SPECIFICAITONS

1. System Overview

1.1. We wish to upgrade an existing NRL surface analysis system through the purchase of a high performance x-ray photoelectron spectroscopy (HP-XPS) system, including a hemispherical electron analyzer, a monochromatic x-ray source, and accessories, capable of producing chemical and compositional maps of surfaces and sputter depth profiling of films. Crucial to the HP-XPS system is the utilization of the existing NRL facility without loss of scientific skills and abilities, while gaining the improvement of the latest generation of equipment design and function. The HP-XPS system will be used for studies of MBE-grown group IV semiconductor materials, ALE of insulators and oxides, silicon carbide and graphitic carbon-based electronics, and cluster-based nanoscale chemical sensors. The essential requirements of this system, derived from the detailed specifications described on the following pages, are as follows:

1.2. This system must include a 180 degree hemispherical electron analyzer with electron detector, focus/filtering lenses, electronics, cables, software, and computer control necessary to perform x-ray photoelectron spectroscopy(XPS), Auger electron spectroscopy(AES), and ultraviolet photoelectron spectroscopy(UPS) experiments.

1.3. This system must include a monochromatic x-ray source with an aluminum x-ray anode, collimating/diffraction crystal, electronics, and cables, capable of operating at a minimum of 300 W x-ray anode power (15 kV and 20 mA)and bakeable to a temperature of 140 °C.

1.4. The system must be able to produce XPS maps of composition of at least 2 mm by 2 mm areas with at least as small as a 60 um spot size resolution, have a secondary electron detector for scanning electron microscopy (SEM)images, and an optical microscope for alignment of XPS and SEM images.

1.5. The system must be capable of acquiring multiple XPS spectra as a function of time during a sputter profiling experiment and using post-calibration data be capable of producing curves of composition as a function of sample depth with the included software.

1.6. The system must include a mu-metal ultra-high vacuum (UHV) chamber in order to maintain a proper alignment geometry for the hemispherical analyzer and monochromatic x-ray source: additionally the belljar should have appropriate ports and alignment geometries necessary to integrate existing surface analysis equipment (electron gun, sputter ion gun, helium lamp, twin x-ray source, flood gun, residual gas analyzer, sample transfer and manipulation, and vacuum

pumps.) The chamber must accommodate the existing *in situ* ultra-high vacuum transfer system that shuttles samples from the MBE growth chamber into the HP-XPS system for analysis

1.7. The system must be capable of analyzing 3 inch Si wafers that are produced by NRL's VG MBE growth system that is attached to the existing NRL surface analysis system.

2. <u>Detailed Specifications</u>

2.1. 180° Hemispherical Electron Energy Analyzer -

2.1.1. -Physical properties
- 2.1.1.1. 180 ° spherical sector
- 2.1.1.2. at least 100 mm radius
- 2.1.1.3. at least 20 mm working distance
- 2.1.1.4. magnetically shielded or fabricated from mu metal

2.1.2. -Electron lens
- 2.1.2.1. variable slits
- 2.1.2.2. selectable spot size for areas from 2mm x 2mm square down to a 60 um circular spots with the 60 um spot size being determined by a 80% to 20% intensity change along a knife edge
- 2.1.2.3. magnifying
- 2.1.2.4. selectable angular acceptance of < 8°
- 2.1.2.5. known transmission function
- 2.1.2.6. dynamically optimized electron transmission as a function of energy

2.1.3. -Electron detector
- 2.1.3.1. multichannel detector or equivalent with at least 5 channels
- 2.1.3.2. pre-amplifier/pulse detector appropriate to the detector.

2.1.4. -Cables
- 2.1.4.1. all necessary cables of appropriate guage, voltage, and shielding must be provided at least 30' (9 m) in length

2.1.5. -Operating modes
- 2.1.5.1. Constant Analyzer Energy (CAE)
- 2.1.5.2. Constant Retard Ratio (CRR)

2.1.6. -Performance
- 2.1.6.1. greater than 300 kcps for Ag 3d 5/2 having a FWHM 0.85 eV under 300 W Mg Kα radiation for a 2 mm by 2 mm area

2.1.6.2. ultimate energy resolution ≤ 20 meV

2.1.7. -Control electronics for electron analyzer
- 2.1.7.1. stable over 8 hour time frame
- 2.1.7.2. 0-2500 eV energy range
- 2.1.7.3. 1-100 eV variable pass energy in CAE mode
- 2.1.7.4. 1:1 to 100:1 variable retard ratio in CRR
- 2.1.7.5. < 10 meV step size for XPS experiments (0-1500 eV range)
- 2.1.7.6. < 1 meV step size for UPS experiments (0-40 eV range)
- 2.1.7.7. < 100 meV step size for AES experiments (0-2500 eV range)
- 2.1.7.8. computer controlled

2.1.8. -Control electronics for electron lens
- 2.1.8.1. stable over 8 hour time frame
- 2.1.8.2. computer control appropriate to the experiment (ie XPS, UPS, or AES)

2.1.9. -Control electronics for electron dectector
- 2.1.9.1. stable over 8 hour time frame
- 2.1.9.2. computer controlled

2.1.10. -Computer control and data acquisition software
- 2.1.10.1. Windows XP Professional or Vista operation system
- 2.1.10.2. ≥ 16 bit DAC (Digital-Analog Conversion)
- 2.1.10.3. individually defined XPS, AES, and UPS consisting of:
  - 2.1.10.3.1.1. 10 different data windows containing
  - 2.1.10.3.1.2. Energy range (defined in terms of binding or kinetic energies)
  - 2.1.10.3.1.3. Energy step
  - 2.1.10.3.1.4. Time per step for data acquisition
  - 2.1.10.3.1.5. Pass energy
  - 2.1.10.3.1.6. Number of scans
  - 2.1.10.3.1.7. Experiment title information
- 2.1.10.4. ability to acquire data in the background while working with saved data in the foreground
- 2.1.10.5. data manipulation consisting of:
  - 2.1.10.5.1.1. Work function correction
  - 2.1.10.5.1.2. Spectra shift correction for charging
  - 2.1.10.5.1.3. Background subtraction (linear, Shirley, and Tougaard)
  - 2.1.10.5.1.4. Smoothing
  - 2.1.10.5.1.5. Integration
  - 2.1.10.5.1.6. Differentiation
  - 2.1.10.5.1.7. Peak Fitting (Voight and other functions)

2.1.10.5.1.8. Peak position and peak area
2.1.10.5.1.9. Spectrum zoom (both energy and counts axis)
2.1.10.5.1.10. Comparison to other data sets
2.1.10.5.1.11. Chemical library (elemental idenfication of peak positions and spin orbit couplings)
2.1.10.5.1.12. Sensitivity factor corrections
2.1.10.5.1.13. Saving of manipulated data
2.1.10.5.1.14. Export of data into ASCII, Excel, and VAMAS / PHI-Multipak
2.1.10.5.1.15. Export of spectra by cutting and pasting in Windows
2.1.10.5.1.16. Export of spectra by jpeg or tiff files

2.1.11. -Computer system
2.1.11.1. CPU: Pentium 4 or faster (> 2 GHz)
2.1.11.2. RAM: 2GB or greater
2.1.11.3. Harddisk: 100 GB or greater
2.1.11.4. Storage: DVD burner
2.1.11.5. Display: 17” or larger LCD (< 0.26 dpi, ≥70 Hz, min 1280 x 1040 resolution (noninterlaced) and at least 256 colors)
2.1.11.6. Networking: TCP/IP card or integrated
2.1.11.7. Expansion: available PCI or PCI express slots
2.1.11.8. Ports: USB

2.2. Monochromatic X-ray Source-

2.2.1. -Aluminum anode
2.2.1.1. water cooled anode
2.2.1.2. water interlock
2.2.1.3. Neslab HX 100 refrigerated recirulating cooler will be provided by NRL
2.2.1.4. mounted on multi-axis manipulator

2.2.2. -Monochromator crystal
2.2.2.1. mounted on multi-axis manipulator
2.2.2.2. capable of 140 °C bakeout
2.2.2.3. pumping ports
2.2.2.4. shuttered

2.2.3. -Control electronics
2.2.3.1. 15 KV energy range
2.2.3.2. 0-30 mA emission
2.2.3.3. electron focusing
2.2.3.4. long time stability > 8 hrs

2.2.3.5. capable of also operating a twin x-ray source (NRL's existing system contains a VG twin Mg/Al x-ray source that can be used or replaced by the contractor as an option)
2.2.3.6. both manual and computer controlled

2.2.4. -Cables
2.2.4.1. all necessary cables of appropriate guage, voltage, and shielding must be provided at least 30' (9 m) in length

2.2.5. -Resolution
2.2.5.1. delta E ≤ 300 meV as measured by the Fermi edge of Ag

2.2.6. -X-ray flux
2.2.6.1. count rate of ≥ 200 kcps for a 0.6 eV FWHM for Ag 3d 5/2

2.3. XPS Composition Maps-

2.3.1. -Minimum composition map requirements
2.3.1.1. 2 mm by 2 mm area at 60 um spotsize with a minimum of 4 user defined photoelectron energies (elements), having an energy window no greater than 0.25 eV, requiring no more than one hour of data acquisition time per element

2.3.2. -User defined map parameters
2.3.2.1. area size
2.3.2.2. spot size
2.3.2.3. photoelectron energy (element specific)
2.3.2.4. energy window (pass energy)
2.3.2.5. data acquisition time
2.3.2.6. experiment title/information

2.3.3. -Data representation processing
2.3.3.1. color scale images (dark to bright) of individual element intensity
2.3.3.2. overlay of at least two individual element images and/or export of data array in tif, jpeg, and ascii format for external data processing
2.3.3.3. cut and paste of data into Windows based applications

2.3.4. -Sample area selection by optical microscopy
2.3.4.1. optical microscope and camera
2.3.4.2. instrument must be aligned so that optically obtained image can be used to determine the area of interest for XPS mapping and sputter depth profiling
2.3.4.3. optical images must be stored as tif, jpeg, or equivalent for comparison to compositional map

2.3.5. -Sample area selection by secondary electron detector

2.3.5.1. a secondary electron detector consisting of scintillator assembly (photomultiplier tube, housing, and cables ≥ 30 ft) and electronics needed to produce secondary electron microscopy images

2.3.5.2. to be used in conjunction with NRL's existing VG LEG 200 AES/SEM electron gun with VG Model 432 controls and Model 384 Digital Electrostatic Scan Unit having a 0.2 um spot size for AES point compositional analysis

2.4. Sputter Depth Profiling-

2.4.1. -Control of x-ray anode and hemispherical

2.4.1.1. user defined XPS experiment as previously mentioned under hemispherical electron analyzer requirements (up to 10 different data windows, energy range, energy step, time per step for data acquisition, pass energy, number of scans, and experiment title information)

2.4.1.2. ability to repeat XPS experiment up to 50 times

2.4.2. -Noble gas sputtering

2.4.2.1. NRL's existing system contains a Leybold-Herarus IQE 12/38 sputter ion gun with model 867 916 Raster Unit and a model 867 918 High Voltage unit that can be used or replaced as an optional item

2.4.2.2. automated operation of high voltage power off and on

2.4.2.3. user defined time for high voltage operation

2.4.2.4. parameters for sputter ion gun operation to be externally set by the electronics of the sputter ion gun

2.4.2.5. admittance of noble gas to be externally controlled so that automated operation of a gas leak valve is not required

2.4.3. -Alternation of XPS data aquistion and noble gas sputtering

2.4.3.1. minimum 50 repetitions

2.4.4. -Data processing

2.4.4.1. ability to represent any energy range as a function of XPS experiment repetition

2.4.4.2. ability to post-calibrate XPS experiment data and XPS experiment number to produce a signal as a function of depth into the sample profile

2.4.4.3. ability to perform all data analysis as previously mentioned under Hemispherical Electron Analyzer (background subtraction, smoothing, integration, differentiation, peak fitting, peak position, peak area,

spectrum zoom, saving of manipulated data, export of data into ASCII, Excel, and VAMAS or PHI-Multipak, and export of spectra by Windows clipboard, jpeg, or tiff files)

2.5. Mu-metal Ultra-high Vacuum Chamber-

2.5.1. -Construction
- 2.5.1.1. Mu-metal
- 2.5.1.2. cleaned for UHV and electropolished
- 2.5.1.3. prior to delivery the chamber will be confirmed leak-free to better than $5x10^{-10}$ std cc/sec for helium

2.5.2. -Bake-out
- 2.5.2.1. bakeable to 140 °C
- 2.5.2.2. typical bake-out at 140 ^{o}C after venting to atmosphere must require no longer than 72 hrs from onset to termination of heating, with system base pressure $\leq 5x10^{-10}$ Torr achieved within the following 48 hrs
- 2.5.2.3. a bake-out box exists on the current NRL XPS system that can be utilized for bakeout or can be replaced as an optional item

2.5.3. -Ports
- 2.5.3.1. conflat-style
- 2.5.3.2. all ports that exist on the current NRL XPS system must be on the mu-metal chamber and maintain their original functionality in an appropriate geometry/location
- 2.5.3.3. alignment of ports for the hemispherical analyzer, monochromatic x-ray source, twin x-ray source, sputter ion gun, AES electron gun, UPS helium lamp, electron flood gun, and optical camera to a common point for analysis
- 2.5.3.4. an empty 6” port for a future load lock station or vacuum suitcase system

2.5.4. -Integration
- 2.5.4.1. the chamber must utilize existing UHV equipment (there must be ports for viewports, wobble sticks, mass spectrometer, nude ionization guage, and system pumping by ion pump, cryopump, and titanium sublimation pumps)
- 2.5.4.2. there must be a port for sample transfer from the NRL’s VG Prep chamber that must be attached to the mu-metal UHV chamber
- 2.5.4.3. pumps and gate valves supplied by the government should be used

2.6. -Location
- 2.6.1.1. the chamber footprint should not exceed current chamber dimensions (4’ by 6’or 122 cm by 182 cm)

2.6.1.2. the chamber must occupy the spot at the end of the VG Prep chamber,
2.6.1.3. the orientation of the chamber will be agreed on by NRL and the contractor

2.6.2. -*In situ* ultra-high vacuum transfer system
2.6.2.1. 8" port near to or on the center-line of the chamber
2.6.2.2. track and trolley system transfers samples into and out of the chamber
2.6.2.3. track and trolley to extend no more than 20" (50 cm) into the chamber from the VG Prep chamber
2.6.2.4. wobblestick used to remove sample from trolley and then place onto a sample stage for analysis

2.7. Analysis of 3 inch (75 mm) Si Wafers-

2.7.1. -Sample stage
2.7.1.1. capable of holding a 3" Si wafers in an MBE wafer holder
2.7.1.2. the existing NRL sample stage can be used, modified, or replaced as an optional item
2.7.1.3. analysis must be achievable on a radial portion of the sample (thus rotation of the sample can result in a complete surface area analysis)

2.7.2. -Sample manipulation
2.7.2.1. use of a wobble stick to transfer samples from the sample transfer cart (brought into the chamber from the VG Prep chamber) onto the sample stage
2.7.2.2. the existing wobble stick can be used, modified or replaced as an optional item

3. <u>General Requirements</u>

3.1. Demonstration of technology-

3.1.1. -Previous installations of equivalent equipment by the contractor

3.1.2. -Previous experience in the field by the contractor

3.2. Instruction manuals-

3.2.1. -either in print or on CD-ROM in PDF format

3.2.2. -operation manuals are needed for

3.2.2.1. hemispherical electron analyzer
3.2.2.2. monochromatic x-ray source
3.2.2.3. secondary electron detector
3.2.2.4. XPS, UPS, and AES data acquisition software
3.2.2.5. XPS compositional mapping software
3.2.2.6. sputter depth profiling software

3.3. Schematics-

3.3.1. -technical drawings for instrument and electronics repair are needed for:
3.3.1.1. hemispherical electron analyzer
3.3.1.2. hemispherical analyzer electronics
3.3.1.3. electron lens and electronics
3.3.1.4. electron detector and electronics
3.3.1.5. monochromatic x-ray source
3.3.1.6. x-ray source power supply electronics
3.3.1.7. optical microscope and electronics
3.3.1.8. secondary electron detector and electronics
3.3.1.9. mu-metal chamber

3.3.2. -troubleshooting
3.3.2.1. in-house repair and replacement of common components and consumables
3.3.2.2. problem solving tree for improperly operating equipment

3.4. System Delivery-

3.4.1. -Delivery should occur within 6 months of contract agreement

3.4.2. -Installation and testing completed on-site by contractor, with performance specifications demonstrated

3.4.3. -Training and instruction for one person of NRL's choosing in all aspects of the delivered system as an optional item

3.4.4. -Documentation explaining all functions of the HP-XPS system and its components, the data acquisition and analysis software, and including technical drawings

3.4.5. -Acceptance
3.4.5.1. Demonstration of XPS, AES, and UPS experiments utilizing monochromatic x-ray source, LEG 200 electron gun, and helium lamp, respectively, with the hemispherical electron analyzer and software of a Ag sample and achieving above mentioned specifications

3.4.6. -Warranty

3.4.6.1. 12 months on parts and labor from system accpetance