INDIAN INSTITUTE OF TECHNOLOGY BOMBAY

MATERIALS MANAGEMENT DIVISION

PR NO. 1000058070 **RFx No.6100003219**

Technical Specifications for Optoelectronic Measurement Setup

Sr. No.	Description	Value / Range	Tech-nical Compli-ance (YES / NO)	Additional Information (if any)
1.	**Capabilities**			
1.A.	Must be able to achieve simultaneous high-resolution topography, mechanical and ultra-low current mapping on quantum materials			
1.B.	Must include light induced current mapping for the characterization of local photoelectrical properties including charge generation, separation and transport properties			
1.C.	Must be compatible with Raman spectroscopy to facilitate correlative chemical and structural analysis			
1.D.	Must Include (as standard) modes and options to achieve measurements and spectroscopies as listed in section 2.			
1.E.	May include (as option) modes and options to achieve measurements and spectroscopies as listed in section 3. If not included, must be able to include them in future by addition of accessories/software components only.			
1.F.	Must include accessories as listed in section 4.			
1.G.	Must fulfil hardware and software requirements as listed in sections 5 to 10.			
1.H.	Must fulfil acceptance criteria as listed in section 14.			
2.	**Modes and options included as standard**			
2.A.	Mapping of topography in air at high resolution through -	2.A.1) continuous contact with sample 2.A.2) oscillating light tapping on sample 2.A.3) periodic tapping with real time interaction force control 2.A.4) electron tunneling between sample and hovering tip 2.A.5) torsional resonance between lateral interaction forces		
2.B.	Measurement and mapping of additional properties simultaneously with topography as listed -	2.B.1) Phase lag during out-of-plane/in-plane oscillations 2.B.2) Continuous and dynamic lateral forces such as friction 2.B.3) Surface potential/work function 2.B.4) Electric field distribution 2.B.5) Magnetic field distribution 2.B.6) Nanomechanical properties 2.B.7) Interaction force during approach/retract		
2.C.	Automatic optimisation of scanning parameters to enable highest resolution with specifications as follows – Sinusoidal Z - modulation frequency of the cantilever at 2 kilohertz with amplitude (< 1 nanometer – 300 nanometer) freely selectable. Determination of the imaging force (force setpoint) should be automatically and continuously optimized without user intervention. Force setpoint			

	control to 10 piconewton required. Effective line rates of at least 2 Hertz at 512 pixels per line even for the smallest force setpoints selectable. Topography, modulus, adhesion, dissipation of energy, and deformation should be simultaneously measured in real time and displayed with quantitative SI units. The tip-sample interaction (power curve) should be continuously displayed while imaging in real time. This mode should be capable of operation without limiting functionality with fluid cells, heating cells and electrochemical cells. User-interaction to collect an image is minimized to specifying scan size only. All scan parameters (speed, feedback setting, feedback gains, etc.) are set by an automated built-in optimization routine.			
2.D.	Dual approach mode for separating additional properties from topography pixel scan with specifications as follows – The sample's topography should be determined on a first pass over a scan line. The data are stored and a second parameter, such as magnetic field, should be determined on a second pass of the same scan line, accomplished by lifting the probe a set short (e.g., 50 nanometer) distance above the surface. It has to be possible to use closed-loop z to achieve the desired lift height. Capability to switch off the laser light during lift scan. Other methods, e.g. which simply skim the tip some height above the sample without regard to topography are not acceptable.			
2.E.	Simultaneously with high resolution topography, measurement and mapping of piezoelectric response in different modes (separate or combined) as listed -	2.E.1) Contact resonance 2.E.2) Off resonance 2.E.3) Vertical 2.E.3) Lateral 2.E.4) Lithography 2.E.5) High voltage (up to ± 150 Volts or higher) 2.E.6) Hysteresis 2.E.7) Switching spectroscopy for calculation of piezoelectric coefficients in picometer/volts 2.E.8) Per pixel multidimensional acquisition of complete off-resonance and contact resonance piezoelectric force spectroscopic data for advanced characterization.		
2.F.	Simultaneously with high resolution topography, measurement and mapping of electrical current between tip and sample with abilities as listed -	2.F.1) Ability to measure and map ultra-low current between tip and sample using periodic tapping with real time interaction force control. 2.F.2) Picoampere level current sensitivity 2.F.3) Sub-100 femtoampere noise level 2.F.4) Additional abilities to measure electrical conductivity and dielectric integrity.		
2.G.	Must integrate side illumination of samples for nanoscale light induced current mapping. It should provide controlled optical illumination, electrical biasing, and low-current detection in the picoampere range or better. The system should enable localized dark/light photocurrent measurements and wavelength-dependent photo response characterization with high spatial resolution, allowing investigation of charge generation, separation, transport, and collection mechanisms in optoelectronic and semiconductor materials. Photocurrent maps should be spatially correlated with topography scans and support quantitative data analysis. The side illumination must be achieved through a laser assembly with specifications as listed in section 10.			
2.H.	Must be able to electrically bias the tip and the sample through the instrument control. The sample should be able to be biased through the			

	chuck or through external probers without hampering the normal scanning.			
3.	**Optional modes and options**			
3.A.	Ability to perform measurements, listed in Section 2, on samples in fluid			
3.B.	Ability to perform measurements, listed in Section 2, on samples in an electrochemical environment			
3.C.	Simultaneously with high resolution topography, profile carriers in semiconductors and dielectrics by -	3.C.1) capacitance sensing using inductor-capacitor oscillator 3.C.2) resistance sensing using current amplifier 3.C.3) impedance sensing using microwave signals		
3.D.	Ability to do thermal analysis on samples as listed, with/without combination with other modes -	3.D.1) Ability to cool the sample to -30 degrees Celsius or below. 3.D.2) Ability to heat the sample to 200 degrees Celsius or above. 3.D.3) Measure variations in sample temperature or thermal conductivity on the nanoscale. 3.D.4) Ability to determine the melting or glass transition temperature of a material up to at least 300 degrees Celsius using a closed-loop point-and-shoot method with sub-100 nanometer inspection region.		
3.E.	Ability to integrate chemical spectroscopic techniques such as Raman or IR spectroscopy to enable nanoscale chemical analysis.			
3.F.	Upgradable to fast scanning up to 90 or 150 Hertz			
3.G.	Optical pattern recognition, system pattern recognition and autofocus functions which enable highly accurate & repeatable positioning of scans, from microns positioning on homogeneous samples to tens of nanometers on patterned samples.			
3.H.	An accessory that allows application of a variable magnetic field parallel to the sample plane. Field strength capable of reaching +/-0.8 Tesla (+/- 8000 Gauss) with Maximum field ramp: 7000 Gauss/minute. An integrated sensor must measure the field strength near the sample with a resolution of ~1 Gauss and the field strength should be software controlled. During steady state operation, the device should not generate heat, even at the maximum field strength. The module should be based on a permanent magnet (not an electro-magnet) so that no cooling of the magnet is required. This module should include capabilities for both in-plane and out of plane operation. The out of plane magnetic fields should be possible just by the inclusion of required pole pieces which should allow field ranges of approximately +/- 1200 Gauss in a bipolar configuration.			
3.I.	Ability to integrate AFM imaging with optical microscopy, allowing the user to automatically import and rescale light microscope images, which can then be used to direct the location of AFM imaging and force measurements.			
3.J.	Ability to quantify nanomechanical and viscoelastic properties of the sample by -	3.J.1) force modulation 3.J.2) frequency sweeping from sub-Hertz to kilohertz 3.J.3) nanoindentation 3.J.4) force pulling 3.J.5) a high-strain, high-travel manual stretching stage that provides two axis stress control of tensile loaded samples and allows control of the sample image region under different loads		

3.K.	Modification of sample surface at nanoscale using modes -	3.K.1) Nanomanipulation 3.K.2) Nanolithography		
4.	**Included Accessories**			
4.A.	Cantilever/Probe holders for each included mode, as per recommendation from OEM (Original Equipment Manufacturer) as published on their website/brochures/handbooks -	4.A.1) At least 2 for high resolution surface topography scanning in air. 4.A.2) At least 1 for each standard or optional mode/option included (if same cantilever holder supports multiple modes (as per OEM recommendation), then minimum requirement applies to all compatible modes combined) 4.A.3) At least 1 high clearance cantilever holder to provide space for external probing		
4.B.	Pre-mounted (preferred) or unmounted tips/probes for each included mode, as per recommendation from OEM as published on their website/brochures/handbooks -	4.B.1) At least 10 probes of 4 types each for high resolution surface topography scanning in air. 4.B.2) At least 40 probes for automatic optimisation of scanning parameters for ultra high resolution scanning. 4.B.3) At least 20 pre-cut/pre-etched tips for scanning using electron tunnelling between sample and tip. 4.B.4) At least 10 probes for each standard or optional mode/option included (if same probe supports multiple modes (as per OEM recommendation), then minimum requirement applies to all compatible modes combined)		
4.C.	Reference samples for calibration and testing for each included mode, as per recommendation from OEM as published on their website/brochures/handbooks -	4.C.1) At least 1 for each standard or optional mode/option included (if same reference sample can be used for multiple modes (as per OEM recommendation), then minimum requirement applies to all compatible modes combined) including but not limited to the ones listed below. 4.C.2) Periodically poled Lithium Niobate 4.C.2) Highly Oriented Pyrolytic Graphite 4.C.3) Silicon sample with patterned gold and aluminium 4.C.4) Calibration sample with grids of known height variations		
4.D.	Tweezers, scribes, disks, stickers etc. for sample preparation and mounting, probe loading etc.			
4.E.	Probe loading stations compatible with included probe holders for safe replacement of probes.			
4.F.	Enough cables and hoses to connect all the components of the instrument to each other and to facilities.			
4.G.	Active air vibration isolation table with acoustic enclosure			
4.H.	Screwdrivers, wrenches, hex keys etc. for installation/maintenance			
4.I.	Granite top table with drawers to hold system hardware			
4.J.	System computer with pre-loaded software and manuals with specifications -	4.J.1) Windows 10 Operating System or newer 4.J.2) Processor with 6 cores (12 threads) or better 4.J.3) Processor with base clock frequency of 3 gigahertz or better		

		4.J.3) 1 or 2 LCD monitors with a combined screen diagonal length of at least 30 inches 4.J.4) Mouse, keyboard, trackball for interfacing with the software		
5.	**General hardware/software requirements**			
5.A.	The Instrument should have a true tip-scanning configuration, i.e., the tip is actuated in all axes for the scanning motion, XY and Z. Moving the sample in XY or XYZ for scanning is not acceptable.			
5.B.	Height noise	Better than 30 picometer (pm) (root mean squared)		
5.C.	Engage mechanism	5.C.1) Single axis vertical 5.C.2) Automated, Fully software controlled		
5.D.	XY drift	Smaller than 200 pm/minute		
5.E.	The dither piezo used to actuate the cantilever oscillation, should be located inside the tip holder, and located directly underneath the cantilever substrate.			
5.F.	Must have a completely automatic engage under software control into feedback on the sample surface, using the stepper motor and the Z-piezo incrementally to find the lowest possible imaging force with a minimum of false engages and a minimum of user interaction.			
5.G.	Control parameters (e.g. sample rate, number of lines, zoom, offset, image field size) should be changeable in real time and on the fly (without stopping and restarting of the scanning process).			
5.H.	It should be possible to continuously monitor, in real time, the full harmonic spectrum (simultaneously monitoring of all harmonics up to at least the 15th) of the flexural (vertical) and torsional (lateral) cantilever oscillation, and use this to reconstruct the tip-sample interactions in full detail and in real-time.			
5.I.	The Instrument should provide the capability to calibrate the cantilever spring constant by thermal tuning of the cantilever by sampling frequencies up to 2 megahertz.			
5.J.	Scanning channels	5.J.1) Up to 8 simultaneous channels in real time scanning 5.J.2) High pixel density images up to 5000 x 5000 data points for each channel		
5.K.	The Instrument should include the possibility to sample at a rate up to 50 megahertz on 2 channels. It should be possible to trigger the high speed data capture by software-defined events, such as: reaching a specific location in the scanned image, or when a user-defined parameter reaches a specified level. The electronics for the high-speed sampling should be integrated into the controller.			
5.L.	Lock-in amplifiers: 3 independent digital lock-in amplifiers, integrated into the controller with the following features:	5.L.1) Two lock-ins up to 5 megahertz 5.L.2) Third lock-in up to 50 kilohertz 5.L.3) Software controlled, including control of the lock-in bandwidth, routing of input signal, routing of output signals.		
5.M.	The controller should provide three independent digital to analog converters (DACs) per axis (X,Y & Z) = 9 in total dedicated to scan motion.			
5.N.	The DACs must have an integral nonlinearlity < 0.5 % in each axis.			
5.O.	Integrated module to allow user access to input/output signals.			
5.P.	The controller should include digital active control of the cantilever quality factor.			
5.Q.	It should be possible – by software control – to ground or apply a voltage to both the tip & sample independently.			
5.R.	Operational in environments with up to C-weighted 85 decibels continuous acoustic noise.			
6.	**Sample Stage Requirements**			

6.A.	Software-controlled Motorized XY stage with possibility to accept samples up to 210 millimeters diameter and 15 millimeters thick.			
6.B.	XY motorised travel range of minimum 180 x 150 millimeters.			
6.C.	Ability to be positioned with video image using computer mouse / joy stick.			
6.D.	The sample stage should have vacuum to hold the samples down.			
6.E.	XY positioning repeatability of 2 micron (µm) (bidirectional), or better.			
6.F.	Ability to rotate about its centroid.			
6.G.	Must be able to bear high weight without degradation of scanning performance.			
6.H.	Must be able to electrically ground/bias the samples through the chuck			
7.	**Scanner Requirements**			
7.A.	Single XYZ tube tip scanner capable of imaging from atomic lattice levels up to µm level eliminating the requirement of multiple scanners. Split scanners in XY and Z are not acceptable due to their high thermal drift rate.			
7.B.	Scanning range	7.B.1) XY range >= 90 µm 7.B.2) Z range >= 10 µm		
7.C.	The scanner should be sensored and be able to operate in open and closed-loop in XY and Z.			
7.D.	The scan head should use a low-noise red laser light.			
7.E.	Noise level in typical imaging bandwidth (625 hertz) -	7.E.1) XY sensor noise <= 150 pm (root mean squared) in closed loop 7.E.2) Z sensor noise <= 35 pm (root mean squared)		
8.	**Video Optics Requirements**			
8.A.	Top-view optics with motorized focus & digital zoom.			
8.B.	Inclusions	8.B.1) 10X objective 8.B.2) 5-Megapixel or better camera 8.B.3) Software-controlled white light-emitting-diode illumination 8.B.4) Software to display and store the optical image from within the system software.		
8.C.	Camera objective should be user changeable without removing covers, outside the beam deflection path, and oriented at an angle of at least 45 degrees to the surface normal.			
8.D.	Field-of-view (FOV)	8.D.1) Maximum FOV >= 1450 µm 8.D.2) Minimum FOV <= 200 µm 8.D.3) Software controlled changing of FOV		
8.E.	Optical resolution	1.6 µm or better		
9.	**Software Requirements**			
9.A.	Capabilities	9.A.1) Can display at least 16 imaging windows 9.A.2) Generalized multi-channel spectroscopy 9.A.3) Generalized multi-meter signal display 9.A.4) Ablility to sweep frequency in both directions in Auto-Tune 9.A.5) Capability to overlay the amplitude & phase signal in Auto-Tune 9.A.6) Can display external signals as images or spectroscopy data 9.A.7) Phase adjustment capability in Phase Imaging for maximum sensitivity (to		

		set the Phase to ‘zero’ at the operating point) 9.A.8) Closed-loop point-and-shoot probe positioning for every mode.		
9.B.	If more than 2 channels selected to be displayed, they all have to show either trace or retrace. A mixture of trace and retrace is not acceptable.			
9.C.	Real-Time Software with an on-the-fly parameter update (i.e., during image acquisition) including feedback gain, drive amplitude, scan rate, setpoint, lock-in filter, lock-in gain scan size, pixels, offset.			
9.D.	Single click transfer of partial images into analysis suite for immediate full analysis during ongoing data acquisition.			
9.E.	Optional synchronizer package enabling full handshaking with external devices for every pixel, line, frame, or point-and-shoot probe position.			
10.	**Side Illumination Laser Assembly Requirements**			
10. A.	The laser assembly must consist of lasers, holders, aligners, optical elements etc. for uniform illumination of sample within scan range as per specifications below.			
10. B.	Laser wavelength ranges	10.B.1) 400-420 nanometers 10.B.2) 620-640 nanometers 10.B.3) (Optional) 800-900 nanometers		
10. C.	Laser specifications	10.C.1) Diode lasers 10.C.2) Power: 10 milliwatts 10.C.3) Beam power stability <= 5% 10.C.4) Beam divergence <= 0.5 milliradi-ans 10.C.5) Operating voltage: 3-5 Volts (Di-rect Current) 10.C.6) Operating Modes: continuous-wave and Transistor-Transistor Logic modulated pulsing with frequency much greater than the maximum per pixel scan-ning frequency of the instrument 10.C.7) Warm-up time <= 3 seconds 10.C.8) Operation lifetime > 5000 hours		
10. D.	The laser assembly must allow the sample to be illuminated from the top at a side angle, such that the normal functioning of the instrument is not affected at all.			
10. E.	The laser assembly must be independent of the sample stage and scanner.			
10.F.	The laser assembly must allow manual or motorised movement and alignment of laser beams for highly precise alignment of beam spot on the region of interest (sample under the scanning tip).			
10. G.	The laser assembly must include optical elements (mirrors and lenses) in the beam path to focus the beam on the region of interest such that the beam spot is round and the diameter is 2-5 times the maximum scan range of the instrument.			
10. H.	The laser assembly must be stable such that the beam spot should not drift more than 5% of beam spot size during a scan, irrespective of the scan range and frequency.			
10.I.	The laser assembly must include holders to allow ND filters to be intro-duced in laser beam path for reducing beam power.			
10.J.	The laser assembly must include holders to allow beamsplitters to be introduced in laser beam path for simultaneous monitoring of beam power.			
10. K.	The laser must be able to turn on and off with high frequency using both manual and automated control via instrument software, so that data for both laser ON and laser OFF can be taken at each pixel during scanning/mapping.			

11.	**Installation & Training**	11.A) At least 2 days for assembly and installation 11.B) At least 3 days until completion of comprehensive and satisfactory on-site training of all included modes and options		
12.	**Warranty**	One year		
13.	**Service and Support**	The vendor must have service engineers and application scientists to provide complete support and service. The downtime of instrument should not go beyond 72 hours.		
14.	**Acceptance Criteria**			
14. A.	Installation and Qualification	Installation and on-site qualification of the system by the OEM.		
14. B.	Training	14.B.1) On-site operational training for two engineers, covering system operation, maintenance, and basic troubleshooting. 14.B.2) Training shall be provided by the OEM authorized/certified skilled personnel.		
14. C.	Tool Performance Verification	14.C.1) Data on standard reference factory samples is repeated on-site with a repeatability error of 5-10 % w.r.t factory data. 14.C.2) The vendor also demonstrates measurement on user-provided samples on-site within the specs of the tool. 14.C.3) The vendor also demonstrates accurate measurements for various features of the purchased tools on-site.		
14. D.	Site Acceptance Test (SAT)	The system must undergo SAT at the IITB site, replicating the factory acceptance test parameters as per following- The vendor demonstrates scanning in all included modes on reference samples (provided by vendor/OEM) across different scan parameters as well as analysis of acquired data. Vendor performs localised optoelectronic measurements to demonstrate the functionality of the included side illumination assembly. The vendor demonstrates advanced acquisition and analysis options of the software including scripting and automation. To verify repeatability, the vendor performs the measurements on the reference samples on-site and shows that the data matches factory data with an error of <5-10 %. The vendor also demonstrates measurements on a user-provided sample on-site within the specs of the tool.		