Thursday Morning, October 28, 1999

Electronic Materials and Processing Division
Room 612 - Session EM2-ThM

Dielectric Passivation/Oxides on Compound Semiconductors

Moderator: K.G. Eyink, Air Force Research Laboratory

9:00am **EM2-ThM3 Dielectric Passivation/Oxides on Compound Semiconductors**, ***F. Ren,*** University of Florida*; M. Hong,* Bell Laboratories, Lucent Technologies*; S.J. Pearton, C.R. Abernathy, G. Dang,* University of Florida*; J.R. Lothian,* Multiplex Inc. **INVITED**

Electronic and optical devices based on GaAs, InGaAs and GaN material systems have been widely used in telecommunication and wireless communication applications. In order to improve the device performance and reliability, device passivation is one of the critical steps in the device fabrication. An electron cyclotron resonance chemical vapor deposition (ECRCVD) silicon nitride (SiN@sub x@) was successfully demonstrated to passivate submicron T-gate. Combining ECRCVD SiN@sub x@ and an in-situ dielectric film passivation technique by dividing a thick film deposition into many thin film (<40Å) depositions and using a N@sub 2@ ion bombardment between the depositions. A thermally stable (up to 800 °C) SiN@sub x@ was achieved with this process. The refractive index of N@sub 2@ treated SiN@sub x@ film only changed 0.3% when the SiN@sub x@ film was heated up to 1000 °C and the film with a continuous deposition showed a 2.5% change. The etch rates of passivated SiN@sub x@ film in BOE and diluted HF are 40 Å/min which is much slower than that of un-treated SiN@sub x@(135 Å/min). Recently, an in-situ deposition of Ga@sub 2@O@sub 3@(Gd@sub 2@O@sub 3@) on InGaAs, GaAs and GaN has been demonstrated. The Ga@sub 2@O@sub 3@(Gd@sub 2@O@sub 3@)/GaAs interfaces showed a very low interface state densities. Enhancement and depletion mode GaAs metal oxide semiconductor field effect transistors (MOSFETs) have been demonstrated with excellent performance. Enhancement mode InGaAs and depletion mode GaN were also demonstrated.

10:00am **EM2-ThM6 Study of GaAs Oxidation in H@sub 2@O@sub 2@ and H@sub 2@O using Spectroscopic Ellipsometry**, ***S.-J. Cho,*** *P.G. Snyder,* University of Nebraska, Lincoln

Oxidation of GaAs in hydrogen peroxide (H@sub 2@O@sub 2@) and deoinized H@sub 2@O (DH@sub 2@O) at room temperature was studied using in-situ real time spectroscopic ellipsometry (RTSE) and ex-situ spectroscopic ellipsometry (SE). GaAs samples were immersed in H@sub 2@O@sub 2@ for periods of up to 2 hours while RTSE data were recorded, then rinsed in flowing DH@sub 2@O and blown dry. SE data (1.5-5.5 eV) were taken before and after immersion. Analysis of the SE data indicated the development of a 2-3 nm interface (modeled as porous GaAs) between the oxide and GaAs, which was not present before immersion. The oxide itself had also become more porous as well as thicker. Accurate modeling of the interface and oxide layers required data in both the E@sub 2@ (~4-5 eV) and E@sub1@ (~2.5-3.5 eV) spectral regions. The RTSE spectral range was limited to below 3.5 eV by UV absorption in the H@sub 2@O@sub 2@ ambient, so the interface could not be included in the real time analysis. Another problem was the formation of bubbles on the surface, which became visible after about 30 minutes. Within these limitations on the RTSE data, their analysis indicated that the oxide growth was approximately logarithmic over at least the first 10-15 minutes. The oxidation rate varied from 0.21 to 0.54 nm/decade (minutes). In DH@sub 2@O no bubbles formed, but an interface again appeared to be present. Oxidation was nearly linear in time, at a higher rate than in the H@sub 2@O@sub 2@, and with a higher void volume (more porous oxide). Growth rates again varied considerably, with a typical rate 0.16 nm/min. Research supported by AFOSR Grant #49620-96-1-0480.

10:20am **EM2-ThM7 The Effective Two-step Passivation of Metal/GaAs Interface with Sulfur and Hydrogen Plasma**, ***M.G. Kang,*** *J.W. Kim, H.H. Park,* Yonsei University, Korea

In application of GaAs to device integration, the reliable and controllable Schottky contact property of metal/GaAs is urgently necessary to yield. However, it is limited to develop furthermore due to the existence of defects at/near the metal/GaAs interface. In this study, a novel method of passivating the defects with sulfur and hydrogen plasma at/near the metal/GaAs interface was investigated. The sulfur-passivation was employed to passivate the defects at GaAs surface, and the defects in GaAs adjacent to the surface were co-passivated using hydrogen plasma. The native oxide of GaAs was completely removed by the surface treatment using HCl solution. The GaAs surface was then passivated with sulfur in a monolayer thickness using (NH@sub 4@)@sub 2@S@sub x@ solution. After the treatment, the surface could be protected from air-oxidation and preserved oxide-free-surface during a followed metallization. In particular, ultra thin Au metal of 5 nm thickness was deposited on the sulfur-passivated GaAs surface prior to hydrogen plasma treatment, in order to protect the GaAs surface from plasma-induced damage. The defect density of the metal/GaAs interface was greatly reduced by this two-step passivation method, compared to GaAs treated with either sulfur or hydrogen. The defects were evaluated by low temperature photoluminescence and deep level transient spectroscopy. The chemical bonding state of GaAs before and after Au-metallization was characterized using an angle-resolved X-ray photoelectron spectroscopic technique.

10:40am **EM2-ThM8 Advanced Selective Dry Etching of GaAs/AlGaAs in High Density Inductively Coupled Plasmas**, ***J.W. Lee,*** *M.W. Devre, B.H. Reelfs, D.J. Johnson, J.N. Sasserath,* Plasma-Therm, Inc.*; F. Clayton,* Motorola, Inc.*; S.J. Pearton,* University of Florida

We report a breakthrough for selective etching of GaAs over Al@sub X@Ga@sub 1-X@As, x = 0.2, etching with a high density plasma source. This results is particularly important for III-V devices such as HBTs or HEMTs. For example, fabrication of HBTs requires a process for selective etching of a GaAs contact layer while stopping on AlGaAs layer. Inductively coupled plasma (ICP) etching with BCl@sub 3@/SF@sub 6@/N@sub 2@/He chemistries showed extremely high selectivity of GaAs over AlGaAs (> 200 : 1) and a photoresist (> 10 : 1). This process also produced excellent sidewall passivation on GaAs with reasonablely high rate (> 1500 Å/min.). Both SEM and AFM data showed AlGaAs etch stop layer was quite smooth after processing. We found that He played a key role in enhancing selectivity and obtaining smooth AlGaAs surfaces. When used with resist masks, addition of N@sub 2@ into BCl@sub 3@/SF@sub 6@ plasma helped formation of passivation on the sidewall and maintained high anisotropy. An optimized condition with BCl@sub 3@/SF@sub 6@/N@sub 2@/He ICP plasmas showed excellent pattern transfer into GaAs with high rate, anisotropy and selectivity.

11:00am **EM2-ThM9 Characterization of Hydrogen Passivation in p-type InP (100)**, ***W.E. Henderson,*** Clark Atlanta University*; M.D. Williams,* Clark Atlanta University, US

Hydrogen in p-type semiconductors acts to passivate (i.e. neutralize) the charge carrier contribution of impurity charge centers by forming acceptor-H+ complexes. We study the passivation of several common p-type dopants in InP (100) including Zn, Be, and Cd. The InP substrates are exposed to atomic hydrogen created by a radio-frequency generated plasma source. Secondary ion mass spectrometry and capacitance-voltage profiling are used to determine the degree of neutralization as a function of depth. This work is supported by the DoE through grant # DE-FG02-97ER45647.

11:20am **EM2-ThM10 Synchrotron Radiation-Induced Wet Processing of GaAs***, ***Q. Ma,*** *D.C. Mancini, R.A. Rosenberg,* Argonne National Laboratory

To explore the potential for photoelectrochemical processing of materials using hard x-rays generated by a third-generation synchrotron radiation (SR) light source, we initiated studies of SR-induced surface wet etching and metal deposition. We report in this paper a room-temperature, x-ray-induced chemical wet etching process that produces smoothly etched surfaces on n-GaAs using a HNO@sub 3@ solution as the reagent. Atomic force microscope measurements indicate a root-mean-square surface roughness of @<=@ 1.5 nm, which compares favorably to the unetched surface roughness. An etch rate of up to 64 nm/min was achieved under current experimental conditions, which still leaves room for significant enhancement. Dependence of the etching rate on photon intensity, photon energy, semiconductor doping types, and solution concentration, as well as the etched surface chemistry have been studied in order to understand the underlying mechanism. We will also report a preliminary result of patterned wet metal deposition on n-GaAs using a commercial Ni-containing electrolyte and describe the processing.

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