Electrical Properties and Microstructure of InAlP Native Oxides for MOS Applications:

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Native oxides of $In_{0.485}Al_{0.515}P$ have excellent insulating properties and are capable of supporting inversion [1]. The leakage current density, J_L, increases by several orders of magnitude when 110 nm oxide films are thinned to ~25 nm, exposing a region with a high interfacial precipitate density [2]. Further studies are presented on the scalability of InAlP native oxides to thicknesses more suitable for MOS device applications as obtained by oxidizing thinner epilayers. Grown by MOCVD on GaAs substrates, the InAlP layers studied are 63, 31, 15, 8 and 5 nm thick. Fully wet oxidized at 500 °C, the films expand ~1.7X to corresponding oxide thicknesses of 110, 53, 26, 14 and 7 nm, measured by variable-angle spectroscopic ellipsometry (VASE). MOS capacitors fabricated with as-grown (AG) oxides formed from thinner InAlP layers have notably lower J_L than 110 nm films etched back to similar thicknesses: J_L=3x10^{-11} A/cm^2 (53 nm, AG) vs. 5x10^{-10} A/cm^2 (49 nm, etched), and 1x10^{-9} A/cm^2 (26 nm, AG) vs. 1x10^{-7} A/cm^2 (24 nm, etched), all at 0.4 MV/cm. At 1.9 MV/cm, a 10^6 disparity is seen: 6x10^{-9} A/cm^2 (26 nm, AG) vs. 9x10^{-3} A/cm^2 (24 nm, etched). Quasi-static C-V measurements show that both 53 nm and 26 nm oxides (AG) support inversion under illumination. J_L remains low for AG oxide films as thin as 14 nm (2x10^{-9} A/cm^2 at 0.4 MV/cm). Breakdown fields for oxides 14 nm and thicker are 3-5 MV/cm. The thinnest AG InAlP oxides (7 nm) show Schottky-diode-like behavior. I-V-T measurements suggest that thermionic emission is the dominant conduction mechanism, with an electron barrier height of ~1 eV calculated using a modified Norde method. From optical constants determined by VASE measurements, the InAlP oxide bandgap is determined from a Tauc plot to be 3.52eV. A comparison of bright-field STEM and Z-contrast images using a high-angle annular dark-field (HAADF) detector in the STEM mode for a 120 nm oxide (obtained by partially oxidizing a 1 μm thick InAlP layer) shows that precipitates are formed in the oxide with higher atomic number (Z) than the surrounding oxide, strongly suggesting that they are In-rich. We observe no such interfacial precipitates in bright-field TEM for 26 nm thick oxide (AG), which exhibits a 10^6 times lower leakage than its etched counterpart. We hypothesize that the degree to which the heavier and more slowly outdiffusing In accumulates near the interface during oxide growth, forming In-rich precipitates responsible for increased electrical conduction, is reduced by the shorter oxidation time of thinner InAlP films. In summary, native oxides of thin InAlP epilayers show considerable promise for MOS device applications and merit further study. [1] P. J. Barrios, D. C. Hall, G. L. Snider, T. H. Kosel, U. Chowdhury and R. D. Dupuis, State-of-the-Art Program on Compound Semiconductors XXXIV, Electrochem. Soc. Proc. vol. 2001-1, pp. 258-264. [2] P. J. Barrios, D. C. Hall, U. Chowdhury, R. D. Dupuis, J. B. Jasinski, Z. Liliental-Weber, T. H. Kosel, and G. L. Snider, paper DD4, 43rd Electronic Materials Conference (Notre Dame, IN, June 27-29, 2001).