Electronic Materials and Processing
Room: Central Hall - Session EM-ThP

Electronic Materials and Processing Poster Session

EM-ThP1 Proton Irradiation of Lattice Matched InAlN/GaN High Electron Mobility Transistors, *C.-F. Lo, L. Liu, T.S. Kang, F. Ren,* University of Florida, *C. Schwartz, E. Flitsiyan, L. Chernyak,* University of Central Florida, *H.-Y. Kim, J. Kim,* Korea University, Republic of Korea, *O. Laboutin, Y. Cao, J.W. Johnson,* Kopin Corporation, ***P. Frenzer***, *S.J. Pearton*, University of Florida

The DC characteristics of InAlN/GaN High Electron Mobility Transistors (HEMTs) were measured before and after irradiation with 5, 10 or 15 MeV protons at doses up to 2×10^{15} cm^{-2}. At 5 MeV, the on/off ratio degraded by two orders of magnitude for the highest dose, while the sub-threshold slope increased from 77 to 122 mV/decade. There was little change in transconductance or gate or drain currents for doses up to 2×10^{13} cm^{-2}, but for the highest dose the drain current and transconductance decreased by ~40% while the reverse gate current increased by a factor of ~6. The minority carrier diffusion length was around 1μm independent of proton dose. The InAlN/GaN heterostructure is at least as radiation hard as its AlGaN/GaN counterpart.

EM-ThP2 Effects of 2MeV Ge^+ Irradiation on AlGaN/GaN HEMTs, *E.A. Douglas, P. Frenzer, S.J. Pearton, C.-F. Lo,* ***L. Liu***, *T.S. Kang, F. Ren,* University of Florida, *E. Bielejec*, Sandia National Laboratories

The DC characteristics of AlGaN/GaN High Electron Mobility Transistors (HEMTs) were measured before and after irradiation with 2 MeV Ge^+ ions at doses from $5x10^{10}$ to $5x10^{12}$ cm^{-2}. The drain current, gate leakage current and transconductance decreased monotonically with dose, while the drain-source resistance increased to a much greater extent than observed previously for proton irradiation of similar devices. The gate leakage current decreased with dose, as shown above. To understand the mechanism, we probed on-chip transmission line method (TLM) patterns receiving the same dose. Those irradiated with $5x10^{10}$ cm^{-2} showed in a ~4x increase in sheet resistance and a 75% decrease in specific contact resistance. TLM patterns irradiated at $5x10^{11}$ cm^{-2} and $5x10^{12}$ cm^{-2} showed nA current (100mA prior to irradiation). Threshold voltage shifted to more positive values for increasing dose. There was no systematic effect of gate width or length (gate length from 0.1 to 1 micron and width from 100-200 micron) on the degree of degradation in device parameters. Reverse recovery switching times in the HEMTs were unaffected by the Ge^+ fluences we investigated. In contrast to proton implantation with moderate doses, which does not lead to high sheet resistivities of the implanted layers, the use of heavier ions like Ge^+ causes the sheet resistivity to be greatly increased. The basic degradation mechanism is still carrier loss from the channel as a result of trap formation in the AlGaN layer and in the GaN buffer.

EM-ThP3 Influence of AlInN Buffer Layer Thickness on the Properties of GaN Films on Si(111) Substrate using RF Metal-Organic Molecular Beam Epitaxy, ***W.C. Chen***, *C.T. Lee, C.-N. Hsiao*, Instrument Technology Research Center, National Applied Research Laboratories, Taiwan

Hexagonal structure GaN films were grown on silicon (111) substrate by radio-frequency metal-organic molecular beam epitaxy with $Al_xIn_{1-x}N$ buffer layers. We discussed the influence of AlInN buffer layer thickness on properties of GaN films. The thickness of the AlInN buffer layer can effectively counteract the tensile stress usually observed in the GaN layer deposited on Si(111). For a 10-nm-thick AlInN, crack density of 2.4 × 10^5/mm and a crystalline quality of 150 arcmin are obtained. Also, the average later thicknesses measured about 300 nm, and the growth rate about 0.2 μm/hr. Also, Strong band-edge emission from GaN on Si(111) is observed at 3.39 eV with 70 nm-thick AlInN interlayer. The reduced lattice mismatch between the GaN film and Si(111) is responsible for improvement of GaN quality using the buffer-layer technique.

EM-ThP4 Morpholigical Study of GaN Films Grown Under ALD Process Conditions as Well as Both Over- and Under- Saturated Growth Conditions, ***J.C. Revelli***, *T.J. Anderson*, University of Florida

Gallium Nitride films were grown by pulsed deposition of $GaCl_3$ and NH_3 using nitrogen as both carrier and purge gas. The pulse and purge times leading to self-limiting, ALD-mode growth were investigated at 585°C. ALD growth conditions led to a constant thickness increment per cycle. The ALD conditions were determined to be a 3-6 second $GaCl_3$ pulse, a 30 second NH_3 pulse, and 30 second nitrogen purge times in between. The surface morphology of all films were examined by AFM. ALD films showed RMS surface roughness of 0.3nm, similar to that of the underlying (0002) sapphire substrate, while films that had a $GaCl_3$ pulse below 3 seconds had an RMS roughness of 0.5mn and films oversaturated with $GaCl_3$ had an RMS roughness of 1.2nm. This result suggests that AFM can be used as a rapid and non-destructive method to identify ALD growth conditions.

EM-ThP5 Structural, Compositional, and Thermal Stability Studies on $In_{1-x}Ga_xN$ Epilayers, ***A. Acharya***, Georgia State University, *M. Buegler,* Technical University of Berlin, Germany, *S.D. Gamage, N. Dietz, B. Thoms*, Georgia State University

The structural and compositional properties of indium gallium nitride (InGaN) epilayers grown by high-pressure chemical vapor deposition have been studied using x-ray diffraction (XRD), Auger electron spectroscopy (AES) and high-resolution electron energy loss spectroscopy (HREELS). In addition, the thermal stability of the epilayers have been studied using temperature programmed desorption (TPD). The XRD pattern shows the InGaN (0002) Bragg reflex at 31.38 deg, indicating single-phase InGaN epilayers. Both XRD and AES measurements indicate a composition x of 4% gallium. The HREEL s pectra of atomic hydrogen-exposed surfaces exhibit modes assigned to a surface N–H species, which were confirmed by observation of isotopic shifts following exposure to atomic deuterium. No In–H or Ga-H vibrations were observed suggesting the epilayer is N-polar. The thermal desorption study indicated that nitrogen desorption from the sample starts at 625 °C and peaks at 740 °C. No significant desorption of NH^*/NH_2^* fragments have been observed. From an Arrhenius plot, an activation energy for the desorption of nitrogen of 1.14 ± 0.06 eV was found.

EM-ThP6 The Influence of the Group V/III Molar Precursor Ratio on the Structural and Optoelectrical Properties of InN Epilayers Grown by High-Pressure CVD, ***R. Atalay***, Georgia State University, *M. Buegler,* Technische Universität Berlin, Germany, *S.D. Gamage, M.K.I. Senevirathna,* Georgia State University, *G. Durkaya,* University of California Irvine, *L. Su,* UNC Charlotte, *A.G.U. Perera,* Georgia State University, *I. Ferguson,* UNC Charlotte, *N. Dietz*, Georgia State University

Over the last two decades, significant research efforts have been devoted to understand and improve the physical properties of InN epilayers. However, even today, there is still a significant lack of understanding how the different partial pressures of the precursor fragments of trimethylindium and ammonia affect the InN surface and growth chemistry and influence the materials properties.

In this study, high-pressure chemical vapor deposition (HPCVD) is used to control and suppress the disassociation of InN alloys at higher growth temperatures, together with a pulsed precursor injection approach to reduce gas phase reactions and to control the surface chemistry. In this contribution, we will present results on the influence of the group V/III molar precursor ratio on the structural and optoelectronic properties of InN epilayers grown on sapphire substrate with a reactor pressure of 8 bar. The group V/III molar precursor ratio was studied in molar V/III-ratio range of 900 to 3600. The structural analysis show for molar V/III-ratio of 2400 an optimum with, Raman and XRD having the lowest FWHM of 7.53 cm^{-1} and 210 arcsec, respectively. The XRD results indicate improved grain size and reduced strain effect. Optical FTIR reflectance analysis of this epilayer found a free carrier concentration of 1.7×10^{18} cm^{-3}, a mobility of 1020 cm^2 V^{-1} s^{-1} and a growth rate of 120 nm/h. The Raman analysis for these epilayers indicate that the non-polar phonon frequency with symmetry of E_2 is changes little within the studied molar V/III precursor ratio range; however, the polar phonon modes of both transverse optical (TO) and longitudinal optical (LO) are affected significantly. The studies showed also reveal that LO-phonon is influenced from the free carrier concentration (n_e) and TO-phonon is influenced from the free carrier mobility (μ). In addition, surface morphology studies by AFM show an improved average grain size of 8.51×10^{-2} μm^2 for the m olar V/III-ratio of 2400.

EM-ThP7 Protoype of Junctionless Transistor on SOI Wafers using Focused Ion Beam Milling, ***L. Petersen Barbosa Lima***, *J. Alexandre Diniz, I. Doi, J. Godoy Filho,* State University of Campinas, Brazil, *H. Ivanov Boudinov*, University of Rio Grande Do Sul, Brazil

Nowadays, Junctionless devices (JL) have gained much attention of microelectronics industry, because it is compatible with CMOS technology and can be useful for 3D devices. In this context, nMOS JL devices were fabricated on SOI substrates using Ga^+ Focused Ion Beam (FIB) milling and for depositions of SiO_2 (gate dielectric) and Pt layers (as gate, drain and source electrodes) of JL transistor. In this work, two methods to fabricate

the JL devices were used. One method is using on FIB system to milling the Si substrate and the other method used Reactive Ion Etching (RIE) and FIB system to etch the Si substrate. The samples with only FIB system were called JLFIB and samples with RIE plasma etch and FIB system were called JLRFIB. First of all, the wafers JLFIB and JLRFIB were doped with phosphorus, dose 10^{19} cm^{-3} and energy of 30 KeV, using ion implantation system. After that, Rapid Thermal Annealing (RTA) were used to anneal the SOI samples after the ion implantation procedure. 0.6-µm-thick SiO_2 were obtained using a wet oxidation on conventional furnace to get thinner height of Si substrate on SOI waffer. So, litography to define MESA structures and RIE SI etching were carried out only on JLRFIB samples. Then JLFIB and JLRFIB samples were insert on FIB system to get the JL fabrication. First of all, using a Ga^+ ion beam the Si substrates were milled to obtain the Si nanowire to define the gate, drain and source regions of JL transistor. Width, length and height dimensions of Si nanowire were about 100 nm, 4 µm and 50-80 nm, respectively. Then, 10-nm-thick SiO_2 was deposited to be gate dielectric and finally, Pt were deposited to be gate, drain and source electrodes. Energy Dispersive X-Ray Spectroscopy (EDS) measurements were carried out to confirm the surface composition of Si nanowire, SiO_2 gate dielectric deposition and Pt electrodes deposition. In addition, EDS results show some Ga incorporation on Si nanowire surface, however, this incorporation was derived from Ga^+ FIB and no significant damage on Si nanowire was occurred. Finally, these devices were sintered in a conventional furnace in forming gas at 450°C for 10 and 20 minutes. Drain-source current (I_d) x drain-source voltage (V_{ds}) measurements of JLFIB and JLRFIB devices were carried out, and indicate that the devices are working, like a gated resistor or JL device, with high Pt source and drain contact resistances, which lead to the distortions of I_d x V_{ds} curves. However, these distortions can be reduced using a longer time of contact sintering process and a Si nanowire height lower than 50 nm. Finally, our fabrication method using FIB process steps can be used to obtain JL devices.

EM-ThP8 Simulation of Millisecond Laser Anneal on SOI: A Study of Dopant Activation and Mobility and its Application to Scaled FinFET Thermal Processing, ***T. Michalak***, *J. Herman, M. Rodgers, D. França, C. Borst*, University at Albany-SUNY

Next generation CMOS requires high activation and hyper-abrupt junction formation for low sheet resistance and device performance. The primary method of doping, ion implantation, provides excellent spatial control of dose. A high temperature anneal (>1000° C) is required to remove defects introduced from ion implantation and to electrically activate the implanted specie. A "diffusionless anneal" by which dopant is activated without significantly diffusing, would be ideal for ultra-shallow junction (USJ) formation. This work investigates one such technique, laser annealing, which uses a scanning laser to locally heat the wafer surface. We investigate the laser system via simulation to determine the peak temperature achieved in the active area during processing. We employed the Sentaurus TCAD software by Synopsys to perform a 2D simulation of a laser scanning across the active area of the device, solving the heat equation in both time and space (Fig 1). An absorber layer is deposited on the wafer surface to encourage the absorption of optical power and consequent heating of the wafer surface. An effective absorption coefficient of α=8861 cm-1 was calculated for the absorber layer, calibrated with the experimental laser intensity of 52526 W/cm2 required to melt silicon at a scan speed of 150 mm/s which lies within the range for amorphous carbon stated in literature (Fig 2). This absorption coefficient correctly predicts the silicon temperature as a function of power with any arbitrarily defined scan speed (Fig 3). To investigate the role of dopant activation, an SOI wafer was implanted at 25 keV, dose 3e15 cm-2 and laser annealed in stripes of target temperatures ranging from 1100-1300 ºC. The sheet resistance was measured on wafer showing Rs improvement with increasing laser temperature (Fig 4). The extracted temperature cycle from the 2D heat simulation was used as an equivalent millisecond RTA in a full 3D finFET process simulation to study dopant distribution and activation using Sentaurus Process Kinetic Monte Carlo (KMC), considering the effect of dopant clusters and point defects. The results of this simulation, supplemented with Hall mobility measurement and secondary ion mass spectroscopy (SIMS), show that there is no further activation of arsenic with increasing laser temperature (~ 25%) which suggests healing of the implant crystal damage may be reducing sheet resistance. As well, an electrical device simulation of the finFET was performed to compare device performance between RTA and laser annealing (schematic Fig 5). Simulation results show a theoretical improvement in drive current with the laser process over standard RTA.

EM-ThP9 Equivalent-Circuit Model for Vacuum Ultraviolet Irradiation of Dielectric Films, *H. Sinha,* ***J.L. Shohet***, University of Wisconsin-Madison

VUV irradiation causes electron photoemission from dielectrics. Photoemission occurs from defect states in the dielectric band gap and results in trapped positive charges. We propose an equivalent-circuit model using which, once the circuit parameters are determined, charging of dielectric materials under VUV irradiation can be predicted. The circuit includes a dielectric capacitor, the intrinsic and photo conductivities of the dielectric and substrate, and the processes of photoemission and photoinjection. The model has the back of the substrate grounded through an ammeter to the vacuum chamber. The ammeter reads the substrate current. To simulate the circuit between the dielectric sample and the vacuum chamber that collects photoemitted electrons, a photodiode is used. The sample itself, *i.e.* the dielectric deposited on a Si substrate, is represented by a combination of capacitors, resistors and dependent voltage sources. An ideal dielectric can be expressed as a parallel-plate capacitor. However in a real dielectric leakage currents are present due to defect states. Thus, we include a resistor in parallel to the capacitor that represents the intrinsic conductivity. In addition, photoconductivity is introduced in the dielectric during VUV radiation, which is shown by another resistor in parallel to the capacitance. A dependent voltage source models the electron depopulation from the defect states. We represent the substrate, which is a semiconductor, by a resistor. This resistor signifies the intrinsic resistance. As VUV photons also cause electron-hole pair generation in substrate, a resistor as a photoconductivity component is added in parallel to the intrinsic resistor. The circuit components were determined using experimental photoemission/substrate current data for SiCOH. The prediction of photoemission/substrate current using the model was found to match experimental results over different thickness of SiCOH. To conclude, an equivalent circuit can model the effect of VUV radiation on charging and currents in dielectrics.

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EM-ThP10 Surface Photoconductivity of SiO_2 and SiCOH Induced by Vacuum Ultraviolet Radiation, ***H. Zheng***, *M.T. Nichols, D. Pei,* University of Wisconsin-Madison*, G.A. Antonelli,* Novellus Systems, Inc.*, Y. Nishi,* Stanford University*, J.L. Shohet*, University of Wisconsin-Madison

The change in the electrical surface conductivity of SiO_2 and SiCOH during exposure to vacuum ultraviolet radiation is investigated[1]. To measure the change in conductivity, special fabricated patterned titanium finger "comb structures" are deposited on dielectric films and exposed to synchrotron radiation in the range of 50–300 nm, which is in the energy range of most plasma vacuum-ultraviolet radiation. For the measurements of the VUV-induced currents along the surface of the layer in between the titanium fingers, electrical connections are made from the test structure to outside circuitry through vacuum feedthroughs. A numerical simulation shows that the bulk current is too small to account for the measured values and most of the current indeed flows across the surface of the dielectric film in the test structure. By measuring the I-V curve of the comb test structures under controlled fluxes of VUV light, we determine that the measured current per unit photon-flux density is linear with applied electric field up to a saturation value that is VUV flux limited. This permits the surface conductivity to be calculated based on a simple photoconductor model. The increase in surface conductivity induced by VUV radiation can be beneficial in limiting charging damage of dielectrics by depleting the plasma-deposited charge.

This work is supported by the National Science Foundation under Grant CBET-1066231 and the Semiconductor Research Corporation under contract 2008-KY-1781. We also thank M. Severson for helping set up the VUV exposure.

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EM-ThP11 Spatial Volume Charge Distribution Measurement in Thin Dielectric Films: Electro-Acoustic Method, ***D. Pei***, *M.T. Nichols,* University of Wisconsin-Madison*, Y. Shkel,* Commet LLC*, Y. Nishi,* Stanford University*, J.L. Shohet*, University of Wisconsin-Madison

Trapped volume charge inside dielectric films can lead to breakdown permanently damaging the dielectric film. Measurement of the spatial volume charge distribution is critical to estimate the electric field and the change in properties of dielectric films. A pulsed electro-acoustic (PEA)[1-2] method is applied to measure the volume charge distribution throughout the thickness of the thin film dielectric. In this method, a high voltage pulse signal (1 kV, 10 ns) or a sinusoidally varying high-voltage signal (4 kV, 5

kHz) is applied across a thin film of low-density polyethylene. An acoustic wave is generated by the volume charge inside the film and transmitted to each side of the film. A piezoelectric transducer on one side of the dielectric film is used as a sensor to detect and measure the arrival times of the acoustic waves in the case of pulsed excitation or the shift in phase of the detected signal in the case of sinusoidal excitation. This allows spatial resolution of both the location and magnitude of the charge distribution.

This work was supported by the Semiconductor Research Corporation under Contract No. 2008-KJ-1871 and by the National Science Foundation under Grant No. CBET-1066231.

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EM-ThP12 Investigation of Photoluminescent Characteristics and Structural Properties of Thin Film Zinc Silicate Doped with Manganese, *K.H. Yoon,* ***J.H. Kim***, Chungbuk National University (CBNU), Republic of Korea

The photoluminescent characteristics and structural properties of manganese-doped zinc silicate (Zn_2SiO_4:Mn) thin films were investigated. The Zn_2SiO_4:Mn films were deposited by radio frequency magnetron sputtering, followed by post-deposition annealing at temperatures of 600 - 1200 °C. The Zn_2SiO_4:Mn films exhibited a pronounced optical absorption edge in the near ultraviolet wavelength region and the maximum transmittance reached approximately 0.922. The refractive index of the Zn_2SiO_4:Mn films showed normal dispersion behavior. X-ray diffraction and atomic force microscopy measurements revealed that the as-deposited Zn_2SiO_4:Mn films had an amorphous structure with a smooth surface morphology. The Zn_2SiO_4:Mn films became crystalline after annealing at 800 °C and the crystallinity of the films was continuously improved up to 1200 °C. The annealed Zn_2SiO_4:Mn films had a polycrystalline rhombohedral structure with no preferred crystallographic orientation of the crystallites. The photoluminescence spectra of the annealed Zn_2SiO_4:Mn films showed broad-band emissions with a peak maximum at about 523 nm. The PL emission intensity was enhanced as the annealing temperature increased, resulting from the improvement of the crystallinity of the Zn_2SiO_4:Mn films. The excitation band exhibited a peak maximum at around 243 nm in the near ultraviolet region, which was considered to be associated with the charge transfer transition of divalent manganese ion in the Zn_2SiO_4 system.

EM-ThP13 The Electrical and Thermal Properties of Nanoscale Multilayered Bi_2Te_3/Sb_2Te_3 and $Bi_2Te_3/Bi_2Te_{3-x}Se_x$ Thin Films, *M. Hines,* ***Z. Xiao***, Alabama A&M University

Nanoscale multilayered Bi_2Te_3/Sb_2Te_3 and $Bi_2Te_3/Bi_2Te_{3-x}Se_x$ thin films were grown using the e-beam evaporation. The in-plane and cross-plane micro thermoelectric devices were fabricated using the clean room-based microfabrication techniques such as UV lithography. The e-beam-grown multilayered thin films and the fabricated thermoelectric devices were measured and characterized. The nanoscale multilayered Bi_2Te_3/Sb_2Te_3 and $Bi_2Te_3/Bi_2Te_{3-x}Se_x$ thin films can have much higher thermoelectric figure of merit than their bulk materials. The measurement results on the electrical and thermal properties of the nanoscale multilayered Bi_2Te_3/Sb_2Te_3 and $Bi_2Te_3/Bi_2Te_{3-x}Se_x$ thin films will be reported in the conference.

EM-ThP14 Mapping the Magnetic Detection Properties of Chip-Scale Optically Pumped Magnetometers, ***N. Ptschelinzew***, *P.H. Holloway, M.R. Davidson*, University of Florida

Magnetometers have a wide range of utilization from Nuclear Magnetic Resonance (NMR), to medical applications such as the Magneto-Encephalogram (MEG), Magnetocardiography (MCG), and Magnetic Resonance Imaging (MRI). However, these techniques often depend on superconducting quantum interference detection magnetometers or the detection of a radio frequency magnetic resonance in a paramagnetic target induced while in a large field. Chip-scale, low-power optical magnetometers can improve the cost and size as well as reduce the complexity of these devices. The directional variation of sensitivity of these detectors can be exploited to make devices that can form images. We have designed and instrument that will be the functional equivalent of a portable MRI that will be capable of near real-time imaging. The inverse algorithm of mapping a series of detector responses to a magnetic "image" has been calculated and an algorithm for rapidly calculating images from sparse optical magnetometer data sets has been developed. Experimental measurement of the directional sensitivity of Rb-based optical magnetometers will be presented. A prototype imaging system for magnetic tomography is being constructed.

EM-ThP15 Characterization of ZnO/CuO Nanolaminate Materials, ***S.T. King***, *L. Bilke, B. Oleson, J. Krueger, E. Tennyson*, University of Wisconsin - La Crosse

ZnO and its alloys have shown much promise to replace ITO as the transparent conducting layer in many electrical devices. However, ZnO typically does not exhibit a low enough resistivity for such applications. Beyond doping ZnO, much work has focused on developing heterostructures in which ZnO is layered with a metal on the nanometer scale [1]. A recent study has suggested that bilayers of ZnO and Cu exhibit properties which may allow such laminate materials to be employed in photovoltaic applications [2]. However, it is apparent that these Cu interlayers will oxidize over time resulting in the formation of CuO interlayers. Therefore, the properties of ZnO/CuO laminates must be understood to determine the effects of interlayer oxidation on these materials.

The current study has employed x-ray diffraction, spectroscopic ellipsometry, UV-Vis spectroscopy, and four-point resistivity measurements to examine the effects that CuO interlayer thickness has on the structural, optical, and electrical properties of ZnO/CuO nanolaminate films deposited by reactive DC sputter deposition. Results suggest that CuO interlayers may afford similar transmittance and resistivity results as Cu interlayers thus alleviating possible difficulties incurred from interlayer oxidation in nanolaminate materials.

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EM-ThP16 Small-Molecule Scaffolds for Directed Self-Assembly, ***P.L. Mancheno-Posso***, *A.J. Muscat*, University of Arizona

Functionalization of oxide surfaces with vinyltrichlorosilane (VTCS, CH_2=CH-$SiCl_3$) was studied using water contact angle, ex situ ellipsometry, X-ray photoelectron spectroscopy (XPS), and atomic force microscopy (AFM). VTCS monolayers can be used as scaffolds for the deposition of a subsequent layer and keep it in close proximity to the surface due to its short length and terminal vinyl group. In this work, Si(100) samples were ultrasonically cleaned in acetone, methanol, and DI water for 5 min each. Native oxide was removed using a 1:100 (v/v) solution of 49% HF in water for 1 min. Subsequently, samples were hydroxylated with a 3:1 (v/v) solution of H_2SO_4 and H_2O_2 for 10 min at 60 °C. VTCS was adsorbed from 1:1000 (v /v) solutions in toluene, chloroform, and acetone. The layer thickness after 30 min in toluene was 47.5±6.4 Å, in chloroform 7.1±0.9 Å, and in acetone 4.0±1.9 Å. These results suggest acetone as the most appropriate solvent to produce a monolayer. The contact angle was near 0° on the piranha-treated surface and increased to 25.3±0.5° after VTCS adsorption. Addition of bromine atoms to the vinyl group was performed by immersing the samples in a 2% (v/v) solution of elemental bromine in dichloromethane for 2 hr. The contact angle was 63.2±3.9° after bromination. A Br 3d XPS peak at 70.0 eV (C-Br) demonstrated the chemical modification of the unsaturated bond of the VTCS molecule. AFM roughness analysis yielded an RMS value of 0.11 nm for the VTCS monolayer. The reaction of VTCS with hydroxyl groups at the surface was demonstrated on a thick hafnia layer by the presence of XPS peaks at 102.6 eV for Si 2p and 532.3 eV for O 1s, which correspond to Si-O bonds formed by VTCS and the substrate. Oxidation of the vinyl group with potassium permanganate (5 mM) and sodium periodate (195 mM) yielded a peak at 286.6 eV for C 1s, suggesting the formation of C-OH moieties.

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