Multi-mode Atomic Force Microscope (with High Voltage Piezo Force Microscope and +/- 8000 Oe Variable Field module.)

Main specifications of the proposed instrument:

1 Instrument Resolution:
1.1 The instrument must have demonstrated atomic lattice resolution in AC mode and contact mode imaging. This must be done with the same large scan-range scanner set that can also image at least 90µm x 90µm (X-Y) and 15 µm (Z).

2 Instrument Geometry:
2.1 The XY scanner must be separate from the Z scanner to eliminate the "bowing" artefact commonly seen in piezo-tube based (XYZ scanners) AFM systems.
2.2 The cantilever holder and the optical lever assembly (laser, optics and detector) must be housed within a single rigid frame thereby eliminating artefacts due to relative motion between the optical lever arm and the cantilever during imaging and force measurements.
2.3 The instrument must accommodate samples of sizes up to 80mm in dia. and 10mm in thickness.

Optional: The vendors are also requested to quote for the scanning ability on samples up to 27mm in terms of thickness (for example, possibly with optional leg extenders). This must be quoted but will be purchased depending on the availability of funds.

2.4 The instrument must be a sample scanning system so that the machine provides the flexibility of using of tip enhanced optical techniques in the future.

3 Operating Modes:
3.1 The microscope must be capable of the following scanning modes, each of which requires at minimum that the signals noted in the corresponding parentheses be recordable simultaneously. Each of these signals must be recorded in both trace and retrace scan directions. Here, auxiliary signals refer to external inputs that are independent of the microscope:
3.1.1 Contact (lateral force, topography, deflection, feedback error, one auxiliary)
3.1.2 Dynamic (topography, amplitude, phase, frequency shift, one auxiliary)
3.1.3 Force vs. displacement (deflection, lateral, two auxiliary)
3.1.4 Electric Force Microscopy
3.1.5 Magnetic Force Microscopy
3.1.6 Surface Potential/Kelvin Probe
3.1.7 Nanolithography and Nanomanipulation
3.1.8 Piezoresponse Force Microscopy, including Switching Spectroscopy PFM**. High Voltage +/-220V Bias** with integrated high voltage amplifiers and software compatibility.
3.1.9 Dual AC: should provide multiple frequency drives and analyses for bimodal and harmonic measurements and imaging.
3.1.10 Conductive (current, voltage, deflection, lateral, topography)
3.1.11 **Variable magnetic field Module with facility to apply in axis magnetic field +/- 8000 Oe.**

4 System Noise:

DC Height Noise must be less than 60pm ADEV in a 0.1Hz to 1kHz BW (<20pm in quiet environments in a shielded room with STC 30 sound isolation). DC Height Noise is defined here as the apparent movement of a moderately stiff cantilever (example: Olympus TR800,100 (m, k=0.61 N/m), or equivalent) in static contact with a hard surface with the Z feedback loop turned down to limit the bandwidth to below 0.1 Hz so that it doesn't affect the measurement. It is not acceptable to estimate this noise based on the Height signal; this test is too poorly defined for the purposes of comparing systems since adjusting the gains affects the measurement. DC Height Noise is also known as "Z Height Noise" and "System Noise".

5 Optical Lever Arm: Light Source and Photodetector:

5.1 The instrument optical lever arm must use a low coherence light source (for example, a super luminescent diode, SLD) to reduce artefacts from optical interference effects.
5.2 The instrument must use an infrared SLD (or equivalent) for the optical lever arm to eliminate optical crosstalk with epi- and transmission- fluorescence measurements.
5.3 The instrument's DC Detector Noise must be less than 20pm ADEV in a 0.1Hz to 1kHz BW. The DC Detector Noise is defined here as the apparent movement of a short, moderately stiff cantilever (example: Olympus TR800,100 µm, k=0.61 N/m, or equivalent) not in contact with a surface.
5.4 The SLD (or equivalent) must be incident on the cantilever at an angle of approx. 22^0 to the sample normal thereby reducing interference problems due to laser retro-reflections.
5.5 The microscope must have an optical sensing bandwidth of at least DC to 2 MHz.

6 System Scanner:

6.1 The scanner must be closed-loop and independently actuated in X, Y and Z with dedicated piezo stacks.
6.2 The scanner must provide XY scan range up to 90µm x 90µm (closed loop) or greater.
6.3 The Z scan range must be 15µm (closed loop) or greater.
6.4 X and Y sensor noise must be less than 500pm ADEV in a 0.1Hz to 1kHz BW, with sensor nonlinearity <0.5% at full scan.
6.5 Z sensor noise must be less than 250pm ADEV in a 0.1Hz to 1kHz BW, with sensor nonlinearity <0.05% at full scan.
6.6 The microscope must utilize a closed-loop XY scanner that can achieve stable, closed-loop scan speeds of at least 1 mm/s.
6.7 Out of plane motion must be <30nm over the closed-loop scan range.

7 System Optics:

The AFM should be configured with Top View, Bottom View or preferably Dual View optics.

For top view: The instrument must include Kohler illumination and a view of the cantilever and sample from above. It must have at least two, software selectable magnifications (720µm and 240µm field of view – with the standard ¼" CCD camera).

8. Liquid Imaging: For imaging in liquid, a closed, sealed chamber with ten inlet and outlet ports for the exchange of liquid or gas media in an otherwise sealed environment. The kit to include various sample accessories, as well as a membrane and clamp for sealed operation should be provided.

9. Environment Controller: Environment controller should be provided and interfaced with different heating and cooling and humidity options. This should be based on closed loop operation to ensure precision and accuracy. The interface should be included which can auto-configure each accessory for easy plug and play operation.

9.1 A temperature control stage for variable temperature studies from -35^0C or less to 300°C or more should be provided. This should be compatible with the system and have the capability to be used in special gaseous environment and/or in vacuum. This stage should support samples up to 20mm in diameter. The kit to include all necessary accessories for sealed operation. This should include special cantilever holder if required for refined results.

10. Conductive AFM

10.1 The system must allow conductive measurements while scanning as well as at user specified locations (I-V curves).
10.2 A sample bias of -10V to 10V must be possible.
10.3 The bandwidth of the trans-impedance amplifier must be at least 17kHz.
10.4 The software must allow user-specified wave forms for I/V spectroscopy (square, sine, triangle, pulse, or user defined).
10.5 The software must allow user-specified wave forms for loading and unloading, including multiple user-specified trigger-points, while simultaneously monitoring current.
10.6 The system should preferably include automated mechanism for reducing contact resistance due to surface contamination in I/V curves.
10.7 The current sensing range must be 1pA to 20nA.

11. High Voltage Module: High Voltage PFM
11.1 The instrument must provide +/- 220V for high-voltage piezoresponse force microscopy.
11.2 Application: Piezoresponse Force Microscopy
11.2.1 The system must provide demonstrated imaging on piezo materials in the following imaging modes; Vertical PFM (out-of-plane polarization), Lateral PFM (in-plane polarization), Vector PFM (real space reconstruction of the polarization orientation) and Lithography for modification of the piezoelectric polarization.
11.2.2 The system must include demonstrated spectroscopy modes including:
11.2.2.1 Simultaneous remnant and applied voltage hysteresis loops on ferroelectric materials and switching spectroscopy mapping (while measuring contact resonance frequency, PFM drive amplitude, PFM phase and tip-sample dissipation/Q-factor).
11.2.2.2 Pulse-relaxation measurements (while measuring contact resonance frequency, PFM drive amplitude, PFM phase and tip-sample dissipation/Q-factor)
11.2.3 The instrument must exhibit extremely low crosstalk between the tip-drive voltage and the measured deflection. The measure of crosstalk is defined as follows:
11.2.4 Position of the tip >1cm from the sample surface.
11.2.5 Apply the bias voltage to the tip.
11.2.6 With a tip bias voltage drive amplitude of 100V, sweep the drive frequency from 50kHz to 2MHz.
11.2.7 The Sum signal should be at least 7 volts and the deflection zeroed to provide the highest measurement sensitivity.
11.2.8 The measured amplitude at all frequencies should be less than 300 microvolts.
11.3 A dedicated high voltage (+/- 150V) module for tip or sample bias is also required to enable measurements on materials with weak piezoelectric response. The high voltage module must provide necessary safety features for safe and easy operation.
11.4 All measurement modes should include the ability to track the resonant frequency using signal enhancing contact resonance, which eliminates topography crosstalk and other artefacts arising from contact resonance frequency shifts. The PFM amplitude, phase, contact resonant frequency and contact resonance quality factor should be measured and returned.
11.5 The system control must allow the user to route the AC bias either to the tip or the sample through software control.
11.6 The ability to perform PFM and Conductive AFM simultaneously is required.
11.7 The PFM control software must include a variety of PFM spectroscopy modes in various complexity levels to perform user defined bias curves.
11.8 The software must include sufficient analysis routines within the data analysis environment to eliminate the need to export, re-import into third party software, or interpret the exported data scales
11.9 High Voltage Closed Cell: An environment control cell for high voltage piezo response force microscopy should also be provided with appropriate safety features. If the regular cell as mentioned in section 9.1 is enough for this application, that should be clearly mentioned.

12 Variable Field Module:

12.1 The instrument must have an option to apply up to a ±0.8 Tesla in-plane magnetic field to the sample.
12.2 The applied magnetic field must be closed loop controlled with a step increment (in closed loop) of ~1G.
12.3 The magnetic field module must be able to ramp the field at up to 7000G/minute
12.4 The module should be based on a permanent magnet (not an electro-magnet) so that no cooling of the magnet is required.

13 Controller and Electronics:
13.1 The AFM control electronics must provide 100% digital operation.
13.2 The electronics must include digitally-controlled switches for user-defined signal routing.
13.3 The system must provide thermal tunes of the cantilever up to at least 2 MHz.
13.4 The instrument must allow digital Q-control in the range 2 kHz – 2 MHz.
13.5 The instrument must include software controlled relays for the X, Y and Z high voltage supplies and the laser power.
13.6 The electronics must provide access to all major signals on BNC connectors on the controller front panel including deflection (A-B), sum (A+B), amplitude, phase, lateral force, X, Y and Z sensors, three user inputs, three user outputs, X,Y and Z piezo drive voltages, and user X, Y and Z modulation voltage inputs compatible with external hardware. There should preferably also be an audio-out for ear phone.
13.7 The instrument must include auto-configuration of external hardware and accessories. Device parameters must be stored in non-volatile RAM on the device itself and read into the software when the device is plugged in. This eliminates the need for parameter files.
13.8 The instrument must include a user programmable control knob that can be used to fine tune and adjust all scan parameters.

14. Software
14.1 Control and analysis must be user-programmable natively in an entirely open-source software programming language.
14.2 The system's software must include a one-click configuration tool that sets up the software for standard and user-defined operation modes, such as AC imaging in air and liquid, contact mode, EFM, KPFM, PFM, force measurements, etc.
14.3 The data acquisition system must be capable of recording individual image sizes of 8000x8000 pixels^2 or greater.
14.4 AFM control software environment must include 3D rendering technology for advanced image display. This feature must allow the user to generate, display and visualize 3 & 4D real-time scan images, as well as off-line processing.
14.5 The software must allow multiple images and channels of a single scan, such as phase, amplitude, topography, conductivity, etc, to be opened and viewed simultaneously, or overlaid on a primary channel for signal correlation. This must include the ability to overlay 3D images with any image data channel in real-time.
14.6 The software must allow image files to be exported to the clipboard or saved as JPEG, PNG, BMP and TIFF.
14.7 The user must be able to define the graphical user interface layout completely and to drag, enlarge/minimize, and define all imaging windows.
14.8 The user must be able to simultaneously perform data analysis using the built-in post processing software functions, while continuing to monitor (in clear view) the real time imaging process.
14.9 Must include multiple built-in spring constant calibration methods, including the "thermal noise" and "Sader hydrodynamic" methods.
14.10 Must include built-in nanolithography and manipulation software.
14.11 Must include drift compensation software. Software must allow a region of interest to be tracked in real time to within 1nm of precision while eliminating any scan distortion in the image. Drift compensation must be able to be applied to any imaging, spectroscopy or advanced characterization mode, and in conjunction with sample heating and cooling options.
14.12 The software must be compatible with PC and Mac for offline image processing.
14.13 Free software upgrades must be available for the life of the instrument.

Multifrequency techniques:
14.14 The instrument must be capable of driving the cantilever simultaneously at two or more arbitrarily chosen excitation frequencies in AC (dynamic) mode, while simultaneously collecting and displaying the amplitude and phase signals and images from each of these frequencies, along with the height or Z-sensor data.
14.15 The instrument must be capable of tracking the resonance frequency of the cantilever during measurement techniques in which the cantilever is actuated mechanically by the sample. For example, the technique must be demonstrated to track the resonance in either or both Contact Resonance AFM or on resonance Piezoresponse Force Microscopy.
14.16 The software must be able to map the drive amplitude, drive phase, resonance frequency and quality factor of the resonance being tracked by the technique described above.

15 System Computer:
15.1 The Computer-to-Controller communication must be via USB2. This simplifies system set-up and allows easy and cost effective future upgrade of the system's computer.
15.2 The computer operating system must be Windows 7-64bit.

16. Instrument Isolation:
16.1 The system must include a thermally- and acoustically-isolating enclosure. The enclosure must provide at least 20dB of acoustic isolation.
16.2 The system must include an active vibration isolation table.
16.3 The enclosure must be actively temperature-controlled to 0.1^{0}C.

17. Guarantee, Warranty, Support and Service
17.1 Must include at least a two year warranty on all parts and labor.
17.2 Must include free software upgrades for the life of the instrument.
17.3 The vendor must clearly specify how the servicing will be done in case of any requirement. They should provide the contact details of the service engineer along with the quotation. In case the purchase committee decides to go for a technical presentation after the tender period, the service engineer should be able to meet the committee for the presentation in a week's notice.

Optional Attachments: The vendors are also requested to quote for the following attachments. These will be purchased only if the price falls within the budget available. However, the vendors must state/certify that the AFM system provided will be compatible with these attachments in case these are purchased separately in the future.

19. Nano-indenter - Maximum Load 500mN: This should include:

- Nanoindenter head that allows optical side viewing of the indenting tip.
- diffraction limited optics system
- At least three diamond tips (1 ea. cubed corner and 2 ea. Berkovich, for example), and one sapphire sphere should be included.

19.1 Nano-indenter for Maximum Load: 20mN. (To work with above NI)
19.2 Nano-indenter for Maximum Load: 4mN. (To work with above NI)

20. A special sample stage for sample stretching:

This stage should be equipped with a manual stretching mechanism thereby providing two axis stress control of tensile loaded samples. The stage should also allow control of the sample image region under different loads. The stress and strain data should be accessible.

21. Micro-manipulator controlled probe station:

A probe station consisting of two fine metal (example: tungsten, platinum, Pt-Ir) probes that can be independently and accurately positioned on the sample with micromanipulators should be provided for the above AFM. The AFM's cantilever should be capable of serving as another electrical probe which allows for in-situ two-point and three-point probe electrical manipulations and measurements. The micromanipulators should have a 3-axis range of motion of minimum 7.5mm and can be used to position one or both probe tips to well within the AFM's full field of view using the integrated optics.

22. Scanning Tunneling Microscopy mode.