Research Title: Passivation of InAs and GaSb with novel high $\kappa$ dielectrics

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InAs MOS devices with MBE-grown Gd$_2$O$_3$ passivation

InGaAs with high $\kappa$ dielectrics is now viable for complementary metal-oxide-semiconductor (CMOS) devices beyond the 15 nm node technology. Recently, intensive research activities for achieving low interface density of states and excellent performance of inversion-channel MOS field-effect transistors$^{[1-4]}$ have been put on In$_x$Ga$_{1-x}$As ($x$=0, 0.2, 0.53, 0.75), however, with less efforts on InAs.$^{[5]}$ Note that the latter has very high bulk electron mobility ($\sim$30000 cm$^2$V$^{-1}$s$^{-1}$) and saturation velocity ($\sim$8×10$^7$ cm/s). In this work, chemical and electronic characteristics on Al$_2$O$_3$/Gd$_2$O$_3$/InAs interface were studied using x-ray photoelectron spectroscopy (XPS). Electrical properties for MOSCAPs and depletion-mode MOSFETs were also studied.

The samples were grown by solid-source molecular beam epitaxy (MBE) on semi-insulating (100) GaAs substrate. The structure, following the growth sequence, consisted of a 200 nm-thick GaAs buffer layer, a 10 nm-thick AlAs transition layer, a 0.2 $\mu$m AlSb/ 1.3 $\mu$m Al$_{0.7}$Ga$_{0.3}$Sb composite buffer layer, a 20 nm AlSb barrier, and a 5 nm-thick InAs channel layer. A tellurium $\delta$-doping was placed at 25 nm below the InAs channel layer. The sample was then passivated by
This is the final report of a project in which chemical and electronic characteristics on Al2O3/Gd2O3/InAs interfaces were studied using x-ray photoelectron spectroscopy.
arsenic at low temperature and ex-situ transferred for deposition of high $\kappa$’s. An additional InAs layer (~2 nm) was freshly grown before the subsequent Gd$_2$O$_3$ (3 mono-layers) was e-beam evaporated to passivated the InAs surface; finally, followed by the atomic layer deposited Al$_2$O$_3$.

Energy-band offsets of the ALD-Al$_2$O$_3$/Gd$_2$O$_3$/InAs were obtained using XPS. The valence-band offset ~3.92 eV was determined by measuring the core level to valence band maximum binding energy difference from the XPS spectra, as shown in Fig. 1. With energy-band gaps of 0.35 and 6.7 eV for InAs and Al$_2$O$_3$, the important parameter for MOS devices, conduction-band offset ~2.43 eV, were determined.\textsuperscript{[6]} The sample was annealed in N$_2$-ambient at 300°C for 60 seconds before the process.

Gate-first process was used to fabricate the ring-gate device. Gate metal, Ti/Au, was first formed by a lift-off process. The ohmic metal was subsequently formed by gate oxide wet-etching, metal deposition and lift-off. The cross-section and top view of the device is shown in Fig. 2. MOS diodes fabricated via the same process exhibited C-V curves with minor dispersion, as shown in Fig. 3. A 12\textmu m-gate-length device demonstrates a saturation drain current ($I_{d\text{-sat}}$) of 45\textmu A/\textmu m (at $V_g$=2V and $V_d$=2V), and a transconductance of 18\textmu S/\textmu m (at $V_d$=2V).

References

Fig. 1 (a) XPS spectra of As 3$d$ CL and valence band of InAs film, Al 2$p$ and As 3$d$ CLs at ALD-Al2O3/Gd2O3/InAs interface, and Al 2$p$ CL and valence band of Al2O3 film. (b) Energy-band parameters

Fig. 2 (a) Cross-section and (b) schematic top-view of D-mode Al2O3/MBE-Gd2O3 (3MLs)/InAs MOSFET.

Fig. 3 (a) CV curve (b) Output characteristics $I_D$ vs $V_D$ and (c) transfer characteristics of depletion-mode $i$-InAs MOSFET with 12$\mu$m gate length.