Abstract #2193, 224th ECS Meeting, © 2013 The Electrochemical Society

Pre-ALD Trimethylaluminum Passivation of Al_2O_3/InGaAs(100) Interfaces

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Metal-oxide-semiconductor (MOS) field-effect devices combining III-V semiconductors and deposited high-κ dielectrics are attracting great interest because of their potential to achieve high carrier mobility and to suppress leakage current in highly-scaled devices. However, developing a thermally stable interface with a low density of electrically active defects between a high-k gate dielectric and a III-V channel has been a long-standing challenge.[1] In0.$_{53}$Ga$_{0.47}$As channels and atomic layer deposited (ALD) Al_2O_3 gate insulator layer are among the leading candidates for high-k/III-V n-channel MOS devices because the semiconductor has high electron mobility and a modest band gap that is suitable for future power supply voltage scaling.[2] Furthermore, the $Al_2O_3/In_{0.53}Ga_{0.47}As$ interface exhibits a relatively low interface defect density (D_{it}) compared to other deposited high-κ dielectrics on III-V semiconductors.[3,4]

Because III-V arsenide semiconductors have native oxides of poor electrical quality and readily form interface defects,[1] it is desirable to 1) suppress oxidation of the InGaAs surface prior to dielectric deposition and 2) passivate defect sites after dielectric deposition in order to achieve superior transistor performance.[5] Several approaches to prevent oxidation of the III-V semiconductors and to reduce the interface defect density have been reported, including post-deposition forming gas annealing,[6] and pre-deposition sulfur passivation[7] or atomic hydrogen treatment[8] of III-V semiconductor surfaces. It has also been shown that the ALD-Al_2O_3/InGaAs interface defects can be avoided by starting the ALD-Al_2O_3 process with a pulse of trimethylaluminum (TMA), a metal-organic precursor for Al_2O_3 deposition, rather than by initially pulsing an oxidant.[4] As previously reported, TMA can decompose the native oxide on III-V arsenide surfaces[9,10] and protects initially clean III-V surfaces from subsequent oxidation.[4]

In this presentation, the effects of large-dose TMA exposure of well-prepared InGaAs (100) surfaces prior to the start of ALD-Al_2O_3 growth are reported. The electrical properties of both n-type and p-type $In_{0.53}Ga_{0.47}As$ (100) prepared under conditions that should result in either As-rich or Ga/In-rich surface structures are compared. The effects of TMA saturation of the substrate surface prior to ALD-Al_2O_3 deposition on the capacitance-voltage and conductance-voltage characteristics of Pd/Al_2O_3/n-$In_{0.53}Ga_{0.47}As$ MOS capacitors are analyzed. The total interface state model[11] is used to characterize the effect of large-dose TMA surface adsorption in altering the D_{it} distribution across the InGaAs band gap. Experimental results on interface defect passivation are compared to predictions of density functional theory of the effects of adsorption of TMA on (100) InGaAs.

The contributions of Jaesoo Ahn and Kechao Tang (Stanford) and Tyler Kent, Dr. Evgueni Chagarov, and Prof. Andrew Kummel (UCSD) to the results described in this presentation are gratefully acknowledged. Funding for this research was provided by the SRC Non-Classical CMOS Center, the Stanford Initiative in Materials and Processes, and the Israel-US Binational Science Foundation.

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