ICFO

SPECIFICATION SHEET

SUPPLY, INSTALLATION AND COMMISSIONING OF A “HIGH RESOLUTION SCANNING ELECTRON MICROSCOPY (SEM) WITH FIELD EMISSION SOURCE” FOR THE NCL LABORATORY AT ICFO, THE INSTITUT DE CIÈNCIES PHOTONIQUES, THROUGH AN OPEN PROCEDURE SUBJECT TO HARMONIZED REGULATION

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CLAUSE 1. Object of the contract and justification of the buy

The purpose of this contract is the supply, installation and commissioning of a "Supply, installation and commissioning of a HIGH RESOLUTION SCANNING ELECTRON MICROSCOPY (SEM) WITH FIELD EMISSION SOURCE " for the NCL laboratory at ICFO.

The types of items supplied are linked to the CPV (Common Public Procurement Vocabulary), **38000000-5** Laboratory, optical and precision equipment (except glasses).

The system will be used for high resolution scanning electron microscopy (SEM) with field emission source (in the following named FESEM) allowing to take electron images (secondary and backscattered) and to get EDS and EBSD analysis. The typical samples to characterize are the following, at least:
- Organic materials or other hybrid combination (perovskite, semiconductors, quantum dots) in solar cells structures
- Quantum dots, as single particles, to be studied in transmission mode
- Quantum dots, in spin-coated thin layer form, for photodetection or photovoltaics applications
- Nanostructures for photonics or electronics applications
- 2D materials, including graphene and TMDs for electronics applications
- Carbon nanotubes or graphene resonating structures for quantum nanomechanics applications
- Catalysts, in transmission or reflection modes, and relative thin polymer layers on metal coated fibres
- Ultra-thin metal layers for electrode

CLAUSE 2. Needs to be satisfied

The current SEM used in NFL at ICFO is a medium range SFEG with a limited resolution especially for low acceleration voltages. The observation of delicate samples or charging samples obliges to go for these conditions, requiring high end SFEG/CFEG microscopes designed to work even at low voltages. Moreover, the age and technology of our current window and small area EDS detector suffers from limitations in working in low voltages too, justifying a large and windowless detector. Integration of EBSD and BSE+EDS will be relevant added analytics for element and crystallinity states determination.

CLAUSE 3. Electron beam source / column

3.1. The electron source must be Schottky field emission gun (SFEG) or cold field emission gun (CFEG). The electron optics system must contain an electron source, electromagnetic lenses, and a condenser at least.

3.2. Cathode lifetime will have to exceed 5000 hours.

3.3. The interaction energy between the primary electron beam and the sample, so called landing energy must be adjustable between 20eV, or less, up to 30keV, or more, without energy bias applied on the sample to decelerate the beam (beam deceleration BD).

3.4. The current at a given acceleration voltage and aperture must be stable and must not vary with time of more than +/- 0.2% over an hour range.

3.5. The minimum beam current must reach 5pA or lower while the maximum beam current must be 20nA. These currents will be measured by Faraday cup on the sample stage or by external cup in the beam path. The beam current must be adjustable to vary between at least the range of 0.05nA to 20nA, with the help of the aperture selector and condenser and without any physical outside change of the electron column.

3.6. The emission start-up to reach the final target condition of emission must be automatical and managed in a safe and controllable way. In the case of the CFEG the heating steps necessary must be managed without any intervention of the user and guarantee long time scans and analysis without interruption.

3.7. The magnification must range between at least 30x and 2.000.000x, in Polaroid format, extremes included.

3.8. The design of the column must prevent electron beam crossover, within all the working conditions, in order to avoid Boersch effect and chromatic aberrations.

CLAUSE 4. Detectors

4.1. The system must include a secondary electron (SE) detector integrated within the electron optics column (so called in-column/in-lens/in-beam SE or equivalent).

4.2. The system must have an Everhart-Thornley SE detector within the chamber.

4.3. The system must include a back scattered electron (BSE) detector integrated within the electron optics column (in-column/in-lens/in-beam BSE or equivalent). A solution must be provided to select the BSE according to their energy.

4.4. The system must include a retractable back scattered electron (BSE) detector within the chamber with at least 4 independent segments, or more.

4.5. The system must have a SE detector compatible with low vacuum condition and able to work until the maximum pressure allowable in the chamber.

4.6. The system must include a retractable STEM detector, with at least 6 independent segments and able to acquire transmission images in the following configurations: bright field, dark field, MAADF, high angle annular dark field.

4.7. The system must include EDS, EBSD and signal combined BSE+EDS detectors such as described below.

CLAUSE 5. Chamber and sample stage

5.1. The system must a working chamber with internal diameter (if cylindrical) or minor dimension (if rectangular) equal or major than 360mm and equal or higher than 270mm. The chamber must include at least 12 ports in the chamber and 2 ports in the door. The system must have a loadlock and the chamber must be kept in vacuum except for exceptional venting events.

5.2. The time to introduce a sample from room to working chamber within the conditions to have high resolution detection must be less than 6 minutes.

5.3. The sample holder in the chamber must be motorized on 5 axis and the eucentricity must be mechanical. To the mechanical eucentricity can be added an electronic compensation. The travel range must be at least the following for the corresponding axis: X>= 50mm, Y>=50mm, Z>=40mm, rotation 0 to 360º and tilt=0-70º or higher (lower than 0º and higher than 70º)..

5.4. The system must be able to host sample with dimensions up to 4” diameter, at least, and height of 40mm, at least. These dimensions must be compatible with the X and Y travel range.

5.5. The offer must include a multiple position stub holder, with the capacity to host 5 different stubs, at least. It must also include a TEM grids holder in horizontal position to perform STEM imaging.

5.6. In the chamber an infrared camera must be mounted so that during operation the sample and the stage can be observed.

5.7. In the loadlock or in the chamber an overview navigation system must be present to facilitate the navigation on the sample while it is in the chamber.

5.8. The analytical distance must be less than 10mm with a take-off angle of 35º.

CLAUSE 6. Resolution and performance

6.1. Maximum warranted resolution in high vacuum and in secondary electron scanning (SE), at optimal WD, without beam deceleration (BD = 0) must be:
- $d_{min,\ SE,\ no\ BD,\ HT=15kV} \leq 0.5$ nm for HT = 15 kV
- $d_{min,\ SE,\ no\ BD,\ HT=1kV} \leq 0.8$ nm for HT = 1 kV
- $d_{min,\ SE,\ no\ BD,\ HT=0.5kV} \leq 1.0$ nm for HT = 0.5 kV

6.2. Maximum warranted resolution in high vacuum and in backscattered secondary electron scanning (BSE) must be:
- $d_{min,\ BSE,\ HT=1kV} \leq 1.0$ nm for HT = 1 kV

6.3. Maximum warranted resolution in STEM mode, at high vacuum:
- $d_{min,\ STEM,\ HT=30kV} \leq 0.4$ nm for HT = 30kV

6.4. FOV for the acquisition of electron images without distortion and without the use of stitching major or equal to 1.6 mm at HT = 1kV

CLAUSE 7. Analytical detectors

7.1. A high resolution windowless SDD EDS detector. Active area of at least 100 mm2. Resolution of at least 127 eV (Mn Kα). Possibility of detecting low energy elements, with atomic number ranging from Bi to Li. In combination with the microscope the spatial resolution of element detection should be equal or better than 10 nm.

7.2. A second EDS detector coupled to EBSD detector (described below). Active area of at least 40 mm2.

7.3. Both EDS detectors must be capable of live mapping and spectrum analysis in real time. It must be possible to merge of the different signals with background subtraction and possible deconvolution of the overlapped peaks.

7.4. An integrated EBSD CMOS detector and a specimen current monitor must be included, allowing measuring the electron current delivered by the electron source.

7.5. An integrated detector combining signals from X-Rays (EDS) and BSE.

7.6. The EDS, EBSD and combined BSE+EDS detectors must have a dedicated computer and must be controlled by the same software.

7.7. The EDS software must include the ability to compensate for the specimen drift while acquiring an EDS map.

7.8. The EDS software must allow to give the element concentration variations over the EDS maps.

7.9. The EDS software must automatically creates maps of the distribution of phases in a specimen.

7.10. The EDS software should include an algorithm for peak deconvolution and background removal to work in real time while acquiring EDS maps.

7.11. The EDS software should include a solution for particle analysis.

7.12. The EDS and EBSD software should include a solution for large area mapping of EDS and EBSD samples, respectively.

CLAUSE 8. Compatibility with accessories and detectors

8.1. The system must be compatible with a possible integration of air-sensitive sample loading directly from a glove box into the loadlock and the chamber.

8.2. The system must be compatible with a possible integration of cathodoluminescence detector.

8.3. The system must be compatible with a possible integration of heating stage up to 200ºC.

8.4. The system must be compatible with a possible integration of cryo-transfer system.

CLAUSE 9. Vacuum pumping

9.1. Turbomolecular type main vacuum pumps properly sized for the characteristics of the main chamber and the loadlock, the pressure to be reached and the processes to be run. Automatic and safe controlled N2 venting when doing a 'process chamber venting' or in case of a power cut. Manufacturer, model and full technical specifications will be included with the proposal.

9.2. Dry, low-noise backing pumps properly sized for the characteristics of the main chamber and the loadlock and for the processes to be run. With shut valve, exhaust silencer and hour counter. Manufacturer, model and full technical specifications will be included with the proposal.

9.3. Complete and safe venting of the main chamber has to be possible within ten minutes maximum after starting a 'process chamber venting'.

9.4. Complete and safe venting of the load lock chamber has to be possible within two minutes (5 min) maximum after starting a 'load lock venting'.

9.5. The electron gun must be differentially pumped and a high vacuum isolation valve between the main chamber and the electron gun must be provided.

9.6. One or more ion pumps for the gun area to reach high vacuum condition for electron emission.

9.7. All pumps will have to operate with standard single phase 230V 50 Hz electrical supply.

CLAUSE 10. Environment control

10.1. The equipment must be equipped with antivibration support to damp mechanical vibrations of the floor.

10.2. The operation should be compatible with temperature variation of +/- 0.5ºC / hour.

CLAUSE 11. System control

11.1. Operation with software-controlled system via PC. The computer must have at least 16GB of RAM, SSD disk of at least 256GB, hard drive HDD of at least 2TB and windows operating system supported at the time of the order. The software must enable the management and the saving of the images at 64 bit. 2 display screens must be included with a size of 24 inches or more, one for the control of the microscope and the other for visualization of images and for analytics.

11.2. System visualization and operation of vacuum system, stage position and control on the 5 axis, electron-beam settings, acquisition of the different detectors, etc.

11.3. Automatic setting and adjustment of the beam (focus, illumination, astigmatism) and possibility to save and load working conditions.

11.4. Independent control panel for the control of stage movement, brightness/contrast, focus, etc…

11.5. All functions will be interlocked to prevent unsafe operation or damage to the system, even during a power cut.

11.6. A software to manage images and their treatment must be provided with at least 5 off-line licenses.

11.7. Parallel acquisition of at least 4 channels signals and their simultaneous visualization. Images of at least 19 MPixels.

11.8. Function for metrology on SE acquired images, including distances, angles, sizes.

11.9. A full description of the software (including a full user manual, screen captures, etc.) will have to be supplied with the proposal.

11.10. Possibility of remote control by the provider service team to be able to take control of the microscope, diagnose problems and provide remote assistance.

CLAUSE 12. Power distribution and safety

12.1. Power system compatible with standard Spanish voltages, frequencies and configurations and with all Spanish laws and regulations.
12.2. CE marking.
12.3. Component wiring routed to a centralized power distribution panel.
12.4. Appropriate safety interlocks.
12.5. The system will be fully protected against unexpected power cuts and, in that case, will be fully safe for the operators. A quick and easy turning on of the system has to be possible after a power cut.

CLAUSE 13. System layout and services

13.1. The system must include a compressor if some parts of the SEM are pneumatical and require it.
13.2. A closed-circuit water chiller must be included, allowing a stable operation of the SEM
13.3. The proposal will include a complete set of pictures, drawings and layouts of the system, including dimensions, location and details of the different components (process chamber, load-lock, transfer arm, substrate holder, vacuum pumps and gauges, power supplies, electron column, controllers, service panels, etc).
13.4. The system must include an oxygen plasma cleaner, installed either on a port of the loadlock or of the chamber in order to clean the sample before visualization, when needed.

CLAUSE 14. Documentation

14.1. Complete set of manuals, drawings, schematics and layouts about system assembly and configuration (mechanical assembly, vacuum system layouts, cooling system distribution, electrical schematics, system modules interconnection, etc).
14.2. Complete system user manual, including routine servicing, troubleshooting and basic repairs.
14.3. System components spare list, specifying quantity, manufacturer, part number, etc.
14.4. All the above documentation will be supplied in English, in electronic format (CD/DVD) and in paper copy.

CLAUSE 15. Tools and systems spares

15.1. Vacuum gauge consumable parts used during regular maintenance (1 set per gauge).
15.2. Spare hardware kit for the entire system (screws, bolts, washers and necessary tools for tightening or removal). Threading tap and die kit for non-metric screws (if used).
15.3. Spare fuse kit (where applicable).
15.4. A sample and a procedure (including software) to check regularly the ultimate resolution of the tool

CLAUSE 16. Transport, installation and start-up

16.1. The proposal will include transportation to ICFO's facilities and all export/import and customs duties.
16.2. The machine will be placed in the selected location by ICFO. Contract winner will cover all costs, organization and coordination of machine placement, including any required specialized equipment or vehicle, and any required component dis-assembly and re-assembly for system unloading and transportation inside the building, following the route specified by ICFO. The machine will have its own

wheels to facilitate these operations and levelling pads to hold it in a stable and levelled position once in place.

16.3. Depending on the size, machine crate may need to be disassembled outside ICFO building. The contract winner will be responsible for taking accurate measurements of the route and plan in advance any required component dis-assembly and re-assembly.
The laboratory height is 2400 mm, and the machine dimensions must be compatible with this height condition.
The contract winner will be responsible for checking the selected location and for taking any required measurements to guarantee the suitability of it for the offered system. The compatibility with the operation of the systems already installed in the lab and the mobility of users will have to be guaranteed as well.

16.4. Installation and start-up of the system, including system checking, functional tests and process qualification.

16.5. The contract winner will be responsible for the removal and proper disposal of the packaging when the machine is delivered and unpacked, or its storage during the warranty period in case the original packaging needs to be kept.

16.6. The microscope will be moved to another laboratory in a timeframe inferior to the warranty time. The contract winner will be responsible to move and put back to function the microscope to work, checking the full correct behaviour within the specs. The proposal will then include relocation of the tool to the final lab destination (decommission, transportation, recommission and acceptance). ICFO will provide all the services necessary in the new location.

CLAUSE 17. Process qualification

- Resolution such as described above
- Beam current stability such as described above

CLAUSE 18. Training

System use and process training to ICFO users and specific maintenance and service training to ICFO lab technicians at ICFO's facilities will be included. The number of training days and approximate schedule will be specified in the proposal.

CLAUSE 19. Warranty and support

19.1. 4-year full warranty, starting at system acceptance. The warranty will include the replacement of any faulty or damaged part(s) during the normal use of the system, no matter the manufacturer of the component(s). It will cover any cost related with the disassembly, transportation, reparation and re-assembly of the damaged component(s), including all travelling and living costs of the required service engineer(s). An on-site repair, or a justified alternative to reduce the system down time to the minimum, will always be the first service option. A team of properly qualified and skilled service engineers will have to be available.

19.2. System lifetime support:

- By phone and e-mail with a response within 2 working days.
- Emergency visit after a system breakdown within 10 working days.

19.3. Spare parts will be available during, at least, 10 years after system supply and, in case of failure, will be delivered within 10 working days.

19.4. An estimation of the cost of a warranty extension or available support contract options after warranty period will be included.

CLAUSE 20. Additional optional improvements

The following points will be evaluated as it is stated in the Annex núm. 2 of the PCAP.

20.1. Variable pressure with pressure ranging from 10 Pa to 500 Pa. The electron optics column must be compatible with variable pressure working, with pressure values inside the chamber of up to 500 Pa at least. Working gas must be Ar or N2.
20.2. System to limit the interaction length of the electron beam and the gas in variable pressure mode.
20.3. Holder and software to perform 3D STEM

CLAUSE 21. Delivery time

The machine should be delivered within 7 months starting from tender assignment.

CLAUSE 22. Technical proposal structure

The proposal has to follow as much as possible the structure of this technical requirements document to facilitate evaluation. Any optional accessories not included in the proposal will have to be put in a separate section, and not mixed with the included items.

Castelldefels, on the date of its digital signature

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