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InAlP Native Oxide/GaAs MOS Heterostructure Interface State Density Measured by Impedance Spectroscopy

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In conventional GaAs-based MESFETs and HEMTs, use of Schottky gate contacts results in appreciable gate leakage current and limited gate voltage swing. An attractive alternative for low-leakage and high-power FETs is a metal-insulator-semiconductor (MIS) gate. However, GaAs-based MIS interfaces formed by oxidation of III-Vs have historically suffered from a high interface trap state density, N_{it}. We report the first N_{it} measurements of native-oxide $In_{0.49}Al_{0.51}P$/GaAs MOS capacitors, using bias- and temperature-dependent variable-frequency impedance spectroscopy. Our measurements indicate that InAlP oxide has a low leakage current density and a sufficiently low N_{it} to allow inversion to be observed [1], making it promising for devices.

InAlP native oxide/GaAs MOS capacitors were fabricated on an MOCVD-grown heterostructure consisting of 63 nm of InAlP on n-type GaAs. The InAlP was oxidized at 500 °C in an H_2O/N_2 ambient, resulting in a 114.6 nm thick oxide. The measured leakage current density was 8.6×10^{-10} A/cm^2 at 5 V bias, demonstrating the oxide's good insulating quality. An impedance spectroscopy technique has been developed to determine the properties of InAlP oxide/GaAs interface states. A new equivalent circuit model (extending the conventional model through added components that model the behavior of an interface layer and interface states) is used to aid the interpretation of the impedance measurements. Capacitor impedance (calibrated using on-wafer open/short/load compensation with a test signal level of 20 mV rms) was

measured on-wafer from 40 Hz to 10 MHz as a function of applied DC bias and temperature in a dark probing chamber.

The measured room-temperature impedance spectra show broad conductance peaks that shift to higher frequency as the bias is scanned from depletion through accumulation, indicating the interface states are distributed over the bandgap. Capacitors with areas from 130x130 μm^2 to 340x340 μm^2 were measured to verify scaling of the equivalent circuit. The bias-dependent equivalent circuit matches closely the measured capacitor impedances over the full range of bias and frequency, and shows the distribution of interface states with energy is approximately exponential, with a total N_{it} of $8x10^{11} cm^{-2}$ and an effective activation energy of E_a=0.34 eV.

The impedance spectra of capacitors have also been measured vs. temperature from 15-90 °C. For biases in accumulation, the measured conductance peak frequency increases with increasing temperature. From Arrhenius plots of the conductance peak frequency, an E_a=0.44 eV has been obtained (r=0.997), in good agreement with room-temperature bias-dependent impedance measurements. This indicates the extended circuit model with an exponential interface state distribution is consistent with both variable-bias and variable-temperature measurements.

In summary, an extended impedance spectroscopy technique has been developed and applied to characterizing trap densities and distributions at InAlP native oxide/GaAs interfaces, and promises to be a useful tool in the further optimization of these MOS structures for potential device applications.

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[1] P. J. Barrios, D. C. Hall, G. L. Snider, T. H. Kosel, U. Chowdhury and R. D. Dupuis, Proc. of the Intl. Symp.: III-Nitride Based Semiconductor Electronics and Optical Devices and Thirty-Fourth State-Of-The-Art Program On Compound Semiconductors (SOTAPOCS XXXIV), F. Ren, D.N Buckley, S. N. G. Chu, and S. J. Pearton, eds., Pennington, N.J.: The Electrochemical Society Proceedings 258 (2001).