T. H. Kosel, U. Chowdhury and R. D. Dupuis, in *State-of-the-Art Program on Compound Semiconductors (SOTAPOCS XXXIV)*, 199th Meeting of The Electrochemical Society (Washington, DC, March 25 - 30, 2001).
[3] M. Hong, J. Kwo, A. R. Kortan, J. P. Mannaerts, and A. M. Sergent, Science **283**, 1897 (1999).