



Marché de fournitures courantes et services (FCS)

CAHIER DES CLAUSES TECHNIQUES PARTICULIERES  
(C.C.T.P.)

Object: Supply of an ALD thin-film growth reactor coupled to a glovebox for CNRS UMR7162



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## Article 1 – Object and form of the public tender

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### 1.1 Object of the tender

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The purpose of this tender is to supply a reactor for growing thin films using the Atomic Layer Deposition (ALD) technique for CNRS UMR7162. The machine must also be equipped with a system for preliminary stripping of the surfaces on which the atomic layers will be grown. The entire system must be integrated into a glove box under nitrogen flow, so as to be able to work with samples sensitive to oxygen and humidity in the ambient air. This contract includes transport, on-site installation and user training.

### 1.2 Form of the tender

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The present contract is an ordinary, non-allocated supply contract.

## Article 2 – Technical Response Framework (Cadre de réponse technique, or CRT in French) and expected tender documents

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The candidate is required to include in its technical offer:

- Data sheets and a technical brief on the various hardware and software components of the instrument
- Documentation on the equipment and its components
- A user manual for the ALD reactor and the glovebox, detailing in particular the procedure for loading samples into the ALD reactor from the glovebox.
- A maintenance manual for the ALD reactor and glovebox.
- How long the spare parts will be available;
- Known or probable date of production stoppage for the proposed instrument model;
- The cost of spare parts and interventions in the event of breakdown outside the warranty period or maintenance contract;
- The quality of the after-sales service (response time, staff expertise, technical support, source of spare parts, software update conditions, etc.);
- The list of components that meet the definition of consumables.

Answers in English are permitted.

## Article 3 – Special technical clauses (in French : Clauses Techniques Particulières)

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### 3.1 User context

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UMR 7162 is home to a micro- and nanofabrication cleanroom. This is a platform open to both academic and industrial players, where users can make direct use of the various micro- and nanofabrication machines at their disposal. Our cleanroom is currently undergoing an expansion project, with the creation of a new space of around 40 m<sup>2</sup> to house the very latest technologies available on the market. The acquisition of the ALD growth reactor coupled with a glovebox is part of this program. The ALD reactor and glovebox will be installed in the new extension.

#### 3.1.1 Instrument destination

The instrument will be used to deposit layers of alumina (Al<sub>2</sub>O<sub>3</sub>) and hafnium oxide (HfO<sub>2</sub>) from monolayer to 20 nanometers thick. Growth must be uniform on surfaces that are not necessarily planar (in other words, growth

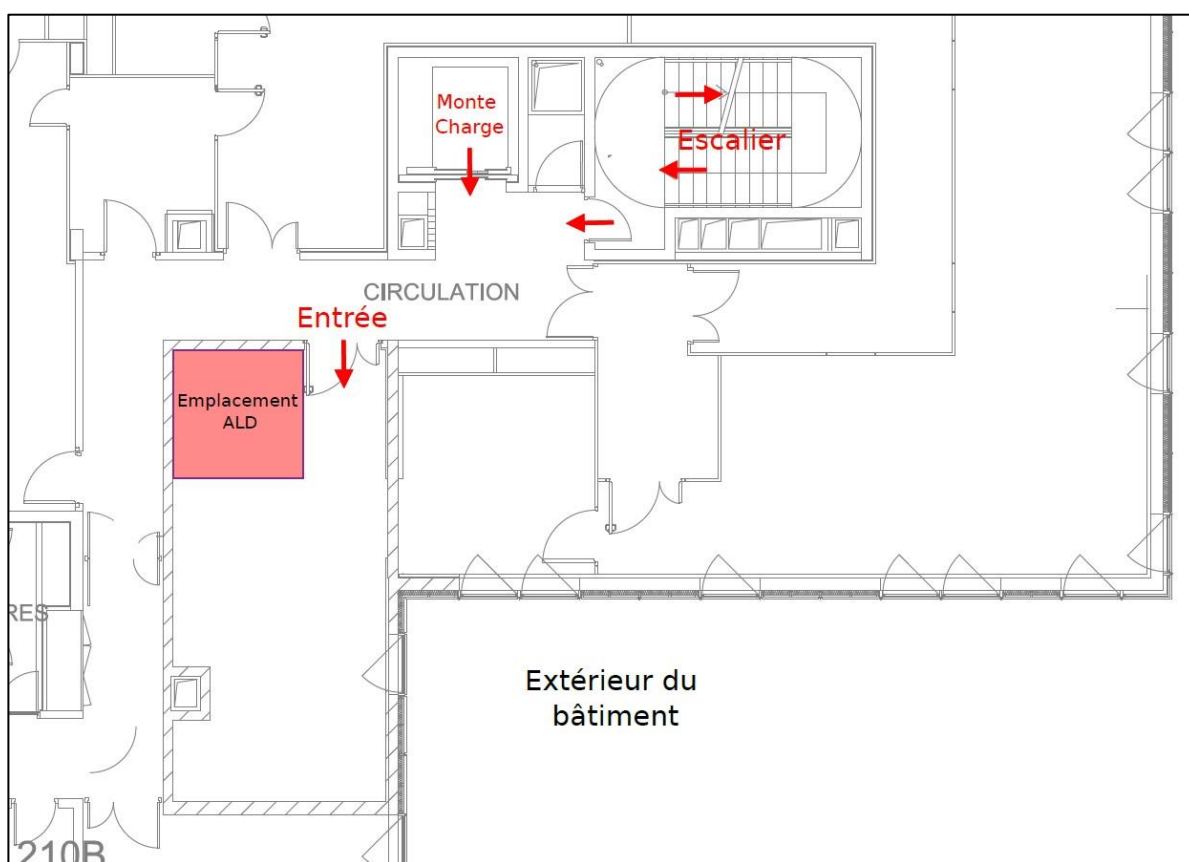
must be conformal). To guarantee quality growth, it is important that the sample surfaces be first cleaned of the superficial layers of reconstruction that form spontaneously on contact with air. The ALD growth reactor must be equipped with a hydrogen plasma to perform this etching operation prior to the actual growth. In addition, the entire system will need to be integrated into a glovebox operating under nitrogen to protect the samples from oxygen and humidity of the ambient air.

### 3.1.2 Particular constraints associated with the laboratory

The footprint of the ALD growth reactor and its glovebox should not exceed 2500 x 2700 mm<sup>2</sup>, glovebox included.

The cleanroom is on the 2nd floor, accessible by a freight elevator (dimensions width x height x depth 130 cm x 205 cm x 190 cm, maximum capacity 2000 kg). The doors to the freight elevator and the cleanroom are 132 cm wide and 205 cm high. A 40-step staircase with an intermediate turning platform every 10 steps, a ceiling height of 2.80 m and a width of 1.30 m can also be used if required.

The map of the second floor, with the location of the freight elevator, the staircase and the entrance reserved for the installation of the new equipment, is as follows:



## 3.2 Technical and functional characteristics of the basic equipment.

### 3.2.1 State of the equipment

New equipment

### 3.2.2 Principal Equipment – Technical Characteristics

The system must be compatible with an ISO7 cleanroom class. The bidder must list the materials from which the ALD chamber, the glovebox, the precursor lines, the gaz lines... and so on, are made of.

### 3.2.2.1 Required Configuration for the ALD chamber:

- The deposition chamber will accommodate samples from 1x10 mm<sup>2</sup> up to 4-inch diameter wafers.
- The ALD machine will be connected to a glovebox operating under a nitrogen atmosphere. A load-lock or crane system for manual sample transfer, installed inside the glovebox, will allow the samples to be loaded and to be put in vacuum through the load-lock and into the ALD machine's deposition chamber.
- The ALD chamber must include tapping for subsequent installation of an ellipsometer for in-situ layer thickness measurement.
- The system must include tapping to include a turbomolecular pump on the reaction chamber.
- Temperature of chamber walls and substrate holder: the chamber walls and substrate holder will enable deposition to be carried out at adjustable temperatures between 50 and 400°C, with an accuracy of  $\pm 1^\circ\text{C}$ .

### 3.2.2.2 Plasma Generation in etching mode:

- To optimize plasma-assisted ALD deposition on semiconductor samples with a surface reconstruction layer due to air contact, such as GaAs or AlGaAs, an H<sub>2</sub> plasma etching procedure is essential.
  - Hydrogen (H<sub>2</sub>) plasma generation in the ALD deposition chamber will be achieved through a capacitively coupled plasma (CCP) configuration. The system must offer the flexibility to operate in both direct and remote plasma configurations, thus allowing adaptation to diverse deposition process requirements.
  - Low-pressure H<sub>2</sub> plasma will be used specifically to etch the reconstruction layers on our 3D samples. This pressure must be adjustable between 10 mTorr and 1.5 Torr, which is crucial for delivering H<sup>+</sup> ions to the sample and ensuring uniform etching across all reconstruction surfaces.

### 3.2.2.3 Thin layer deposition with plasma-assisted ALD

- Plasma generation will be in the same configuration as in section 3.2.2.2.
- The RF power of the plasma must be adjustable between 10 W and 300 W at a frequency of 13.5 MHz.

### 3.2.2.4 Ports/Inlets for the ALD equipment:

- The ALD machine will be equipped with the precursor lines and sources required for ALD deposition of alumina and HfO<sub>2</sub>.
- In addition, the machine will be equipped with an extra line to accommodate an additional source for developing other recipes in the future, such as TiO<sub>2</sub> deposition.
- The ALD deposition machine will have three process gas inlets: one for argon (Ar), one for oxygen (O<sub>2</sub>) and one for nitrogen (N<sub>2</sub>).
- The ALD deposition machine will also feature a hydrogen gas (H<sub>2</sub>) inlet for plasma cleaning of the reconstruction layers at the surfaces of the samples prior to ALD deposition.
- The ALD deposition machine will be also equipped with a nitrogen (N<sub>2</sub>) gas inlet to bring the ALD chamber up to the same pressure as that of the glovebox for sample loading and unloading operations.

### 3.2.2.5 Vacuum system of the ALD equipment

#### Efficiency and nitrogen consumption:

The pumping system must demonstrate optimum operating efficiency, with the lowest possible nitrogen consumption in process mode (i.e. when the machine is used to make a deposit), or ideally, operate without any nitrogen consumption at all.

**Standby mode autonomy:** After a deposit has been completed, the pumping system must be able to go into standby or idle mode after a user-defined delay (e.g. 1 hour). In this configuration, the pumping system is then able to continue operating without the need for nitrogen injection.

**Pressure capability:** The pumping system must be capable of maintaining a pressure in the ALD chamber at a minimum level of  $10^{-2}$  mbar or less outside deposition periods. This requirement guarantees the performance required for ALD layer deposition processes as well as reconstruction layer etching.

#### **Distance between pumping system and equipment**

All primary pumps must be vertically offset by 3m so that they can be installed in the equipment room one floor above the cleanroom.

#### **Cooling system**

There is no cold water line in the future cleanroom extension. As a result, cooling with standalone chiller(s) is essential.

All chillers must be vertically offset by 3 m in order to install them in the technical room one floor above the cleanroom.

Any chiller required to cool one or more parts of the equipment must be included in the bidding offer.

#### **3.2.2.6. Glovebox**

- The glove box must be equipped with three gloves and operate with nitrogen at overpressure as the working gas, with residual oxygen and water levels less than or equal to 1 ppm. It will be equipped with a primary vacuum pump to operate the loading locks and to regulate the glove box atmosphere, as well as all accessories required for its proper operation and maintenance (e.g. foot switch for pressure adjustment during use, condenser for regeneration output, etc.).
- The primary pump must be powerful enough to be placed in the technical room located on the floor immediately above the clean room. The length of the pipe between the glove box and the pump located on the technical floor will be 5 meters.
- The pump must be controllable by the PLC controlling the glovebox.
- Two loading airlocks, one standard (approximately 390 mm in diameter) and one mini-airlock for loading samples only (approximately 150 mm in diameter) must be provided.
- When the glovebox airlocks are brought to ambient pressure, this must be done with fresh nitrogen and not with the nitrogen already present in the glove box.
- The position of the airlocks must be such that their use will not interfere with the sample loading system of the ALD system.
- The glovebox must be equipped with a gas purifier (to remove oxygen and residual water from the nitrogen and achieve residual levels below one ppm) that can be regenerated regularly, as well as a filter capable of trapping solvents.
- The gas purifier and solvent filter must be located outside the glovebox enclosure to maximize the interior volume of the glovebox.

- Glovebox maintenance operations, such as regeneration of the gas purifier, must be as ergonomic as possible.
- The glovebox must have electrical outlets inside the enclosure.
- The glovebox must have a pressurized nitrogen gun to remove any dust from the samples.
- The glove box must be equipped with an energy-saving mode (or equivalent), allowing the control system to turn off the vacuum pump when it is not needed (particularly when the box is not in use).
- The coupling between the ALD chamber and the glovebox must ensure a perfect seal. The method for loading samples from the glove box into the ALD frame must be as ergonomic as possible. The loading method and the ALD frame must be compatible with sample sizes ranging from 1x10 mm<sup>2</sup> to 200 mm diameter wafers.
- The coupling between the ALD chamber and the glovebox must include a safety device in the event of excessive pressure difference.
- An isolation valve (which may also be used for the previous point) must be provided to isolate the glovebox from the ALD during cleaning and maintenance operations.

### 3.2.2.7 Recipes that must be included with the ALD delivery

This or these recipes will enable:

- Plasma etching of the reconstruction layer (gallium arsenic oxide) present on GaAs or AlGaAs samples (this step will be performed just before the deposition step).
- Deposition of an alumina layer on GaAs or AlGaAs samples with an adjustable thickness from one monolayer to 20 nm.
- Deposition of a hafnium oxide (HfO<sub>2</sub>) layer in amorphous or crystalline phase at a temperature below 400°C on GaAs or AlGaAs samples, with an adjustable thickness from one monolayer to 20 nm.
- An integrated sequence will be implemented to efficiently combine the aforementioned plasma etching, alumina deposition, and hafnium oxide deposition steps, allowing for a smooth and consistent transition between each process. This sequence aims to optimize the quality and reproducibility of the deposited layers, while minimizing the total processing time.

### 3.2.2.8 ALD deposit residue treatment system

- The ALD machine must include a solid residue filter system between the ALD machine and the vacuum pumping system.

### 3.2.2.9. Requirements in terms of ergonomics

The system must be designed for daily use by multiple users. To this end, a particular emphasis must be put on facilitating the various maintenance operations.

- To clean the ALD reaction chamber, a liner or a spare chamber must be provided.
- Maintenance of the ALD machine must be performed without opening the glovebox.

- Condensation of precursors must be avoided.
- Glovebox maintenance operations (reactor regeneration, filter replacement, etc.) must be as ergonomic as possible.

### 3.3 Integrated Software

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The ALD system must be computer-interfaced. The software must allow the loading of recipes pre-programmed by the manufacturer to:

- Etch the reconstruction layer of semiconductor samples (particularly GaAs) using low-pressure H<sub>2</sub> plasma (see section 3.2.2.2).
- Deposit a 10 nm thickness of alumina.
- Deposit a 10 nm thickness of HfO<sub>2</sub>.

In addition:

- The software must allow the development of new deposition and etching recipes.
- There will be at least three possible user profiles:
  - o Administrator mode for the manufacturer
  - o Engineer mode for recipe development
  - o User mode to load only pre-established recipes.

The candidate must specify whether software updates are free or not.

- A remote intervention system will be provided by the manufacturer in order to carry out maintenance, maintenance tests and/or recipe development remotely.

### 3.4 Requirements in terms of performances

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#### Deposition Reproducibility

The thickness of the deposited layer within the ALD operating window must be achieved with a repeatability/reproducibility greater than 95%. The ALD process window defines the temperature range where the deposition rate remains uniform throughout each cycle, ensuring conformal and stoichiometric film deposition. An ALD cycle consists of a rigorously controlled sequence, beginning with the saturating injection of precursor A, followed by a purge to remove excess, then the addition of precursor B until saturation, and ending with a second purge.

#### Conformal deposition

The ALD system must guaranty conformal deposition on samples with aspect ratios equal or larger than 50 as illustrated in Figure 1.



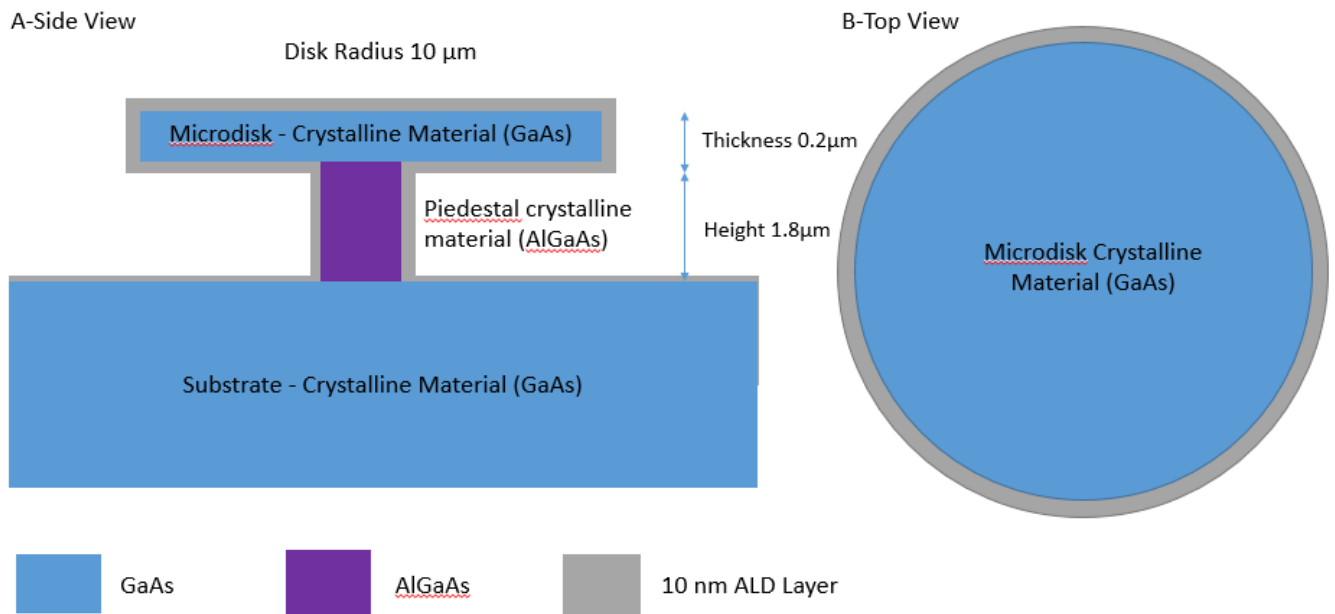


Figure 1 - Illustration of a typical structure made in our cleanroom. The aspect ratio is  $10\mu\text{m}/0.2\mu\text{m}$ , i.e. a factor of 50. This structure represents a vertical section (A) and a cross-sectional view (B) of a GaAs microdisk (blue) suspended using an AlGaAs pedestal (purple) which rests on a GaAs substrate (blue). The ALD layer will have the same thickness on the sides of the disk and pedestal as well as on the top and bottom surfaces of the disk. The system must be capable of depositing two different types of materials: alumina layers and HfO<sub>2</sub> layers.

### 3.5 Variants

#### 3.5.1 Variants to the basic offer

N.A.

#### 3.5.2 prestations supplémentaires éventuelles (PSE) / Possible Additional Services

##### PSE obligatoires / Mandatory PSE:

PSE 1 : Two-year warranty extension (après the mandatory 24 first months).

PSE 2 : Price of two years' preventive maintenance, and number and type of preventive maintenance visits. Maintenance will take effect once the warranty period, increased or not, has expired.

PSE 3 : Gas scrubber system to treat gases leaving the ALD machine. This scrubber must be vertically offset by 3 meters in order to install it in the technical room located on the floor immediately above the cleanroom.

##### PSE facultatives / Facultative PSE:

PSE 4 : Supply of a kit enabling conformal deposition with a high aspect ratio of around 2000.

PSE 5 : In-situ measurement system for deposited thin films. Ideally, this measurement system should be able to interact with the ALD control software, in particular to stop layer growth when a pre-defined target thickness is reached.

PSE 6 : Turbomolecular pumping system with pressure gauge for secondary vacuum, with transfer of the measured pressure value to the ALD control software, so as to reduce the deposition chamber pressure to  $10^{-5}$  mbar.

PSE 7 : Additional deposition chamber for PEALD deposition.

### 3.6 Requirements for associated services

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#### 3.6.1 : Delivery time

The maximum delivery time for the instrument is **24 months** from the date of notification of the contract.

#### 3.6.2 Delivery address

Laboratoire Matériaux et Phénomènes Quantiques  
CNRS- Université Paris Diderot  
Bât. Condorcet – 4 Rue Elsa Morante,  
75013 Paris  
FRANCE

#### 3.6.3 Installation, verification and equipment acceptance:

*This tender includes transport, on-site installation and user training.*

##### 3.6.3.1 "Particular Installation Conditions

The supplies/services covered by this tender must be delivered/performed at the following address:

Laboratoire Matériaux et Phénomènes Quantiques  
Université Paris Cité, Campus Paris Rive Gauche  
10, rue Alice Domon et Léonie Duquet  
75013 Paris  
France

The equipment will be delivered and installed on the second floor of the Condorcet B building, in the Université Paris Cité cleanroom. A freight elevator, with dimensions width x height x depth of 130 cm x 205 cm x 190 cm and a maximum capacity of 2000 kg, is available. The size of the doors to access this freight elevator and the cleanroom is 132 cm wide and 205 cm high. A 40-step staircase with an intermediate turning platform every 10 steps, a ceiling height of 2.80 m and a width of 1.30 m may also be used if required (see also the building plan in section 3.1.2).

##### 3.6.3.2 Verification and equipment/service acceptance

Equipment and associated services will be accepted in accordance with the provisions of article 12 of the CCAP.

##### 3.6.3.3. Training

###### Getting started:

Training must take into account the specific technological features of the system.

In order to acquire a good knowledge of the instrument and its operation, user training must take place no later than 2 weeks after installation of the equipment. In particular, this training should enable users to etch the reconstruction layers of GaAs samples using hydrogen plasma, and then to grow alumina and HfO<sub>2</sub> in the correct

manner. The samples to be stripped and coated with alumina or HfO<sub>2</sub> will be microdisks as shown in the figure in section 3.4.

The training date will be agreed between the cleanroom staff and the successful candidate.

#### **Cleaning:**

Les opérations de formation destinées à habilitier les utilisateurs à exécuter correctement les tâches de nettoyages seront organisées conjointement avec la formation relative à la prise en main de l'appareil. La programmation de ces sessions de formation sera établie de manière concertée, suite à un accord mutuel entre les représentants de la plate-forme et le fournisseur.

Training operations designed to enable users to carry out cleaning tasks correctly will be organized in conjunction with the "getting started" training on how to operate the equipment. These training sessions will be scheduled by mutual agreement between the cleanroom staff and the successful candidate.

### **Article 4 – Contractual guarantees**

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#### **4.1 – General**

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Complaints relating to defective parts or a malfunction of all or part of the equipment delivered shall be made by the contracting authority.

The supplies benefit from the guarantee provided for in Article 1641 of the Civil Code, and the warranty against defective products provided for in Articles 1386-1 et seq. of the Civil Code, as well as the contractual guarantee provided for by the Contract.

**In accordance with Article 33 of the CCAG-FCS, the starting point of the contractual guarantee period is the date of notification to the Contractor of the admission decision by the contracting authority.**

#### **4.2 – Minimum duration and content – Commencement**

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All instruments, including accessories, are guaranteed under the conditions set out in Article 33 of the CCAG-FCS. The warranty covers the cost of defective parts (including optical, mechanical, electronic and computer components) with no limit on the amount, labor and travel expenses to the site.

By way of derogation from the provisions of Article 33.1 of the CCAG-FCS, the instruments are fully covered by a guarantee of **a minimum duration of 24 months**, with the exception of consumables;

Consumables are defined as components with a normal lifespan of less than 12 months.

The Licensee has a duty of transparency when responding to consultations on the components of the devices it markets that meet this definition of "consumables".

If the Contractor has proposed in its tender a guarantee longer than **the minimum guarantee of 24 months** and/or a more extensive cover (replacement of consumables for example), the elements of its tender which are more favourable to the contracting authority than those stipulated in this SCAF shall be binding on the Contract.

## Article 5 – After-sales service

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The Holder's after-sales services are provided throughout the period of the contractual warranty and any extension.

The after-sales service during the warranty period may provide for preventive maintenance operations (visits) or servicing of the instruments subject to the Contract.

In any event, the after-sales service provides for at least and at no extra cost during the warranty period the services described in the following articles:

### 5.1 – Software

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The Owner's after-sales service includes, at a minimum, software updates and version changes.

### 5.2 – Technical Support

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The Holder's after-sales service includes free and unlimited technical support (including on software) during working days throughout the warranty period of the instruments.

Telephone support is accessible by phone (non-surcharged call) and by email.

**The Account Holder undertakes to respond within 48 hours.**

The Holder's other commitments regarding technical support are included in its offer.

### 5.3 – Failure response times

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Throughout the warranty period, the Contractor has an obligation to achieve results concerning compliance with on-site intervention deadlines in the event of a breakdown of the instruments purchased pursuant to this contract.

By way of derogation from the provisions of Article 32.3 of the CCAG-FCS, this period is understood to be in working days from the date of the request for intervention. It takes into account the location of the location of the instrument subject to the Contract. **This period is mentioned in the Holder's offer.**

The request for intervention by the contracting authority may be made by telephone, confirmed electronically or by fax.

The registration of the request for action must be confirmed in writing (e-mail or fax) by the Registrant.

The intervention period begins as soon as the contracting authority's request for intervention is registered by the Contractor.

In the event of failure to comply with this deadline, the Holder incurs a penalty as described in Article 12 of this CCAP.

#### 5.4 – Set-up times and repair times in the event of a breakdown

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Throughout the guarantee period, the Contractor has an obligation of result and deadline concerning the restoration of the instrument to operational working order in accordance with the technical and functional performance initially planned in the Contract.

In accordance with the provisions of Article 33.3 of the CCAG-FCS, the time limit for the Contractor to carry out an adjustment or repair requested of it is that which is set by decision of the Contracting Authority, after consultation with the Contractor.

**This period is mentioned in the Holder's offer.**

The starting point of this period for fine-tuning or repair in the event of a breakdown begins on the date of the contractor's first on-site intervention or, in the event of no intervention by the contractor, on the date of the contracting authority's request for intervention.

After this period, the Holder incurs penalties as set out in Article 12 of this CCAP