Variable Pressure or Environmental Thermal Field Emission Microscope Instrument Specification
for
University of Oregon

Oct 27, 2005

(this specification supersedes all prior specifications)

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A. General Requirements

The vendor shall furnish all facilities, labor, and materials to provide goods and services in accordance with the terms and conditions described in this specification for both the hardware and software. The Vendor shall maintain an inventory of spare and repair parts and such tools and instruments as necessary to properly and efficiently maintain the equipment for the life of the Variable Pressure or Environmental Thermal Field Emission Microscope itself, at least 10 years. Spare parts and consumables must be obtainable within a maximum of 10 working days after a purchase order number is received by the Vendor. The specifications listed in this document are the **minimum** requirements for the University of Oregon Electron Beam Variable Pressure or Environmental Thermal Field Emission Microscope.

Please provide a detailed **competitive** price quotation for each major component, device or feature. Please quote each price and the system total on a **duty free basis (no sales tax)** and inland transportation costs) as we will be applying for a customs duty exemption. The prices quoted should reflect any educational discounts that can be applied to a non-profit educational organization purchase.

The payment plan will be negotiated but the following schedule is suggested:

50% on receipt of order
30% on completed installation at UofO (meeting all Vendor specifications)
20% on acceptance (meeting all University specifications in this document)

Please include in the quotation any additional equipment or software and pricing that will be required to efficiently operate **all** instrument features specified in this document if they are not standard equipment or not explicitly stated in the specifications.

A catalog and current price list of all spare parts and assemblies shall be provided by the Vendor with the instrument.

B. Inclusion of Vendor's Technical Proposal into this Specification

The Vendor's technical performance specification proposal entitled, [ ] dated [ ], is incorporated by reference and made a part of this contract. In the event of any inconsistency between the provisions of this contract and the Vendor's technical proposal, the contract provisions in this document take precedence.

C. Preliminary Testing by Vendor Prior to Shipping

Documentation of performance in accordance with following **preliminary** specifications shall be provided by the Vendor before shipping the instrument. The seller shall provide the necessary personnel, equipment and facilities to conduct these tests and the other specifications described in section G. below entitled "Technical Specifications" on the installed instrument, unless this document specifically states that UofO (University of Oregon) shall provide the items required.

1. **Ability to easily resolve 10-100 nm grains of WSe2 using the specified backscatter detetctor.**

D. Installation and Initial and Final Acceptance Testing

Initial Acceptance of the instrument shall be based upon completion of installation and after testing of instrument hardware performance ***on site*** at UofO, Eugene, OR to ensure that the instrument meets all Vendor factory specifications as determined by Vendor field engineers and by personnel selected by UofO.

Vendor reserves the right to use samples of its discretion to prove specification compliance during initial acceptance.

Final Acceptance is after the instrument meets all specifications is this document and all Vendor factory specifications as determined by by personnel selected by UofO. The final acceptance tests shall be performed on samples provided by John Donovan or his designated assistant at UofO, including metal elements, alloys, Si substrates, resolution and magnification standards and insulating materials. Final payment will be made after all acceptance tests have been completed and the instrument meets all specifications in this document.

The Vendor shall provide all parts, materials, labor, and transportation required to perform **preventive and remedial** maintenance on the instrument during the **installation and acceptance testing** period (up to one year or until the instrument has met all acceptance tests, **whichever is longer**). The maintenance services shall also be performed in accordance with the terms, conditions, and statement of work set forth herein. The Vendor's warranty shall not begin until the instrument has passed all acceptance tests and meets all technical specifications described in this document. Any consumables (filament, ion pump elements, light bulbs, etc.) required to run the instrument during the acceptance testing shall be supplied by the Vendor at no extra cost to UofO. **During System Installation and Initial Acceptance, Vendor has exclusive access to the system. During Final Acceptance both UofO and Vendor have access tp the system. Any exclusive use by UofO for a period of one month or greater denotes acceptance of all acceptance criteria by UofO.**

Preventive maintenance shall include, but not be limited to, cleaning, adjusting, lubricating, inspecting, and testing procedures to keep the equipment in good operating condition, preclude equipment failures to the greatest extent possible, and extend useful equipment life. It includes running of all diagnostics, and repair and replacement of all defective parts.

Remedial Maintenance shall include replacement of parts that do not meet the specifications or requirements described in this document. This includes all transportation, labor and parts required for the parts replacement or upgrade.

All parts, materials, and components, including expendable items, shall be replaced when necessary during the installation and acceptance testing period at no additional cost to the University. Replaced parts shall become the property of the Vendor.

The work to be performed shall be in accordance with the original equipment Vendor's specifications and recommendations. All services are to be performed by competent personnel, experienced and highly qualified to provide required services in accordance with the best commercial practices, without unnecessary delays or interference with University functions.

E-1. Technician Service Training

Service Training will be provided for one designated personnel for complete servicing of the instrument hardware and electronics at the Vendor’s manufacturing site. **Training shall be in conjunction with scheduled service visits and shall cover all aspects of the instrument including electronics, vacuum, mechanical, electrical and gun servicing including replacement of the field emitter.** All available service schematics and manuals [in English] will be provided to the designated personnel upon completion of the service training.

E-2. On Site Operational Training

Operational Training for one designated personnel for the instrument in the operation of all hardware and software shall be provided at destination by the Vendor. Training shall be approximately one week in length, starting once the initial acceptance of the instrument is completed and to be conducted during regular business hours Monday through Friday onm site at UofO.

F. Documentation

Documentation manuals shall be provided (where available) for the instrument, that clearly and completely describe hardware and software operation, troubleshooting, user maintenance and user servicing of all components of the Variable Pressure or Environmental Thermal Field Emission Microscope. All manuals for Vendor supplied third-party items shall be provided. The manuals must be originals or high quality copies and must also be completely legible and readable without magnification or other reading aid.

General interconnect and wiring schematics **in English** and spectrometer, sample stage and sample holder(s) mechanical drawings with dimensions and tolerances shall be provided by the Vendor. Detailed instrument schematics shall be provided **on a request basis per module** from the vendor in the event that UofO might make future modifications. **A complete list of all o-rings and part numbers and where used in the instrument shall be provided.**

All vendor supplied TCP/IP and/or dynamic link library (DLL), or COM/Active-X interfaces and functions shall be completely documented so that UofO may write programs in C, C++ or Visual Basic to access them. Several code examples shall be supplied to demonstrate the ability to interface to the Vendor's instrument interface and all specified Variable Pressure or Environmental Thermal Field Emission Microscope functions.

All manuals for Vendor supplied third-party items such as the computer boards and interface cables shall be provided. All documentation shall be provided **in English.**

G. Technical Specifications and Requirements

The University of Oregon requires a state-of-the-art, fully automated electron Variable Pressure or Environmental Thermal Field Emission Microscope to conduct its research programs. This Variable Pressure or Environmental Thermal Field Emission Microscope shall be able to image secondary and backscatter electrons and provide simultaneous EBSD and EDS spectrum acquisition at 70 degrees sample tilt at variable pressure conditions on insulating samples between 1 and 30 keV and must meet the following additional MANDATORY requirements.

1. Electron gun:

a) beam current must be regulated using a constant feedback mechanism to ensure stability 0.2 % or less per hour (+/- 01 %) and 0.5 % or less per 12 hours (+/- 0.25 %) and 1 % or less in 24 hours (+/- 0.5 %) as measured at 30 KeV and 1000 pA while repeatedly inserting the faraday cup once per minute

b) gun control and filament heating is to be digital to be automatically biased as accelerating voltage is changed from 100ev to 30 keV.

c) Schottky thermal field emission design cathode. Typical operating life of the filament shall average 20,000 hours or better at typical operating conditions for EBSD work with standard emission and beam conditions (1 nA beam current at 10-15

KeV) when operating in the variable pressure range sufficient for charge neutralization on insulating samples.

2. Electron column :

a) accelerating voltages regulated from 200eV to 30 KeV in at least 0.1 KeV steps

b) **absolute accuracy** of accelerating voltage **at 10 keV** must be less than 0.1 % (+/- 0.05%) from the nominal accelerating voltage or within 10 volts at 10 KeV as determined using the Duane-Hunt limit test on EDS (when calibrated on known x-ray line energies). The **absolute accuracy** of accelerating voltage **at 5 keV** must be less than 0.1 % (+/- 0.05%) from the nominal accelerating voltage or within 5 volts at 5 KeV as determined using the Duane-Hunt limit test on EDS (when calibrated on known x-ray line energies).

c) high voltage instability must be no more than +/- 0.05 % per hour at 30 KeV as determined by repeated Duane-Hunt limit test on EDS (with Cu $K\alpha/L\alpha$ calibration).

d) an object in the SE image shall remain centered in the field of view to within 5 um as the voltage is varied from 5 to 30 keV in 5 keV steps

e) beam shall focus/defocus in a symmetrical manner when the objective lens current is varied and at 5, 10, 20 and 25 kev without column or aperture readjustment

f) beam current shall not change more than 0.5 % (+/- 0.25 %) and the SE image shall not shift more than +/- 1 um while the stage Z axis is driven over it's full range when a point of interest is viewed under SE at 50,000X.

g) the beam monitoring aperture (faraday cup) current variation shall be less than 0.5 % (+/- 0.25 %) when measured on both a pure carbon sample and on a pure Fe sample at both 10 KeV and 25 KeV @ 1 nA beam current and enough replicate measurements to achieve sufficient precision and the stage position, i.e., stepper motor winding circuits) shall have an effect on the beam current of less than 0.1% (+/- 0.05%)

h) the carbon contamination intensity rate of change shall be less than 0.01% C/minute on a polished Cu sample for 30 minutes at 20 KeV and 1 nA with a focused beam

i) absolute accuracy of all magnification readouts or displays at 5, 10, 15, 20, 25 and 30 KeV must be less than 2 % (+/- 1 %) at 100x, 200x, 500x, 1000x, 2000x, 5000x, and 10,000x, using NBS/NIST standard 484a or other appropriate magnification standards. Additionally the scan rotation must be maintained within 0.5 degree rotation for each magnification change as specified above at both 5, 10 and 30 keV.

j) the instrument shall demonstrate no discernable image defocus at 150,000X when the beam shift in X and Y is moved from +100% to –100% from the beam normal axis, at a working distance of 15mm and 20 keV operating voltage.

k) The instrument *ultimate spatial resolution* shall be 1 nanometers (nm) or otherwise specified below. The specification shall be demonstrated during installation by imaging with secondary electrons under high vacuum condition using a standard

Au-C resolution standard. The Vendor shall indicate the working distance for *optimal* resolution. If a removable *pressure limiting aperture* may be present, the Vendor shall indicate its effect on resolution.

Working Distance below final lens →		**Optimal**	**15mm**	**25mm**
Condition ↓	**keV ↓**			
Attainable resolution, noting minimal beam current	30			
	15			
	5			
Attainable resolution at 1 nanoAmps	30			
	15			
Attainable resolution at 10 nanoAmps	30			
	15			

3. Secondary and backscattered electron digital imaging system :

UofO requires excellent secondary electron imaging using an "in column" or Everhart-Thornley type system, but it is essential that the pole face mounted BSE detection system be of the utmost sensitivity for atomic number contrast.

Tests will be performed on samples provided by UofO by all vendors to demonstrate the backscatter sensitivity of their pole face mounted solid state backscatter detection systems at working distances compatible with the EDS x-ray analysis system (typically 15 mm or 25 mm).

It may be necessary to have two separate poleface mounted BSE detectors, one for TV rate "survey" mode and another high sensitivity detector for slow scan acquisition.

A "forward scatter" BSE detector for backscatter imaging at high stage tilt (70 degrees) should also be provided. This can be mounted on the EBSD fiber light optics.

a) secondary image resolution of 1 nanometer at 15 KeV and a beam current of at least 100 pA defined as 95 % of primary electrons as measured on an Au nano particle resolution standard and measured using a signal from the SE detector and determined using the SMART resolution FFT macro by David Joy and and SCION software

b) backscattered electron spatial resolution of 15 nanometers or better at 30 KeV shall be performed using a sample of Au particles on carbon with a beam current of at least 500 pA

c) backscattered electron atomic number resolution must be at least 0.1 Z at Z=29 or better (must easily contrast α/β brass sample) at **both 5 keV and 10 keV using a 1000 pA beam and the pole face mounted BSE detector**

d) SE and BSE image distortion as determined by viewing a ball bearing at 200X must be less than 1 % (+/- 0.5 %) on the CRT

e) two (2) high contrast, high brightness, LCD flat panel diplay monitors for operating system and application and image display, 19"minimum diagonal.

f) the signal quality of the internal electron image system and the analog external outputs (for 3rd party imaging systems) must be of equal electronic quality in terms of noise and linearity

g) there shall be **dedicated** adjustment wheels or knobs for electron beam focus (fine and coarse), X and Y astigmatism, contrast, brightness and magnification at all times. The adjustment sensitivities should be magnification compensated where appropriate.

h) the system shall include both an Everhart-Thornley style SE/BSE chamber mounted detector and an "in-lens" or "through-lens" SE/BSE type column mounted detection system. The column mounted SE/BSE system shall show no obviously discernable adverse effects on the electron beam focus or stigmation as the energy selection detector voltage bias is adjusted through it's complete range.

i) the BSE detection system must be able to easily contrast a sample of alpha/beta brass using the BSE detector mode at 1000x, 1000 pA beam current at 3 keV, 2 keV, 1 keV and 500 eV using **a digital image integration times of 100μsec/pixel (e.g., 100seconds for 1024x1024 image). At 25keV, and at the above contrast settings, the BSE image shall show *<u>uniform coverage</u>* (flat field) across 2mm (horizontal and vertical).**

j) *<u>Scan correction for tilt and rotation</u>* shall be provided. For the given tilt, it shall (1) correct for spatial distortion of raster coverage, and (2) *dynamically* correct for focus, up to 70 degrees of tilt. Both (1) & (2) shall accommodate tilted specimen holders and electronic *scan rotation*.

k) The instrument shall provide an integrated dynamical focussing option in hardware that corrects for defocussing due to extreme beam deflection at extremely low magnification (< 100x). This is termed a dynamical radial beam deflection correction and must be automatically integrated when the instrument is used below 100x.

l) All imaging A/D systems must be 16 bit minimum and the *<u>image file format</u>* shall accommodate standard 8bit formats and a non-proprietary 16bit format, and shall include the *Tagged Image File Format* (TIFF). All saved TIFF files must be compatible with *Adobe Photoshop* v.6 or later (I.E., the TIFF 6.0 Specification). For the sake of automated image analysis, images shall be free of *<u>useless pixels</u>* (e.g., empty pixels usually found at image borders). The images shall also be free of any indication of frame/line synchronization (e.g., bright pixels along the left edge)

m) The detector must be *<u>twin-segmented (dipole)</u>*, and BSED segment selection shall be provided for *atomic number* mode, versus *topographic* enhancement, the segments shall be *<u>balanced</u>* relative to signal level and also with respect to noise. For accommodating change or age, a systematic procedure for balancing segment amplifiers shall be provided. NOTE: we recognize quad-segmented BSED are equally as functional, except to note it requires the balancing procedure described to be all that more important.

n) The *<u>spatial resolution</u>* of 15nm or better at 15keV shall be performed using a sample of Au particles on carbon. At 25keV, the *<u>brightness and contrast controls</u>* shall be functioning (i.e., not out of range) for Z~30 and beam currents relative to EDS acquisition. For example, the SEM shall be capable of BSE acquisition (atomic numbers Z=20-30) at normal beam currents typical of elemental mapping (beam currents: 1 to 15nA).

4. Specimen chamber with specimen exchange system :

The SEM shall minimally offer a *variable pressure* (VP) option from 1 to 260 Pascals (0.1 to 2 Torr), air or water vapor, and also minimally offer, possibly as a optional upgrade in the field, extended range (EP) of variable pressure (up to 2500 Pa). The *extended pressure* optional upgrade shall be quoted separately.

Working vacuum pressure (Pascals) →		**Res at 100 Pa**	**Res at _____ Pa**	**Res at _____ Pa**
Condition ↓	**keV ↓**			
BSE detector	30			
	15			
	5			
"VP" SE detector	30			
	15			
	5			
	2			

The variable pressure options shall be provided via *computer control*. The *state of vacuum settings*, chamber pressure, and *system ready* shall be observable in real time.

a) using automated vacuum system for vent and pumpdown, and allow sample exchange

b) a minimum of 4 **complete** sample holders (without part exchange) shall be provided and accommodate a variety of sample shapes and sizes for :

- 8mm, 10mm, 12mm and 25mm diameter round stubs in various configurations

d) sample exchange shall take no longer than 5 minutes. Time to beam ready shall be less than 5 minutes with a clean, dry sample.

e) It is critical that the entire gun, column and sample chamber vacuum system be assembled with high vacuum protocols, including but not limited to gloved assembly, all viton o-rings, completely degreased mechanical parts, under vacuum for 24 hours and back-filled with dry nitrogen prior to shipment.

f) Complete and detailed mechanical assembly drawings shall be **provided on a per request basis** showing all clearances above the specimen with all dimensions given of the objective lens pole face, backscatter detector, stage mechanism, sample shuttles and suitable side access port so that UofO may add detectors or other acquisition systems as necessary in the future

g) automatic protection against power, water supply , compressed air or vacuum failure

h) Uninterruptible Power Supply (UPS) using an "on-line" technology (no switching to or from batteries) for electrical system backup able to run all pumps, chiller, computers and electronics (6.4 KVA minimum) for a period of at least 5 minutes must be supplied.

5. Sample stage/motor system :

The University of Oregon requires a eucentric 5 axis stage stage with the best possible accuracy and precision capable of high speed movement between horizontal and 70 degrees tilt for EBSD work.

a) high speed and reliable servo or stepper stage motors with at least 0.1 um or less movement on all all three (x, y and z) axes. **The stage drift measured at 150,000X on Au/C standard shall be more than 4 nm per minute as tested for 30 minutes.**

b) there shall be **dedicated** trackball, thumbwheels or joystick for manual stage adjustment of X and Y (and Z) axes **simultaneously** that is linked to the current magnification of the instrument to scale the stage motion appropriately

c) Regarding the chamber ports: The SEM shall *provide chamber ports* for acquisition of analytical EDX, backscattered electron imaging, and cathodo-luminescence imaging at the analytical working distance (AWD) of 15mm (see CL detector specifications below).

d) The SEM shall provide a chamber port for a *horizontal EBSD camera* aimed at a working distance of 15-25mm. If a camera mount requires tilt, the Vendor shall otherwise state the angle of tilt.

e) **The vendor shall state if the *tilt can be in the same plane as, and towards the primary EDX detector*. If this requirement is considered non-standard and requires a modification, the Vendor shall quote a *non-standard modification* independent of the actual bid price.**

f) The SEM shall additionally provide a port for a *secondary EDX* mounted for the same AWD.

g) The Vendor shall quote a *camera for sample chamber observation*.

h) The chamber camera shall be installed specifically for *observation of the sample relative to the pole-piece and EBSD camera* (e.g., proximity of the sample relative to EBSD shall be without parallax and be obvious).

i) The *display for the chamber camera* shall be incorporated into the computer display.

j) The specimen stage shall offer *tilt* solely and exactly towards the EBSD port.

6. Instrument control and data interface :

a) all automation, acquisition and control software interface functions of the Vendor's instrument (stage, column/beam control, imaging, etc.) shall be specified and documented **in English**

b) complete documentation of interfaces and communication protocols to **main** instrument microprocessor(s) and/or hardware systems and subsystems shall be provided **in English** to allow UofO the option to interface directly to the probe hardware in the future. A non-disclosure agreement can be negotiated with UofO if required by the Vendor.

c) All Variable Pressure or Environmental Thermal Field Emission Microscope interface functions (TCP/IP, GPIB, serial and/or Windows 32 bit DLL and/or Active-X COM software interfaces) for stage, column control, and imaging acquisition **must be documented and clearly specified**, including but not limited to Variable Pressure or Environmental Thermal Field Emission Microscope interface hardware, column and stage configurations, also stage positioning, and analog digital image acquisition. The following table will assist in determining the minimum set of functions that will be required to interface the instrument to the software used by UofO.

The following are the minimum interface protocols required by UofO:

Required Instrument Specific Functions :

Instrument Function/Description	Values passed	Values returned
Initialize Instrument		success or error number
Shutdown Instrument		success or error number
Move Stage To Absolute Position	stage axis number, position	success or error number
Read Stage Move Status	stage axis number	Boolean
Stop Stage Move	stage axis number	Success or error number
Read Stage Position	stage axis number	Stage position
Get Accel Voltage		Kev
Get Beam Current		Current
Get Magnification		Mag
Set Accel Voltage	KeV	success or error number
Set Beam Current	Current	success or error number
Set Magnification	Mag	success or error number
Set Faraday	In/Out	success or error number
Set Beam blanker	On/Off	success or error number

Required Imaging Specific Functions :

Setup Image Acquisition	Channel type, channel number, magnification, scan speed, dwell time, pixel dimensions, pixel averaging, frame averaging, etc.	success or error number
Start Image Acquisition		success or error number
Read Image Acquisition Status		boolean
Stop Image Acquisition		success or error number
Get Image Data	Channel type, channel number	ixpixels, iypixels, image data()
Move beam to pixel position	X Pixel/X Pixel Max, Y Pixel/Y Pixel Max	success or error number

H. Interface acceptance tests to be performed by UofO :

The following testing of the software interface software shall be performed for evaluation of the Vendor's software and hardware at UofO :

1. Hardware Interface Tests :

a) Interface to the Variable Pressure or Environmental Thermal Field Emission Microscope interface shall demonstrated by reading the availibility or value and writing the value of the following instrument configuration parameters and all errors using a test program running on a Windows NT/2000 or XP PC based platform:

- Electron column control, electron gun control, faraday cup, high voltage control, magnification control, beam blanker
- Number of stages axes
- Read Beam current
- Operating conditions (accelerating voltage, beam current, faraday cup, magnification)
- Stage motion control (relative and absolute movement, backlash)
- Machine shutdown or filament standby
- Image control and acquisition (image size (resolution), integration parameters, etc)
- Start image, get image data

I. Additional Equipment Options :

In addition to the standard equipment necessary to meet the above specifications, the quotation should also include the following instrument options, unless they are already included as standard equipment :

1. A water cooled water recirculator for instrument cooling, running in hot gas bypass mode for maximum temperature stability.

2. A 1 year full coverage warranty (parts and labor) on the **entire** instrument to begin **after** the acceptance of the instrument by UofO, followed by 2 years of full coverage warranty (parts only) on the **entire** instrument.

3. A computer controllable (motorized) faraday cup for accurate beam current measurements in the electron column.

4. An ultra high sensitivity backscatter detector capable of resolving atomic number differences of less than 0.0001 Z at an average Z of 10.5 during slow scan imaging and capable of resolving atomic number differences of less than 0.001 Z at an average Z of 10.5 at TV rate imaging.

5. An infrared chamberscope must be propvided for viewing the sample, pole face and stage area

6. Uninterruptible Power Supply (UPS) using an “on-line” technology (no switching to or from batteries) for electrical system backup able to run all pumps, chiller, computers and electronics (6.4 KVA minimum) for a period of at least 5 minutes must be supplied.

7. An EDS x-ray analyzer system with full imaging capabilities integrated with an orientation/texture measurement EBSD system and integrated with the SEM control system. See specification J.

8. A electron backscatter diffraction system (EBSD) with full orientation imaging cabilities compatible using 16 bit CCD technology with full integration of stage motion and beam control using the available external communication interface.

9. All gas pressure regulators necessary for operation of the instrument (e.g., N2 venting tank)

J. Energy dispersive analyzer and EBSD Orientation System

Minimal employment of multiple computers shall be adhered to whenever possible. Each computer and its input devices (e.g., keyboard, mouse) shall be justified. The *specifications for all computers* shall be:

a) The *processor* shall be Intel Pentium 4, 3.0GHz or better
b) Included *RAM* shall be 1Gb or better
c) All *display cards* shall be for AGP bus and be dual-head compatible (I.E., allow for multiple (minimum 2) dual-RGB or dual-DVI monitors) per computer. 1280x1024x32 shall be the minimum display resolution for all monitors.
d) The computers designated for SEM control and for EDX control shall offer compatibility with *one mouse and one keyboard*.
e) The *primary hard drive* shall be 200Gb or better.
f) 100Mbit networking

1. Microprobe EDS acquisition and analysis software :

a) High level graphical user interface program(s) for complete qualitative and quantitative X-ray microanalysis and image acquisition, processing and analysis, data and image storage, retrieval, and graphical high resolution hard copy output. It is desirable that the application software run on a Windows XP operating system.

Licenses (and any hardware copy protection devices if necessary) shall be provided for running **two** copies of the vendor EDS/EBSD software simultaneously on separate computers. This is to allow UofO to one copy for on-line acquisition and analysis and another copy for off-line processing of spectra, orientations, calculation of quantitative data and image processing of previously acquired spectra, images, data and x-ray maps

k) The Vendor shall supply documentation of a method to control the Vendor supplied EDS spectrum acquisition and control functions (External Programmers Software Interface Kit) from a user written application using standard Microsoft Windows operating system calls such as active-X (COM) or standard public DLL calls. This requirement is to allow UofO to develop software to interface to the Vendor's EDS acquisition/imaging and control hardware.

l) All vendor provided software upgrades shall be provided at no extra cost to UofO for a period of 5 years after the system is accepted.

d) EDS peak identification and peak markers shall display or list :
- ALL (K, L, M, α, β, γ, etc.) x-ray lines capable of being generated at the current operating voltage
- As an option, all sum and escape peaks for the major peaks (if available in the software)

e) The quantitative x-ray microanalysis software shall provide complete routines for flexible and robust analysis of all major analytical peaks with a quantitative treatment and correction for spectral interferences, and also (but not limited to):

- output of raw spectra to disk file in EMSA spectra standard format (or ASCII format)

- element and spectral line selection ($K\alpha$, $L\alpha$ and $M\alpha$) standardization and calibration and recall of standard position and intensity calibrations from previous runs

- analysis (non-normalized) of a minimum of 25 elements or oxides (32 preferred), including calculating an element by difference, by stoichiometry, by fixing formulas proportional to oxygen

- oxide cation ratios can be defined by the user during the analytical run for the calculation of oxygen calculated by stoichiometry or measured

- a standard database that can store profiles for up to 1000 standards with 25 elements (32 preferred) each and include support for composition input by element weight percent or oxide weight percent (with default or user specified oxide cation ratios), or mole or atomic percents or formula atoms. If available, the ability to specify an element by fixed concentration is desirable when using user acquired standard profiles and the sum is NOT normalized to 100%.

- provide correction routines for x-ray intensity data x-ray emission vs. depth/density [$\phi(pz)$ or PAP or XPP]

    - provide complete saving of all instrument settings and user specified analytical options to disk and the ability to recall any sample raw data for further recalculation and to allow restarting the saved run or starting a new run based on a previous run instrument setup

    - background modeling of the x-ray continuum based on the displayed composition, properly scaled and corrected for detector configuration parameters

f) The EDS digital mapping and imaging software shall provide for :

- digital x-ray maps at 2048 x 2048 x 16 bits (64K gray levels) per pixel to be acquired using the EDS detector ROI signals. **At 1024 x 1024 resolution per map, a minimum of 16 separate x-ray maps (plus 2 analog signals) must be able to be acquired simultaneously.** The maps must be capable of being stored to hard disk or optical storage media in a TIFF or other standard image format

- provide qualitative elemental mapping (beam scan with X-Y position using relative or absolute microns or stage position) capability and output of background corrected intensities to image or ASCII file

- provide quantitative elemental mapping of with background concentrations (beam scan with X-Y position using relative or absolute microns or stage position) capability and output of background corrected intensities to image or ASCII file

- image acquisition and processing software shall be provided for X and Y manual and automated beam control and digitization of sample coordinates, pixel **and** frame averaging, software selectable X-Y internal/external beam scan control, background subtraction, contrast/brightness, image enhancement, RGB combination maps, false color processing, text annotation (and if available the NIST style logarithmic 3 band coloring of x-ray maps to show both major and trace element intensities).

- x-ray maps stored to disk must be registered to stage coordinates for scale calibration for off-line processing. The EDS interface to the instrument must automatically read HV, MAG, WORKING DISTANCE, and STAGE COORDINATES for each spectrum and image acquisition.

- x-ray maps constructed from spectral map datasets must also include net intensity maps which incorporate removal of background and peak overlaps, and the software must provide also provide a method to export the maps for quantitative post processing.

- pulse processing times easily adjustable in software, with at least 6 processing settings from lowest resolution/highest count rate to highest resolution/lowest count rate.

- spectrum imaging capability must be provided for at least 1024 x 1024 pixel images and 2048 MCA channels per pixel and the spectrum imaging file formats must be provided. Various tools must be provided for extracting images from the spectrum image data cube including (if available) “max pixel” or “maximum channel” and/or other standard spectrum imaging phase identifying algorithms for both major and trace (single pixel) phases.

2. Energy dispersive x-ray analyzer and image analysis system (EDS) :

a) EDS detector (Si(Li) $10mm^2$) shall have built-in safeguards against vacuum system degradation or failure, through durable detector window composition, design and construction and provide vacuum protection interlocks. The window must be rated to withstand at least 2 atmospheres (or 15 PSIG) and shall be able to withstand repeated venting of the column chamber to atmosphere or dry N_2.

b) The window composition shall be of the thin window type and shall be able to detect C at approximately the 1 % concentration level with 95 % confidence (test to be performed on a standard tool steel sample of composition in weight percent : 1.04 carbon, 9.9 Ni and 89.06 Fe) at 15 KeV and 30 nA sample current, using a thin window detector.

c) EDS detector resolution shall be 133 eV (or less) at Mn kα (measured on Mn metal) at 15 KeV **and** at a count rate of 2500 cps (or more) and under the same conditions vary by less than 1 eV when the count rate is varied from 1,000 to 10,000 cps.

Under the same conditions, the detector resolution shall also be 75 eV at F kα (or less) at a count rate of 2500 cps (or more). Under the same conditions, the detector resolution shall also be 70 eV at C kα (or less) at a count rate of 2500 cps (or more). Under the same conditions used to measure these resolutions, confirm that the full width and 1/10th the maximum for Mn kα is less than or equal to 1.9 FWHM. The detector shall maintain this specification after repeated thermal cycling and/or thermal conditioning.

In addition the detector resolution shall be 138 eV (or less) at Mn kα (measured on Mn metal) at 15 KeV **and** at a count rate of 10,000 cps (or more).

d) The energy calibration, when measured using the same x-ray lines, shall shift less than 1 ev at deadtimes from 0 to 50% and count rates from 0 to 10,000 cps.

m) the detector and electronics shall be capable of sustaining count rates up to 50,000 cps and simultaneously maintain a deadtime of less than 70% in order to perform under fast x-ray mapping conditions.

n) The Manufacturer shall indicate the detector-to-sample distance for ***uniform collection*** from a sample area 2mm (square) when spectral mapping. The homogeneous sample can be steel or brass, and elemental maps shall be from soft and hard x-rays (e.g., Fe L & Fe Ka or Cu L & Cu Ka). The Manufacturer shall indicate if and how their collimator affects this distance.

o) The EDX acquisition and quantification software shall offer *standard-less* capability. Software options for *quantifying oxygen and carbonate* shall include *by difference* and *by stoichiometry*

p) If an EDX analysis is claimed to be *quantitative* (e.g., relative to standard intensities), the analysis shall include a determination of error, and a reference to how it is determined.

q) EDX *mapping* shall include *spectral mapping* (i.e., saving the entire spectrum). This capability shall also be true of linear determinations (e.g., line scans), and the dwell times for discrete special acquisitions shall be deadtime-corrected.

r) **The Vendor shall provide an automated stage drift correction for extended mapping sessions.**

s) When the analyzed area is too large for uniform beam exposure or detection, the EDX software shall offer the capability of *stitching together* multiple x-ray maps or images.

t) Subsequent numeric and *graphical presentation* of line scans and spatial mapping shall include absolute and background corrected counts, weight percent and atomic percent.

u) The EDX software shall accommodate *unattended automation* of the stage with respect to (1) unattended spectral acquisition from selected points, and (2) automating lines and spatial grids relative to (a) sample center and (b) selected endpoints.

v) Unattended automation shall be *capable of loading shutdown or standby conditions* when the project has finished.

w) The EDX spectral acquisition software shall include *automatic peak identification*, including artifact peaks (e.g., high count rate pile-up, detector escape peaks).

x) The EDX software shall be able to generate *synthetic spectra* for any compound of known composition and density, given the instrumental conditions and determinable detector characteristics.

3. Electron Backscatter Diffraction and orientation imaging system (EBSD) :

a) The *EBSD camera and phosphor* shall:

a. Minimally offer electron backscatter diffraction pattern (EBSP) image capture with *1024 x 1024 pixels and 12 bit precision*. All pixels shall be employed, or the Manufacturer shall state the percentage used.

b. The Vendor shall provide a *orientation contrast forescattered electron detector* (FSD) option.

c. The *Camera's insertion and retraction* shall be motorized via remote control and digital readout, and insertion shall be accurately reproducible to within 0.1mm.

d. The EBSD system shall be capable of *map acquisition speeds* greater than 100 points per second during orientation mapping applications demanding pattern acquisition and indexing. This would include the saving of x-y coordinates and Hough transforms during the acquisition.

e. The camera shall employ an *adapter to the SEM port* which aims the camera at a sample working distance of 20mm, and which also allows for a user-selectable range in working distance of 10mm (i.e., 15mm to 25mm).

f. Any *optimal position* of the camera shall not hide the EDX detector from the sample's source of x-rays, and it shall accommodate optimal positioning of the EDX detector.

g. The camera shall employ an *audio alarm and auto-retract mechanism* that is sensitive to contact with sample during camera insertion or stage movement.

b) The EBSD system shall either share a *digital scan generator* (DSG) with the EDX system (if integrated with EDX), or shall provide its own (if not integrated). The DSG provided shall be capable of 12bit precision, interface with EBSD for acquiring images independent of SEM or EDX, provide options for image acquisition and resolution, and correct the image for any tilt typical of EBSD applications (e.g., 70 degrees).

c) The EBSD system must be capable of *reading the SEM* stage position and column conditions (e.g., HV, magnification, working distance, etc.).

d) The EBSD system must employ a *Hough transform optimized for EBSD Kikuchi patterns* for indexing the acquired patterns in real time.

e) The software must provide a *high accuracy indexing* software tool (less than 0.5 degree mean angular error) for post-acquisition indexing independent of Hough.

f) The EBSD system shall allow *saving, while acquiring*, the (a) Hough transforms, (b) pattern images for all acquisition points, and (c) pattern images of acquisition points that failed to index. JPEG image compression shall be an option without affecting the accuracy of post-acquisition indexing.

g) The Vendor shall quote the *software option for phase identification*, and make note of which diffraction databases are included. All 11 *Laue* groups and all 230 space groups much be accommodated.

h) The software for phase identification and indexing shall be capable of *creating a subset of possibilities* with respect to (1) integrating with EDX and acquiring qualitative elemental composition, or (2) querying the user for similar input.

i) The phase identification and indexing software shall accommodate *application-specific databases* (e.g., user defined, or created, specifically chosen subsets of the general databases).

j) The Vendor shall quote the *phase identification* and *crystal orientation* software.

k) The *post-processing orientation mapping* software shall provide the possibility for users to create their own mapping algorithms, and allow for subset creation of maps using logical operations (e.g., AND, OR, XOR of grain size, shape, orientation). The software shall also provide the *standard map components* for:

   a. Diffraction Pattern Quality
   b. Orientation coloring (Euler angles, unit triangle, RF vectors)
   c. Any user-defined texture component
   d. Phase coloring
   e. Grain and sub-grain boundaries
   f. CSL and special boundaries
   g. Phase boundaries
   h. Mean orientation of grains
   i. Mean misorientation within grains
   j. Grain shape characteristics
   k. Deformed / recrystallized fractions
   l. Strain contouring
   m. Schmid and Taylor factors

l) An extra site license shall be provided for post-acquisition processing of all proprietary data files.