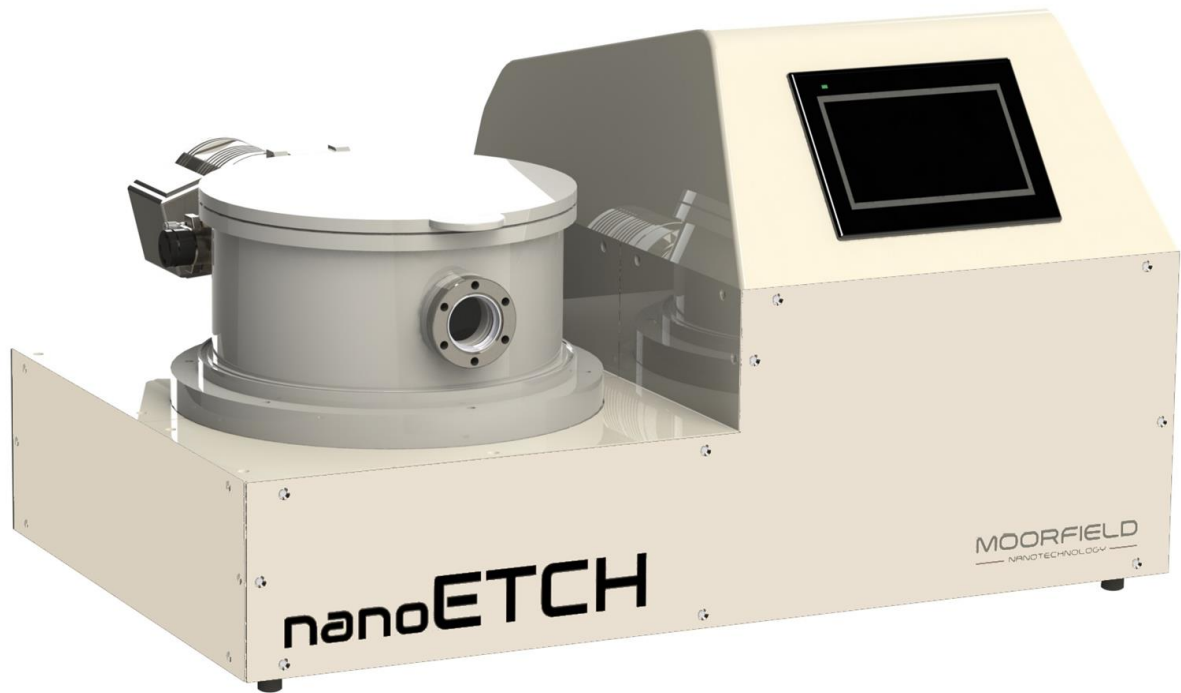


# nanoETCH



## Precision Soft Etching System for 2D Materials

### Installation/Operation Manual

**MOORFIELD**  
— NANOTECHNOLOGY —

## nanoETCH

### Precision Soft Etching System for 2D Materials Installation/Operation Manual

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## Table of Acronyms

DC	Direct current
MFC	Mass flow controller
PSU	Power supply unit
RF	Radio frequency
RPM	Revolutions per minute
WRG	Wide-range gauge

## 1. Health and Safety

The nanoETCH system has been designed to account for user safety when operated as intended. The system is intended to be used with this manual as a guide. All users should read this manual fully prior to using the system. Where clarification is required, users should contact the manufacturer (see Section 12 for contact details).

### 1.1 Safety Interlocks and Features

The system has the following safety interlocks and safety features:

- The system continuously monitors for adequate water flow of at least 1 L/min via a water flow switch mounted inside the unit.
- It is not possible to start the chamber pump routine unless the water flow switch indicates that there is adequate flow.
- It is not possible to switch on the electrical etching power supplies until the chamber is in the pumped state (i.e., the chamber pressure has dropped below  $5 \times 10^{-5}$  mbar since the pump routine has been initialised leading to deactivation of the vacuum interlock) and without sufficient water flow as indicated by the water flow switch.
- If the flow switch indicates a decrease in water flow below the required level while the system is in the pumped state, then all electrical power supplies and mass-flow controllers (MFCs) will be switched off and the chamber vent routine will be initiated.
- Should the system detect that the door is not closed after the chamber pump routine has been initiated (through a failure to reach the door vacuum setpoint level sufficiently quickly), then the chamber vent routine will be started.
- Should chamber pressure not decrease sufficiently quickly after the pumping system has been started, to the setpoint that indicates the chamber has reached the pumped state, the pumping system will be switched off and the vent routine will be initiated.
- Should the MFCs be unable to provide their setpoint flow rates, users will be presented with an error message.
- In case of a detected electronics error, the system will terminate any running process, and will initiate the chamber vent routine.
- The backing pump is fitted with a mesh guard on its inlet to catch any debris/substrate material originating from the chamber.
- If the main chamber is fitted with a viewport, this is equipped with a mesh to prevent RF leakage (if the system is fitted with an RF power supply).
- Various locations of the system are fitted with earth connections.
- Upon power failure, the system is designed to terminate all MFC gas flows and electrical power supplies, and switch off the pumping system.

### 1.2 User Precautions

Users should take the following precautions at all times while the tool is being operated:

- Only inert, dry service gas should be connected to the unit.
- The pressure of the service gas supplied to the unit should be 60–80 psi. Service gas

- pressures outside of this range may result in improper operation and/or system damage.
- Only the correct process gases should be connected to the unit. The process gas connections are labeled with the gases they are to be supplied with.
  - The process gas supply pressures should always be set to 20–25 psi. Improper operation and/or damage to system hardware may result from process gas pressures outside this range.
  - No electrical or gas connections to the unit should be removed or tampered with while the system is switched on.
  - Electrical and vacuum connections between the unit and the backing pump should not be disconnected while the pump is running.
  - Users should not attempt to open the chamber while the pumping system is running and before it has been vented.
  - The unit should only be placed on a flat, hard surface capable of securely supporting the system weight.
  - The unit should be situated away from exposure to direct sunlight.
  - Nothing should be placed on any side of the unit less than 20 cm away from its side panels.
  - The unit has cooling air inlets and outlets on the base and rear. These vents should be kept clear.
  - The system should never be moved while it is switched on.
  - Users should ensure that substrates inserted into the system are compatible with process conditions to be employed, and carry out appropriate risk assessments, including consultation of corresponding material safety data sheets (MSDS), to identify possible dangers whenever new substrate types are inserted.
  - Substrates should only be placed onto the designated area of the etch stage.
  - Substrates larger than that for which the system is designed should never be placed within the chamber.
  - System exhaust that emerges from the pump outlet must be vented appropriately (e.g., into an appropriately specified fumehood, and according to site-specific regulations). Failure to provide adequate venting could result in the creation of hazardous atmospheres depending on the substrate material, and process gases being employed.
  - For periods of no use, the system should be isolated from its process gas supplies (but may be left switched on).
  - Following any work that may result in contamination being introduced into service/process gas supplies (e.g., swapping a process gas cylinder), steps should be taken to ensure such contamination is adequately purged before any process is carried out.
  - For any process that could generate hazardous material (e.g., fine floating particulates), always ensure adequate personal protective equipment is worn before opening the chamber.
  - Users should never use the electrical power supply units (PSUs) to output excessive power to the etch stage. since this can lead to stage and system damage. Guidance regarding suitable maximum PSU output levels is contained within this manual.
  - Users should avoid looking directly at plasma generated within the chamber during use.
  - Users should always ensure that the chamber door is closed before starting the pump routine.
  - Users should never attempt to switch on the etching electrical power supplies while the chamber is open or before the pump routine has finished and the system is in the pumped state.

- Users should never remove the metallic mesh viewport insert.
- Never attempt to modify, reconfigure, repair or open the system without first consulting the manufacturer.
- Users should be aware that after use, chamber internal components may be hot. Users should ensure that they never make direct contact with the etch stage or any other chamber interior surface for this reason (e.g., use tweezers).

## 2. System Description

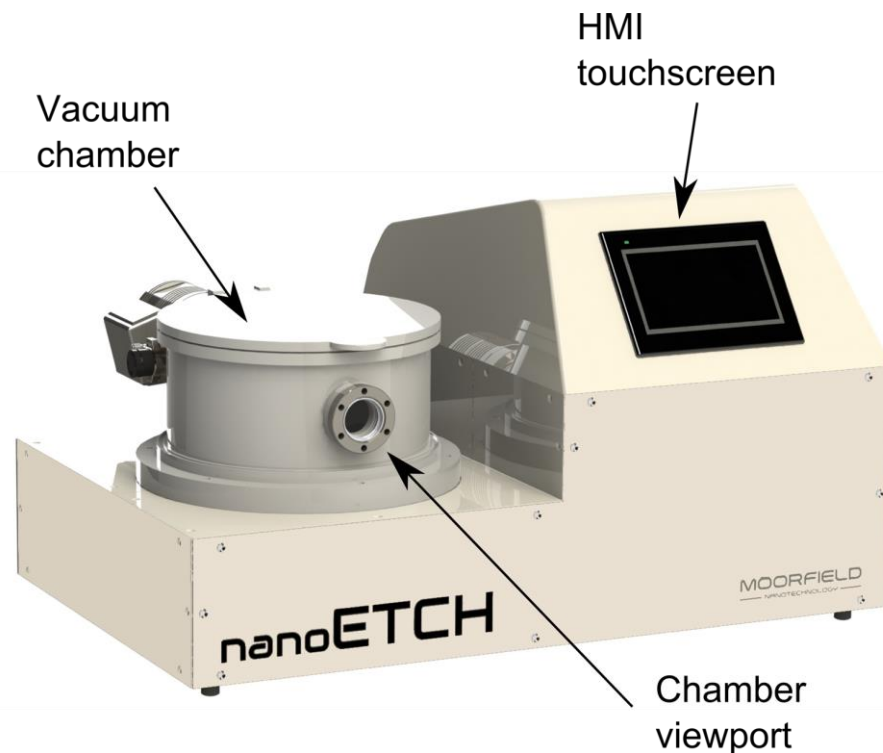
The following sections provide an introductory description to the nanoETCH system and its functionality.

Note that some sections are only relevant where the system has been fitted with corresponding modules.

### 2.1 Overview and Key Features

The nanoETCH is a compact etching system designed to provide for soft etching applications required as part of 2D materials research. Figures 1 (a) and (b) show the front and back of the main unit of the system (the backing pump is omitted).

(a)



(b)

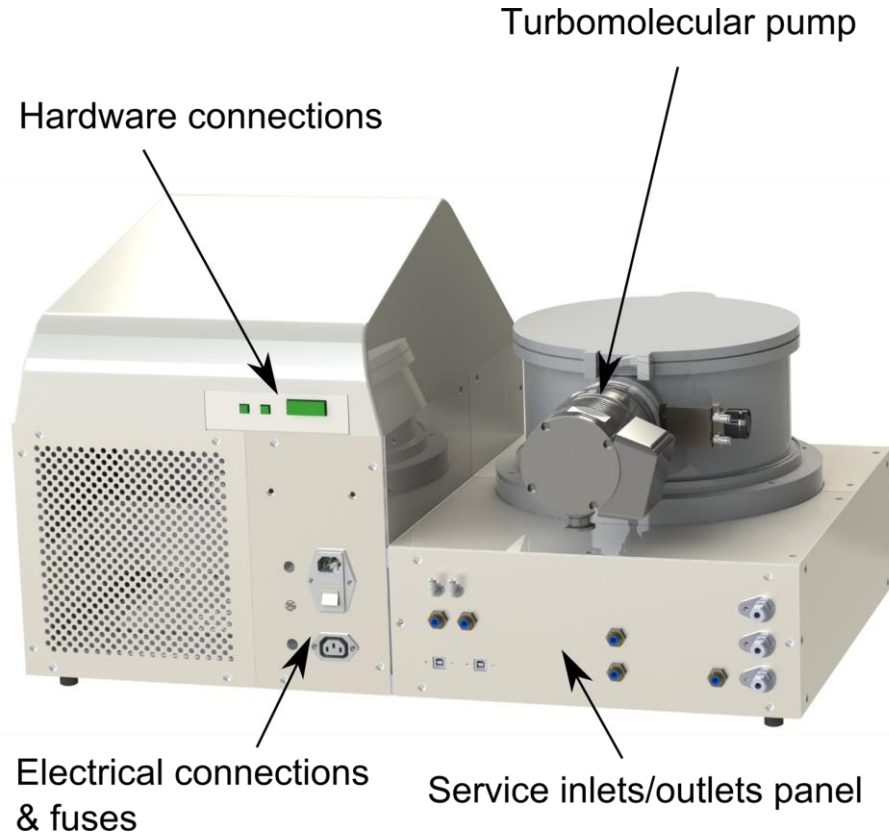


Figure 1: Overview of the nanoETCH main unit, from (a) front and (b) rear perspectives. Key features are indicated. Note that exact system appearance may change depending on configuration.

## 2.2 Interlocks

Each nanoETCH system is fitted with 3 primary interlocks:

1. **Water:** This interlock is active when the water flow rate through the system falls below 1 L/min. When active, the system prevents use of the PSUs and heater assembly and shuts down the pumping system if it is in use (initiates the chamber vent routine).
2. **Door:** This interlock is active when the WRG chamber pressure is above that defined as the door interlock pressure setpoint (default 100 mbar). When active, this interlock prevents use of the PSUs and heater assembly, and prevents processes from being run in automatic operation mode.
3. **Vacuum:** This interlock is active when the WRG chamber pressure has not fallen below  $5 \times 10^{-5}$  mbar after the chamber pump routine has been started. Key system hardware such as electrical power supplies and processes in automatic operation mode cannot be started until this interlock has been deactivated.

## 2.3 Vacuum Chamber

The system contains a cylindrical high-vacuum chamber that is fixed to a baseplate on which

it sits. The baseplate contains four 1” ports. At the top of the chamber, there is a door that allows for access. This door is connected to the chamber by a hinge at the back. The front of the chamber is fitted with a viewport for monitoring the chamber internal hardware during operation.

The chamber baseplate ports are fitted with various components including the etch stage, vacuum gauges and gas inlets. Exact system and port allocations depend on the system configuration selected (see section 3). Unused ports are fitted with blank feedthroughs that effectively seal the chamber against the external atmosphere.

## 2.3 Pumping System

The pumping system consists of a turbomolecular pump that sits directly on a port on the rear of the chamber. A backing pump is connected to the outlet of the turbomolecular pump by a flexible bellows. A pneumatically actuated two-position throttle valve is positioned inside the chamber immediately before the front face of the turbomolecular pump. This throttle valve is normally fully open to allow for maximum conductance between the turbomolecular pump and the chamber. However, it is closed to a fixed position for controlling pressure during etching.

Figure 2 is a schematic of the nanoETCH basic vacuum system.

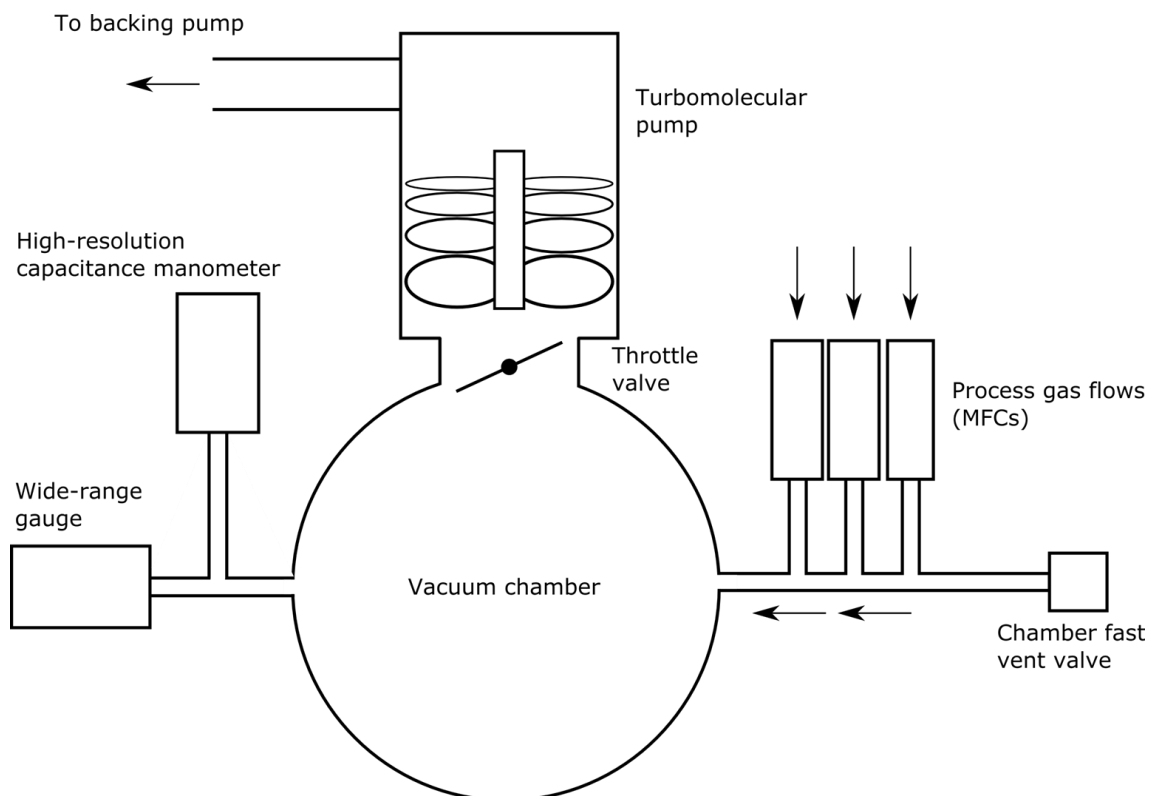


Figure 2: Schematic indicating the key features of the vacuum system of the nanoETCH unit.

Further details regarding the pumps are available in the pump-specific manuals supplied with



the nanoETCH system.

## 2.4 Chamber Pressure Measurement

Every nanoETCH system contains a wide-range gauge for measurement of chamber pressure. This gauge is suitable for obtaining approximate pressure readings in the range  $10^{-9}$  to 1000 mbar. If the high-resolution pressure control option is fitted to the system, then a high-resolution capacitance manometer will also be fitted to the system. This will enable accurate measurement of chamber pressures in the regime required for etching.

## 2.5 Process Gas Control

Typical etching applications require chamber pressures in the  $10^{-3}$  to  $10^{-2}$  mbar range. To obtain these pressures, a process gas is introduced into the nanoETCH chamber through at least one MFC fitted to the system (maximum of 3, for gas mixtures). Throughout this manual, and in the control software on the system HMI, these MFCs are identified as MFC1, MFC2 and MFC3.

The results of any etching process are strongly tied to the chamber pressure, since this affects the nature of the plasma.

The nanoETCH system allows the user to control chamber pressure in two different ways, depending on system configuration:

1. Flow-rate control. For this, the simplest method of pressure control, the user specifies MFC flow rates. When these are initiated, the nanoETCH system automatically closes the throttle valve between the chamber and the turbomolecular pump to a fixed, low conductance setting. This system state leads to particular chamber pressure.
2. High-resolution pressure-control. For this advanced control mode, the user defines a setpoint pressure and the system automatically controls the chamber pressure at that value by running a feedback loop between a high-resolution capacitance manometer pressure measurement and the MFC flow rates. For this latter mode, the system must be fitted with the high-resolution pressure-control module.

## 2.6 Etch Stage

The nanoETCH system is fitted with an etch stage suitable for accommodating substrates with diameters up to approximately 3". The etch stage is attached to the chamber baseplate, and contains two electrically isolated sections. The outer shield is connected to the system earth, while the core section, on which substrates are placed, is connected to the negative output of a PSU that drives the generation of plasma during operation.

## 2.7 Etching Electrical Power Supplies

Each nanoETCH system is fitted with at least one etching electrical power supply unit (PSU).

Both DC and RF PSUs can be fitted. The power supplies are mounted inside the unit. The DC PSU (but not the RF version) has a front panel that is visible to the user at the front of the system.

The nanoETCH system controls the DC PSU in constant-current mode. As such, the % output refers to the percentage of the maximum current available from the PSU. On the other hand, RF PSUs are controlled in constant-power mode. That is, for RF PSUs, the % output is the percentage of the full-scale power output of the PSU.

For units with two PSUs fitted, internal PSU switching allows for the routing of either PSU to the etch stage (only one PSU can be operated at any one time).

## 2.8 User Interface

All system operation is via the 7" touchscreen human-machine interface (HMI) mounted on the front of the nanoETCH main unit. A detailed explanation of the use of this HMI is given in Section 8, below.

## 2.9 Manual/Automatic Operation

Etching processes using the nanoETCH system can be operated in two distinct modes: Manual and automatic.

In manual mode, the user operates all hardware directly, as and when required. For example, the user can dynamically choose when to operate MFCs and pressure control, and set PSU output levels.

In automatic mode, the user first defines and saves a process using the system software. When this process is selected and run, the system controls all hardware, automatically, until the process is finished.

## 3. Technical Specification

The technical specifications of the base nanoETCH system is as follows:

- Vacuum chamber: Stainless steel (304 grade), approx. 8 L internal volume
- Etch stage: Moorfield RIE-3", aluminium; 3" diameter
- Process gas control: Mass-flow controllers (MFCs)
- Pressure measurement: Wide-range gauge;  $10^{-9}$  to 1000 mbar
- Turbomolecular pump: Edwards EXT75DX
- Backing pump: Rotary (3 m<sup>3</sup>/hour or 8 m<sup>3</sup>/hour) or scroll (6 m<sup>3</sup>/hour) pump
- User interface: 7" touchscreen display
- Cooling: Chilled water circulation (an appropriate system must be provided for installation)
- Interlocks: Water flow switch (1 L/min) and vacuum

- Dimensions (main unit, approximate): 800 mm (width) × 500 mm (depth) × 460 mm (height to top of chamber door)
- Weight (main unit): 45–70 kg (depending on exact configuration)

## 4. Specific Configuration and Available Upgrades

When shipped from the manufacturer, the exact configuration of the specific unit with which this manual was supplied was as follows:

- Serial number: 3122
- MFC1: Argon, 50 sccm full scale
- MFC2: Oxygen, 50 sccm full scale
- MFC3: Not fitted
- High-resolution pressure control: Not fitted
- Backing pump: Supplied by customer
- Etch stage: Moorfield RIE-3", aluminium; 4" diameter
- DC power supply: Not fitted
- RF power supply: 150 W maximum 13.56 MHz RF power supply with auto-matching unit, limited to 30 W output
- High-resolution RF power control: Not fitted
- Power supply/source switch: Not fitted
- Fast chamber vent: Not fitted

Where components are not present, it is possible for the manufacturer or their representative to retrofit these as upgrades at a later date. Please contact the manufacturer for advice in this regard (for safety reasons, unauthorised upgrades should not be attempted by the user).

## 5. Installation

The system is intended to be installed by the manufacturer or its authorized representative.

The system is shipped disassembled, with the following components:

- Main unit: Sealed process/service gas connections; power switch off; touchscreen protective cover in place; turbomolecular pump outlet connection covered.
- Backing pump: In original packaging, with manual. Includes oil where appropriate. Power switch off.
- Electrical power cables: 1 IEC male-to-female cable for connecting the main unit to the backing pump; 1 IEC mains plug cable.

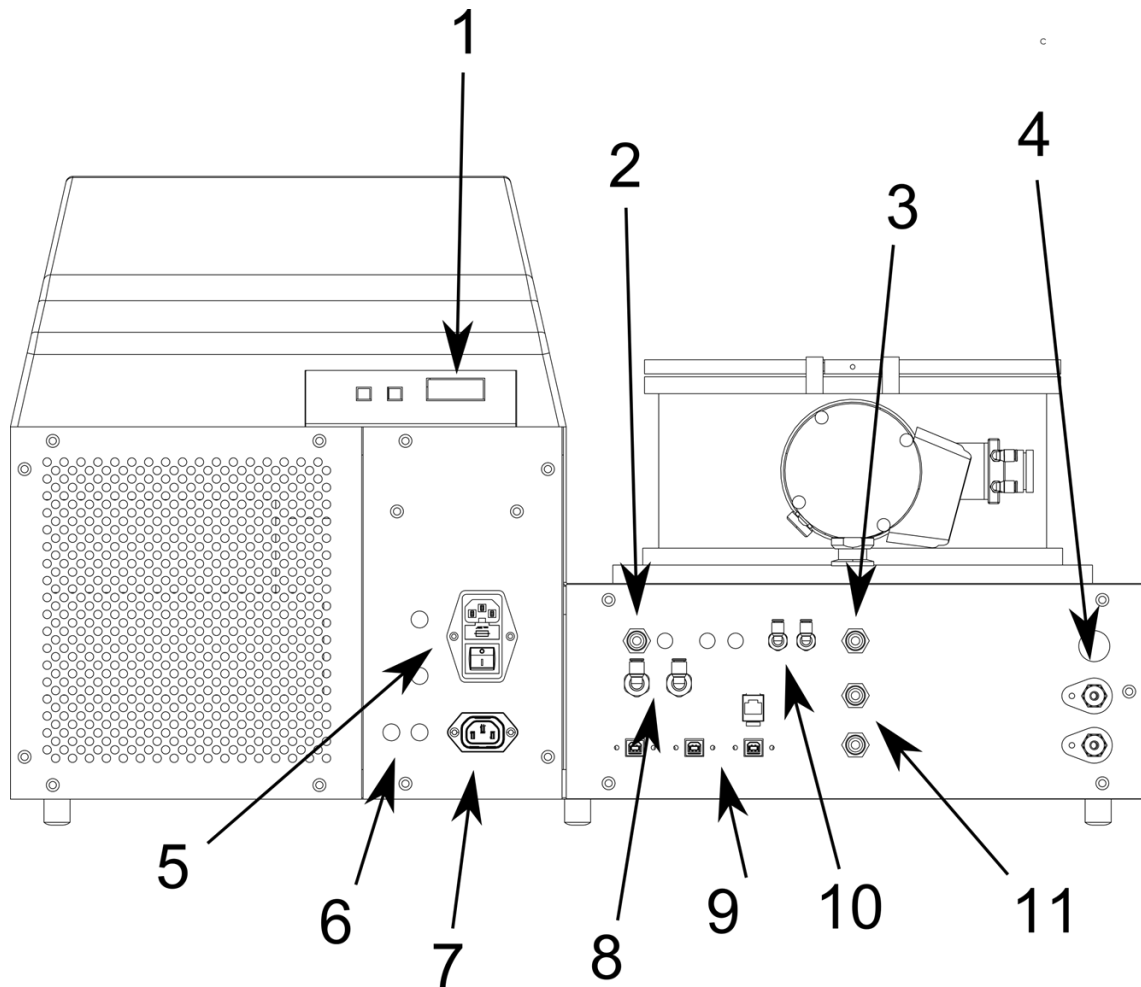
The system has the following operating requirements:

- Process gases: Recommended high purity, dry, 20–25 psi pressure per supply. Connection via 1/4" tube Swagelok fittings. Maximum flow rates in accordance with MFCs fitted (see section 3).

- Service gas: Dry gas at 60–80 psi. Examples of suitable gases are nitrogen and compressed air. Connection via 6 mm outer diameter push-in pneumatic fitting.
- Fast vent gas: Dry gas at max. 5 psi.
- Electrical power: 230 V, single-phase 60 Hz, 10 A.
- Chilled water: Flow rate of at least 1 L/min, recommended chilled to 20 °C with cooling power of at least 1 kW (requirements can depend on local conditions; contact manufacturer for advice).

The unit should not be used in any situation where it is suspected or possible that these requirements are not being met, for even short periods of time.

Figure 3 shows the connections on the back panel of the unit. These connections are used during installation.



- |                                                               |                                                                                  |
|---------------------------------------------------------------|----------------------------------------------------------------------------------|
| 1: Turbomolecular pump 15-way connection                      | 8: Cooling water flow/return to/from turbomolecular pump (6 mm push-in fittings) |
| 2: Fast vent gas inlet (6 mm push-in fitting)                 | 9: USB/ethernet data connections                                                 |
| 3: Service gas supply inlet (6 mm pneumatic fitting)          | 10: Shutter/throttle valve pneumatic control fittings (4 mm pneumatic fittings)  |
| 4: Process gas supply inlets (1/4" tube fittings)             | 11: System cooling water flow/return (6 mm push-in fittings)                     |
| 5: System electrical mains inlet (IEC plug) and on/off switch |                                                                                  |
| 6: Fuse holders                                               |                                                                                  |
| 7: Electrical mains outlet to backing pump (IEC socket)       |                                                                                  |

Figure 3: Layout of the system's back panel indicating the nature of the various connections present.

The following procedure describes general system installation (note that some sections may not be necessary, depending on exact unit configuration):

1. Unpack all system components and check they are in the condition described above.
2. Place the main unit on a hard, level surface capable of securely supporting the system weight.
  - There should be at least 20 cm clear space on each side.
  - There should be clear space available above the unit for opening the chamber door.
3. Place the backing pump where it is to be situated.

- The backing pump can be positioned next to, behind, or below the main unit.
  - Ensure there is adequate ventilation to the backing pump (see separate backing pump manual for further details).
  - Position the backing pump as close as possible to the main unit for optimum performance.
4. Connect the backing pump to the outlet of the turbomolecular pump using the flexible stainless steel bellows and the KF25 fittings supplied.
    - Minimize the number of sharp bends in the bellows for optimum performance.
  5. Follow any pump-specific setup procedures (see pump manual for further details), e.g., oil-filling for wet rotary pumps.
  6. Securely connect the process gas supply lines to the appropriate fittings (labeled with the MFC number, together with the chemical symbol for the gas to be used) on the back of the unit.
    - At this stage, there should be no gas pressure supplied to the process gas supply lines.
  7. Turn on the process gas pressure on each process gas line fitted to 20–25 psi. Use leak checking fluid or a leak sniffer to check that there are no leaks where the process gases are connected to the main unit. Once leak checking is complete, turn off the process gas supplies to the system.
  8. Ensure the service gas lines from the rear of the main unit to the throttle valve are connected. The appropriate outlets on the back of the main unit are labelled 'THROTTLE VALVE'.
  9. Connect the turbomolecular pump control cable to the appropriate connections on the unit's back panel. The back panel connection is labelled 'TURBO'.
  10. Securely connect the service gas supply line to the appropriate fitting on the back of the unit. This fitting is labeled 'SERVICE GAS'.
    - At this stage, there should be no gas pressure supplied to the service gas supply line.
  11. Using two lines of 4 mm tube, each having a flow restrictor in its length, connect the pneumatic actuator on the throttle valve mounted between the chamber and the turbomolecular pump to the back of the main unit.
  12. Apply 60–80 psi gas pressure to the service gas supply line.
  13. Securely connect the chamber fast vent gas supply line to the appropriate fitting on the unit's back panel. This fitting is labeled 'FAST VENT'.
  14. Apply 5 psi gas pressure to the service gas supply line.
  15. Connect the chilled water supply tube to the 6 mm push-in fitting on the back of the system labeled 'WATER IN'.
  16. Connect the chilled water return tube to the 6 mm push-in fitting on the back of the system labeled 'WATER OUT'.
  17. Connect the electrical mains IEC cable between the pump and the main unit. The appropriate connection on the back of the main unit is labeled 'IEC PUMP'.
  18. Ensure the switch on the pump is turned on and the pump is configured correctly for local mains electrical supply (see pump manual for further details).
  19. Connect the electrical mains IEC cable to the main unit (connection labeled 'IEC MAINS') and insert the plug into a mains socket.

Warning—never connect any gas to the system's process gas connections other than that for which the system has been designed. The process gas fittings are clearly labelled; always ensure the correct process gas is supplied to the correct back panel fitting.

Warning—always use dry, particulate-free high-purity process gases. Impurities can produce undesirable results, may damage the system and may lead to unsafe operating conditions.

Warning—always ensure that service and chamber fast vent supply gas pressures are within limits detailed. Incorrect pressures may damage the system and may lead to unsafe operating conditions.

## 6. System Setup

This section provides detailed information regarding the calibration and setup of the hardware present in the nanoETCH system.

Note that some sections only apply where certain options have been selected, e.g., setup of the high-resolution pressure control module.

In this section, *italic formatting* is used to indicate references to the displayed names (titles) of software screens and interface controls displayed on the touchscreen.

### 6.1 Throttle Valve

In some cases, it may be necessary to adjust the fixed positions of the throttle valve that is situated between the turbomolecular pump and the chamber. This may be necessary, for example, when the correct process pressures are not being achieved in the chamber during etching.

To adjust the throttle valve fixed positions, the procedure below should be followed:

1. Carefully close both flow restrictors (rotate clockwise until tight) on the service gas lines leading from the back of the main unit to the pneumatic actuator mounted on the throttle valve.
2. Disconnect the service gas lines from the pneumatic actuator.
3. Use an allen key to adjust the mechanical stop positions of the pneumatic actuator, per the guidance below.
4. Reconnect the service gas lines to the pneumatic actuator (ensure the correct line is connected to either side), and open the flow restrictors as required for correct actuation.

If it is the case that the maximum pressure that is being achieved is too low (i.e., it is not possible to raise the pressure to sufficiently high levels), then the mechanical stops need to be adjusted such that there is lower conductance between the chamber and the turbomolecular pump when the throttle valve is in the closed position. On the other hand, if the minimum pressure that can be achieved is too high (e.g., due to minimum flow rates through the MFCs), then the mechanical stops need to be adjusted such that there is greater conductance between the chamber and the turbomolecular pump.

Warning—do not make any adjustments to pneumatic actuators while there is a chance they could be operated or without first disconnecting their service gas supply lines! Else, injury to users may result.



## 6.2 Mass Flow Controller Offset Calibration

It is possible zero the MFCs in order to calibrate their offsets. This can be done at any point when all MFCs are set to zero flow. To carry out this procedure, first use the *Manual Control* screen to check that all MFCs are set to zero flow. Then, navigate to the *System Settings* screen and press the *Zero MFCs* button. The button will darken as the procedure is being carried out, and then return to its original state.

## 6.3 High-Resolution Pressure-Control

This section is only relevant for systems that have the high-resolution pressure-control module fitted.

It is possible to check whether the current system setup will allow for a particular pressure to be achieved. To do this, users should navigate to the *Gas & Pressure Control* section of the *Manual Control* screen, enter the MFC flow rates and setpoint pressure corresponding to the etching conditions to be used and then engage pressure-control.

If this procedure reveals that the setpoint pressure cannot be achieved, it may be necessary to adjust the position of the throttle valve located between the turbomolecular pump and the chamber (see Section 6.3).

If the pressure-control mode is seen to provide poor performance (e.g., slow to achieve setpoint pressure, or oscillatory behaviour) it may be necessary to tune the feedback loop involved. To do this, with pressure-control engaged, press the *Pressure control AT* switch on the *Manual Control* screen.

Note that the ability of the pressure-control routine to achieve the setpoint pressure also depends on the defined proportions of the gas flow rates relative to the minimum and maximum flow rates allowed by the system MFCs. As the relative proportions of the gas flow rates deviates further from the ratios of the full scales of the corresponding MFCs, the ability of the system to automatically control pressure will become increasingly restricted.

## 6.4 Etching Electrical Power Supplies

The nanoETCH system can be fitted with a maximum of one DC electrical power supply and one RF electrical power supply.

If the system includes a DC PSU, this will be visible on the front panel of the system. The supply is set up during system manufacture. However, before this supply is used, the user must ensure it is switched on (independent of switching on the nanoETCH system). For this, there is a switch on the supply's front panel. Every time the supply is powered on it is necessary to enable its power output. To do this, the user should press the button labeled 'MAIN' on the supply's front panel, once. If this has been done correctly, this button is lit green when the supply is delivering output power during etching.

If the system includes an RF electrical power supply, this will be set up correctly by the



manufacturer. No further action is necessary by the user prior to its use for etching. Note that this type of electrical power supply does not have a front panel visible to the user (refer to Section 4 to find out if this is fitted).

## 7. Operating Instructions

This section provides detailed instructions for system operation. The underlying states of system hardware are also explained to provide the user with an understanding of processes taking place inside the nanoETCH unit.

For detailed information regarding the software screens described, refer to Section 6 of this manual.

In this section, *italic formatting* is used to indicate references to the displayed names (titles) of software screens and interface controls displayed on the touchscreen.

During typical use, an operator will first open the chamber and mount a substrate on the etch stage. They would then close the chamber and initiate the chamber pump routine. Once the chamber is pumped, they can then run etching hardware as required. With etching finished, the chamber can be vented and the coated substrate removed, ready for application. Each of these stages is described in detail below.

Warning—the system should not be used prior to correct installation, or in any situation where operating requirements are not being met (see Section 3).

### 7.1 Turning the System On

To switch on the system, ensure the unit is connected to mains power and all services as described above, and then press the power switch on its back panel. The touchscreen will display a startup screen followed by the *Main Menu*.

Inside the system, the control electronics and hardware are initialized. Hardware is continuously checked for any errors while electrical power is being supplied to the system.

### 7.2 Inserting a Substrate

To insert a substrate, the chamber must first be opened. To do this, use the extending piece at the front of the chamber door to lift the door on its hinge. Move the door fully back, so that it rests on its hinge and stays there by itself. Note that it will not be possible to open the door until the chamber vent routine has been carried out. It is possible to check whether the chamber vent routine has finished by checking for air flow through the vent valve fitted to the turbomolecular pump. When the chamber is fully vented, the internal atmosphere will be at atmospheric pressure, and there will be no air flow through this vent valve. Excessive force should not be applied to the door in an attempt to prematurely open it.

With the door open, the etch stage will be visible standing proud from the center of the chamber baseplate. The substrate should be placed, carefully and securely, onto the center of the etch stage. Users should ensure that the entirety of a substrate is within the central metallic

section of the stage, and does not make contact with the outer ring. Otherwise, an electrical short may be produced during operation.

Figure 4 shows the etch stage mounted on the chamber baseplate.

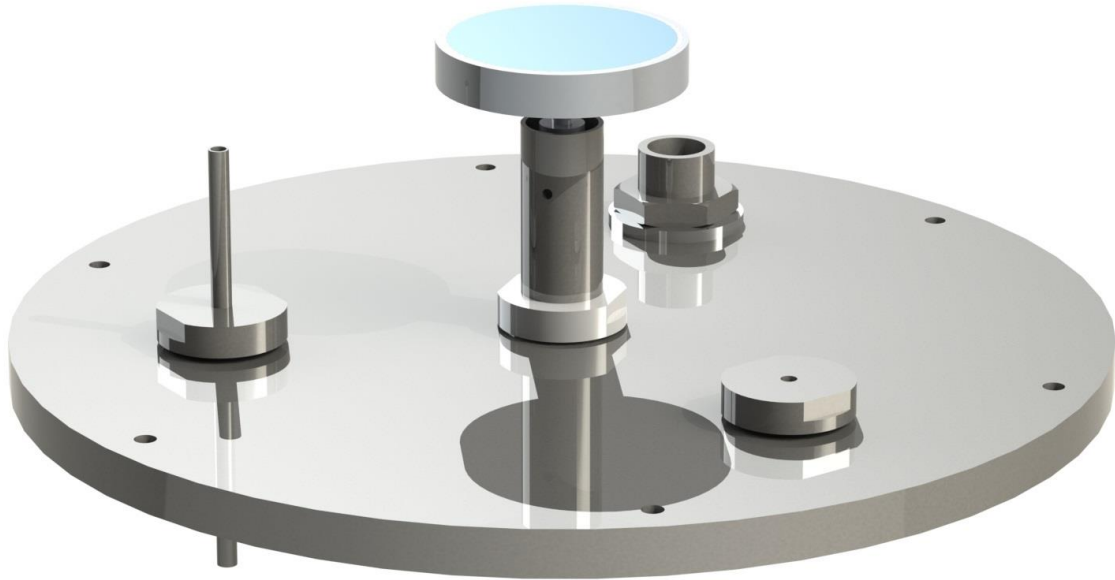


Figure 4: Illustration of the etch stage mounted on the chamber baseplate.

Once a substrate has been placed onto the etch stage, the chamber door should be carefully lowered back into its closed position. The chamber is now ready to be pumped.

Warning—chamber internal components may be hot! This may also apply to substrates and substrate stages. Avoid direct contact with all chamber internal surfaces (use tweezers).

Warning—chamber components are delicate! Do not apply excessive force.

Warning—ensure that substrates are located entirely within the central metallic section of the substrate stage. Substrates that contact the central and outer parts of the etch stage may produce an electrical short.

Warning—users should ensure that substrates inserted into the system are compatible with process conditions. Appropriate risk assessments must be carried out prior to any process operation.

Warning—users should wear gloves whenever the chamber is open, to avoid the introduction of contamination that can affect system performance and etching results.

### 7.3 Pumping the Chamber

Before carrying out any etching, it is necessary to pump the chamber to a suitable vacuum level by carrying out the pump routine. To initiate the pump routine, press *Pump Chamber* on the *Main Menu*.

When the pump routine is started, the backing pump is immediately switched on. This rough pumps the vacuum system of the nanoETCH unit. Once the chamber pressure has dropped

below the 'door' pressure setpoint (i.e., the pressure at which the system detects that the door is closed during pumping), and at least 30 s after the pump routine was initiated, the turbomolecular pump is switched on. As the turbomolecular pump speed increases, the chamber pressure will drop rapidly. When the pressure drops below  $5 \times 10^{-5}$  mbar, the vacuum interlock will be deactivated and it will then be possible to use interlocked etching hardware such as the electrical power supplies, and to start processes in automatic mode.

While the pump routine is in operation, the *Status* text on the *Main Menu* reads 'Pumping...'. When the pump routine has finished, and the system is ready for carrying out etching, this changes to 'Pumped'. The green/red indicators on the *Main Menu* report the status of the system interlocks at all times.

**Warning**—ensure the chamber door is closed before starting the chamber pump routine! Attempting to evacuate a non-sealed chamber could result in damage to the system and to unsafe operating conditions.

## 7.4 Automatic Mode: Process Definition

In automatic operation mode, etching runs are carried out according to pre-defined processes. Each process consists of a number of stages. When a process is run, the system starts with the first stage (i.e., stage 1) and sets the system hardware according to the conditions defined as part of that stage. Once a stage has finished (as it reaches a defined endpoint—see below), the system moves to the next stage and adjusts the system hardware according to the conditions corresponding to that stage. A running program finishes when the system moves into a stage that contains an etching time of 0 s.

Note that processes can only be defined in supervisor mode. To access this mode, users should move to the *Main Menu*, press *Supervisor Login*, and enter the correct password.

To define a process, first enter a process ID using the *Process Selection* screen. At this point, process author and description details can also be updated. Once a process has been selected, navigate to the *Stage Editing* screen using the *Edit Process* button.

The system is capable of storing up to 30 processes, each having up to 20 stages. Using the *Stage Editing* screen, it is possible to move between stages and to define the etching conditions corresponding to each of these stages.

Stage parameters indicate how the system will operate when a process is run, and what conditions should be achieved before the system moves to the next stage. The following important guidelines should be taken into account during stage parameter definition:

1. For systems fitted with multiple electrical power supplies, the system will not allow both PSUs to be operated at the same time.
2. It is possible to set PSU output levels up to 100% of their full scales. However, during automatic operation, the actual output levels will be limited to the maximum levels defined using the *System Settings* screen.
3. If the etching time is set to 0 s then the stage will be interpreted as a signal to terminate

- the running process.
4. If the setpoint pressure is  $0.0 \text{ mbar} * 10^{-3}$ , the system will not attempt to control pressure (applicable only when the high-resolution pressure control module is fitted).
  5. If the pressure is greater than  $0.0 \text{ mbar} * 10^{-3}$ , the system will attempt to control pressure by changing the total MFC flow rate while keeping the ratios between the flow rates of the different gases constant (applicable only when the high-resolution pressure control module is fitted).

Note that any changes made to stages or processes are saved to memory immediately.

## 7.5 Automatic Mode: Process Operation

Prior to system operation in automatic mode, users should first define a process (see above). Note that processes can only be defined in supervisor mode. To access this mode, users should move to the *Main Menu*, press *Supervisor Login*, and enter the correct password.

To run a defined process, the user should first navigate to the *Process Selection* screen and select the process to be run.

Once the desired process has been selected, the user should enter the *Process Execution* screen and press *Process Start* to begin the process. The system will then automatically carry out the process according to the stages that have been defined.

While a process is running, the *Process Execution* screen displays a variety of information relating to system conditions. In addition, the *Plots* screen provides a summary of conditions in a graphical format.

During automatic operation, it is possible to skip to the next stage and hold at the hardware settings defined for the current stage. A running process will be terminated when the system moves into a stage that has a zero value for etching time.

It is also possible to manually terminate a running process at any time using the *Stop* button on the *Process Execution* screen.

Note that the system will automatically move to the next stage once the current stage has run for more than 167 mins, regardless of whether or not the endpoint conditions have been achieved.

If the nanoETCH system is fitted with the high-resolution pressure-control module, then the system can operate in either flow-rate or pressure-control modes (otherwise only flow-rate control is available). During automatic operation, the mode in effect depends on the setpoint pressure. If the pressure is set to exactly zero, then the system will operate in flow-rate control mode. But if the setpoint pressure is greater than 0 then pressure-control mode will be enabled.

When a process ends, the system reverts to its standby, pumped state.

In case an error occurs while a process is running, a dialog box will be displayed on the

*Process Execution* and *Plots* screens to warn the user. For some errors, a running process will be immediately terminated. Detailed error information is available via the *System Log* and *Diagnostics* screens.

## 7.6 Manual Operation

For operation in manual mode, the user should navigate to the *Manual Control* screen. Here, through selection of the correct section (using the *Gas & Pressure Control* and *Etching Control* buttons) it is possible to manually control all aspects of system hardware. For example, the user can specify MFC flow rates and ratios, enter a setpoint pressure for pressure-control mode and set PSU output levels, as required. Exact control options that are available will depend on system configuration.

As an example of an etching process carried out in manual mode, a user might first introduce a process gas flow through an MFC to bring the chamber pressure to that required (flow-rate pressure control). Once the pressure has stabilised, the user would then set an electrical PSU to a level suitable for striking a plasma. Once a plasma has been struck, the output power may be changed to the level required for actual etching before leaving it for the required length of time.

Manual operation is useful for checking that a particular set of system conditions will allow a plasma to be struck. There are several ways in which a user can determine that a plasma has been struck. If the nanoETCH chamber is fitted with a viewport, then the appearance of a plasma over the source in use will be directly visible. When using a DC electrical power supply, stable voltage and current readings on the front panel will be visible when a plasma is present. When using an RF power supply, feedback parameters displayed on the *Manual Control* screen will indicate the presence of a plasma (e.g., a low reference power compared to the forward power together with stable tune and load motor positions).

## 7.7 Venting the Chamber

After the chamber has been pumped, it is possible to vent the chamber at any time (except when a process is in operation or etching hardware is being operated in manual mode).

To vent the chamber, users should navigate to the *Main Menu* screen and press *Vent Chamber*. The chamber vent routine is then activated. This routine starts by stopping power to the turbomolecular pump. The system then waits for the rotor speed on this pump to decrease. After a few minutes the system begins to introduce gas into the chamber. This gas is passed through the vent valve connected to the turbomolecular pump, but also through the MFCs (if the MFC Vent setting is enabled, see Section 8.9). If the system is fitted with the chamber fast vent module, and this has been enabled via the *System Settings* screen, then gas will also be introduced into the chamber through the fast vent valve, once the turbomolecular pump speed has fallen below 50%. A short time later, electrical power to the backing pump will be terminated. After this, the gas flows will gradually bring the chamber to atmospheric pressure.

While the vent routine is running, the status display on the *Main Menu* screen shows 'Venting...'. When the vent routine has finished, this changes to 'Vented'.

Note that the chamber may not be at atmospheric pressure even if the status has changed to 'Vented'. It is possible to tell if venting has finished by checking for gas flow through the vent valve (this will cease when atmospheric pressure has been reached).

## 7.8 Removing a Substrate

To remove a substrate after a process has finished, first carry out the chamber vent routine as described above.

Once the vent routine has finished, the chamber can be accessed as per the procedure given in the 'Inserting a Substrate' section above.

Warning—chamber internal components may be hot! This may also apply to substrates and substrate stages. Avoid direct contact with all chamber internal surfaces (use tweezers).

Warning—chamber components are delicate! Do not apply excessive force.

Warning—ensure that substrates are located entirely within the central metallic section of the substrate stage. Substrates that contact the central and outer parts of the etch stage may produce an electrical short.

Warning—users should ensure that substrates inserted into the system are compatible with process conditions. Appropriate risk assessments must be carried out prior to any process operation.

Warning—users should wear gloves when working with all internal chamber components, to avoid the introduction of contamination that can affect system performance and etching results.

## 7.9 Periods of Inactivity

The system is designed to be left switched on when not in use, with the pumping system on and the chamber in the pumped state. To this end, users should close the chamber door and carry out a chamber pump routine before finishing a session of use. They should also isolate the system from process gas supplies (but leave the service gas supply on).

For long, sustained periods of inactivity, or where the system is to be relocated, etc., it may be necessary to switch the system off. For the applicable procedure in this case, see the following section.

## 7.10 Turning the System Off

When it is necessary to turn the system off, the following procedure should be followed:

1. Ensure the chamber has been vented (if necessary, carry out a chamber vent routine—see above).
2. Isolate the system from process and service gas supplies.
3. Turn the system off using the switch on the electrical inlet on the back panel.

## 8. Software Reference

All system operation is carried out through software that is controlled via the touchscreen HMI. User interaction with the software is via interface controls. Four different types of interface control are employed: buttons, switches, indicators and data-entry areas.

- A button is an area that can be touched to move between software menu screens or to access a particular function. Each button consists of blue text within a light blue box. Buttons with red outlines must be pressed and held for 2 s for operation.
- A switch is an area that can be pressed to turn on/off a specific functionality. Switches change their appearance depending on whether they are on or off. When on, a switch is a black box with a cross inside. When off, a switch consists of an empty black box.
- An indicator is an area that changes its appearance depending on whether a particular functionality is on or off. Indicators appear as filled green boxes when representing an on state, and empty red boxes when representing off.
- A data-entry area is a location that can be pressed to show a keyboard through which data (e.g., parameter values and text) can be entered.

The following guide indicates the locations of all buttons/switches/indicators/data-entry areas and describes their use.

The buttons, switches, indicators and data-entry areas that are available depends on which menu screen is currently being displayed and the configuration of the system (controls may be invisible where the system has not been configured with corresponding hardware).

In this section, *italic formatting* is used to indicate references to the displayed names (titles) of software screens and interface controls.

Once the software has loaded, it is possible to move through the different menus and screens that constitute the software using buttons present on each screen. Figure 5 displays the navigation routes between all menu screens present in the software.



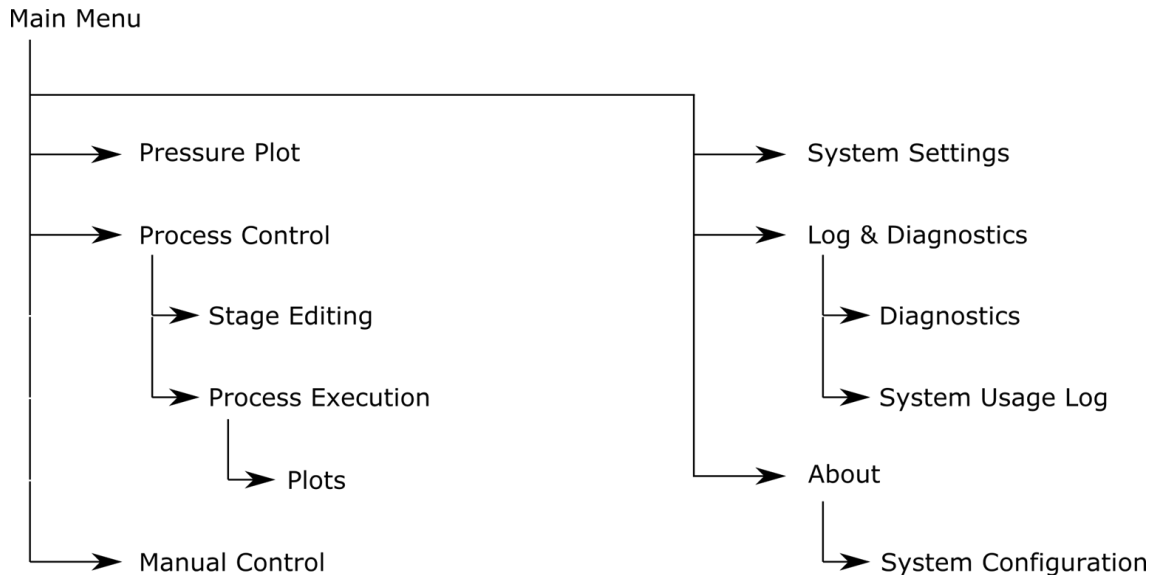


Figure 5: The relationships between the menu screens present within the software. Arrowed lines indicate where direct navigation between two menu screens is possible.

The following descriptions cover the structure and function of each menu screen.

## 8.1 Main Menu

The *Main Menu* screen is the root menu from which all software functionality is accessed.

The *Main Menu* contains several buttons:

- *Pump Chamber*: When pressed, this button starts the chamber pump routine. When pressed, this button will terminate any running vent routine.
- *Vent Chamber*: When pressed, this button initiates the chamber vent routine. When pressed, this button will terminate any running pump routine and turn off the vacuum interlock.
- *Pressure Plot*: This button displays a plot of the system WRG pressure over the last 30 minutes.
- *Process Control*: Press this button to move to the *Process Selection* screen. From there, it is possible to define and run processes.
- *Manual Control*: Press this button to navigate to the manual control screen. There, it is possible to control all system hardware, manually.
- *Supervisor Login*: Press this to display a dialog through which supervisor mode can be accessed (through provision of the correct password).
- *System Settings*: This button will take the user to the a screen that allows various general settings to be viewed and altered.
- *Log & Diagnostics*: Press this to access the *System Log* screen, where system messages are displayed.
- *About*: Press this button to view system information.



The *Main Menu* screen also displays the current WRG chamber pressure, turbomolecular pumping speed, text relating to the current system status, and indicators that show the states of all interlocks.

## 8.2 Pressure Plot

The *Pressure Plot* screen (note that this screen is untitled, for clarity) allows users to follow the WRG chamber pressure over time, graphically.

In the horizontal direction, the spacing between gridlines represents 5 minutes (30 minutes full width). In the vertical direction, the spacing between each gridline represents 1 decade of the WRG pressure (this is a logarithmic scale). As such, the full vertical scale is from  $10^{-8}$  to  $10^3$  mbar.

The *Pressure Plot* screen contains one button: *Back*. Pressing this button allows the user to return to the *Main Menu*.

## 8.3 Process Selection

The *Process Selection* screen allows the user to select a process for operation in automatic mode. Each process describes a progression of etching stages (each defined stage consists of a set of defined parameters) that a user would like to subject a substrate to.

The *Process Selection* screen contains several data-entry areas:

- *Process ID*: This data-entry area allows the user to specify which process they would like to work with. Valid process IDs are in the range 1–30 (inclusive). When the process ID is changed, the selected process is loaded and the other text on the *Process Selection* screen is updated.
- *Description*: This data-entry area allows a user to modify/enter text that describes a process. A maximum of 20 characters can be entered.
- *Author*: Here, the process author can enter their initials/name. Maximum of 12 characters.

Also displayed on this screen is the date on which the selected process was last modified.

The screen also contains several buttons:

- *Back*: Pressing this button returns the user to the *Main Menu* screen.
- *Delete Process*: Pressing this button clears the currently-selected program. This button must be pressed and held for 2 s; a confirmation dialog is also displayed. Warning—clearing a program is an irreversible operation!
- *Edit Process*: Pressing this button takes the user to the *Stage Editing* screen, where a etching process' constituent stages can be defined.
- *Process Execution*: This button allows the user to navigate to the *Process Execution* screen, where processes can be run and those in operation can be monitored.

## 8.4 Stage Editing

The *Stage Editing* screen allows a user to edit the stages that define the selected process.

Note that processes can only be defined or modified in supervisor mode. To access this mode, users should move to the *Main Menu*, press *Supervisor Login*, and enter the correct password.

This screen contains several data-entry areas:

- *Stage name*: This allows the user to assign a name to the current stage. Maximum of 12 characters.
- *Stage number*: This allows the user to move between the different stages that make up the selected process.
- *RF PSU (W)*: Here, the user can enter the RF PSU output level for the current stage.
- *RF source*: The source to which the RF power should be routed from the RF PSU. The sources available will depend on exact system configuration.
- *DC PSU %*: The DC PSU output level for the current stage.
- *Etching time (s)*: This allows the user to specify the etching time associated with the selected stage. The time entered must be in the range 0–9999 s.
- *MFC1 flow (sccm)*: The flow rate of gas through MFC1. Valid settings are from 0 sccm to the full scale of the MFC.
- *MFC2 flow (sccm)*: The flow rate of gas through MFC2. Valid settings are from 0 sccm to the full scale of the MFC.
- *MFC3 flow (sccm)*: The flow rate of gas through MFC3. Valid settings are from 0 sccm to the full scale of the MFC.
- *Pressure (mbar \* 10<sup>-3</sup>)*: Here, the user can enter the chamber pressure for high-resolution pressure control operation.

Note that the data-entry areas that are enabled depends on the exact system configuration.

In addition to data-entry areas, this screen also displays multiple buttons:

- *Back*: This allows the user to navigate back to the *Process Selection* screen.
- *Delete*: This deletes the current stage. All stages following the current stage are moved backwards in system memory (e.g., if stage 3 is deleted, stage 4 becomes stage 3, stage 5 becomes stage 4, etc.). A new stage is inserted at position 30. Warning—deleting a stage is an irreversible operation!
- *Insert*: This inserts a stage at the current position. All stages from the current position onwards are shifted forwards by one position (e.g., if a stage is inserted while stage 4 is selected, then stage 4 becomes stage 5, stage 5 becomes stage 6, etc.). Warning—this operation results in stage 30 being deleted!
- *First*: By pressing this button, the first stage (stage 1) is selected.
- *Prev.*: This moves to the stage before that currently selected.
- *Next*: The moves to the stage after that currently selected.
- *Last*: This moves to the last stage in the program (stage 30).

Warning—any changes made to stages are saved to memory immediately! Care should be

taken when overwriting previously defined processes.

## 8.5 Process Execution

The *Process Execution* screen allows a user to run or stop the currently selected process.

This screen also displays information about the system hardware and the status of any running process. This information includes:

- The current stage number.
- The time that has passed since the current stage was started.
- The time that has passed since the etching stage was started.
- The current RF PSU output level.
- The current DC PSU output level.
- The current flow rates through all MFCs.
- The current high-resolution chamber pressure.
- The current WRG chamber pressure.

The screen contains the following buttons:

- *Back*: This allows the user to navigate back to the *Process Selection* screen. This button is disabled while a process is running.
- *Plots*: This displays the *Plots* screen, where a graphical view of system state is displayed.
- *PSU Detail*: This brings up a dialog window that displays various parameters indicating the current status of the RF electrical power supply, if this is fitted.
- *Next Stage*: This moves the process to the next stage. If the current stage is the last, then the process will end.
- *Hold Stage*: This maintains the process at the current stage. System conditions will remain as defined for this stage until this button is re-pressed (button is darkened while a stage is being held).
- *Process Start*: Used to run the selected process.
- *Process Stop*: Prematurely stops a running process.
- *Start Stage*: This button is only visible when the operator stage start setting is enabled, and when the process is currently between stages. Pressing the button starts the next process stage.

Note that once a process has been started, it is not possible to return to lower-level screens until the process has finished or has been terminated.

While a process is running, a dialog will appear on this screen should an error occur. Detailed error information can then be obtained via the *System Log* and *Diagnostics* screens.

## 8.6 Plots

The *Plots* screen (note that this screen is untitled, for clarity) allows users to follow a running process, graphically.

The screen displays a grid, and several differently-colored lines that represent various system conditions. In the horizontal direction, the spacing between gridlines represents 5 minutes (30 minutes full width). In the vertical direction, the spacing between each gridline represents 10% of the full scale for each condition plotted.

On the plot, solid lines indicate actual condition values. Dotted lines indicate current setpoint values.

The *Plots* screen contains two buttons:

- *Key*: Displays a legend screen that indicates which colors correspond to which conditions, and details the full vertical scale for each. The legend screen also allows users to pause plotting or reset the plot.
- *Back*. Pressing this button allows the user to return to the *Program Control* screen.

## 8.7 Manual Control

The *Manual Control* screen allows the user to manually, and dynamically operate system hardware including that involved in etching.

To the left of the screen there are 2 buttons that allow the user to choose between the different types of hardware they are able to control:

- *Gas & Pressure Control*: Displays controls relating to the gas and pressure control system hardware.
- *Etching Control*: Displays controls relating to the etching hardware.

If the *Gas & Pressure Control* section has been selected, then the following controls and indicators are displayed:

- *MFC setpoints/actuals*: The setpoint and actual flow rates (in sccm) through each of the MFCs. For the setpoints, valid settings are from 0 sccm to the full scale of the MFC.
- *High-res. pressure (mbar \* 10<sup>-3</sup>)*: The current high-resolution chamber pressure as measured by the capacitance manometer (if fitted).
- *Pressure setpoint (mbar \* 10<sup>-3</sup>)*: Here, the user can enter the setpoint chamber pressure for high-resolution pressure control operation.
- *Pressure control*: Allows the user to switch on pressure control.
- *Pressure control AT*: Allows the user to auto-tune the feedback loop responsible for high-resolution pressure control.

If the *Etching Control* section has been selected, then the following controls and indicators are displayed:

- *DC PSU %*: The DC PSU output level.
- *RF PSU (W)*: Here, the user can enter the RF PSU output level.
- *Forward power (W)*: The forward power of the RF electrical power supply.
- *Reference power (W)*: The reference power of the RF electrical power supply.

- *Plasma power (W)*: The reference power of the RF electrical power supply.
- *Tune motor (%)*: The tune capacitor motor position of the RF electrical power supply matching unit.
- *Load motor (%)*: The load capacitor motor position of the RF electrical power supply matching unit.
- *Relays enabled/disabled*: Indicates whether or not the PSU-source switching relays are enabled for switching (the relays are disabled while and for 30 s after any system etching power supply has been in use).

In addition to the above, the Manual Control screen always displays the current WRG chamber pressure.

There is also a *Back* button that allows the user to return to the *Main Menu*.

Note that the exact appearance of the *Manual Control* screen will depend on the configuration of the current system.

## 8.8 System Settings

The *System Settings* screen is the starting point for changing various settings related to system operation.

Note that system settings can only be modified in supervisor mode. To access this mode, users should move to the *Main Menu*, press *Supervisor Login*, and enter the correct password.

This screen contains three data-entry areas:

- *Door interlock setpoint (mbar)*: The chamber pressure at which the system deactivates the door interlock during the pump routine. Valid settings are between 1 and 600 mbar.
- *Gas stabilisation time (s)*: The length of time, at the start of each stage, when the chamber pressure is allowed to stabilise. Only used for operation in automatic mode. Valid entries are between 0 and 600 s.
- *Inter-stage time delay (s)*: This allows the user to specify a time for which the system should wait between stages of a running process (when operating in automatic mode).
- *MFC1 max. flow rate (sccm)*: The maximum flow rate that can be passed through MFC1.
- *MFC2 max. flow rate (sccm)*: The maximum flow rate that can be passed through MFC2.
- *MFC3 max. flow rate (sccm)*: The maximum flow rate that can be passed through MFC3.
- *DC PSU max. (%)*: The maximum of the full scale DC PSU current (1.4 A) that can be applied. This limit is in effect for system operation in both automatic and manual modes.
- *RF PSU max. (W)*: The maximum of the full scale RF PSU power that can be applied. This limit is in effect for system operation in both automatic and manual modes.
- *Pressure control period (10 ms)*: The control period, in multiples of 10 ms, used for the PID feedback loop that is responsible for automatic pressure control.
- *Pressure P/I/D*: The P, I, and D parameters for the feedback loop responsible for automatic pressure control. Note that these will be reset when this feedback loop is auto-tuned.

This screen contains three switches:

- *MFC vent*: If this is set on, then the system will use gas flow through MFC1 to accelerate the rate at which chamber pressure increases to atmospheric levels during the chamber vent routine.
- *Fast vent*: If this is set on, then the system will introduce gas via the fast vent diaphragm valve to provide for rapid chamber venting.
- *Operator stage start*: With this selected, the operator will be prompted to press a button to start the next stage when a stage has finished during a running process.

There are also three buttons:

- *Zero MFCs*: When this is pressed, the zero offsets for the MFCs will be re-calculated.
- *Supervisor Password*: When in supervisor mode, this displays a dialog that can be used to change the supervisor password.
- *Back*: Returns the user to the *Main Menu*.

Note that settings can only be changed when the system is in supervisor mode.

## 8.9 System Log

The *System Log* screen displays a list of messages generated by the system. Next to each message, the time and date on which it was generated is displayed.

Messages are stored in permanent memory that is not erased when the system is turned off.

This screen presents the user with two buttons, for software navigation:

- *Diagnostics*: This button allows the user to access the *Diagnostics* screen.
- *Usage*: This button takes the user to the *System Usage Log* screen.
- *Back*: This button enables the user to return to the *Main Menu* screen.

Error messages displayed here include a letter code. Refer to the Troubleshooting section of this manual for explanation of errors associated with each letter code.

## 8.10 System Diagnostics

The *System Diagnostics* provides extended information about errors that may have occurred.

Errors are grouped into categories, the names of which are clearly displayed. Against each name is a numeric error code. A code of 0 indicates that no errors have occurred. Any non-zero code indicates that an error has occurred.

The numeric error codes displayed on this screen are intended to provide the manufacturer with diagnostic information. For error codes that can be deciphered by users, the *System Log* screen should be consulted.

While some errors will cause the system to terminate any running etching hardware or process, and prevent etching hardware from being operated, this does not apply in all cases. In

addition, it is possible to clear discontinuous errors that do not frequently recur in order to return the system to a usable state. However, users must take steps to identify the nature of errors as they occur (see the Troubleshooting section) and to assess the requirement for action in response to these errors. In case of any doubt, contact the manufacturer.

If it is appropriate to clear an error category, then press the *Clear* button next to the category name. The numerical error code will return to zero when the errors have been successfully cleared (but will quickly acquire a non-zero value if this has failed—e.g., due to a recurring/continuous error).

Further information regarding errors is provided in the Troubleshooting section.

## 8.11 System Usage Log

The *System Usage Log* screen provides the user with information relating to the usage of the system and the PSUs.

The screen contains one button, *Back*, that allows the user to return to the *Main Menu* screen.

## 8.12 About

The *About* screen displays information about the nanoETCH system.

The screen contains two buttons: *Configuration* and *Back*. The *Configuration* button navigates the user to the *Configuration* screen, while the *Back* button returns the user to the *Main Menu*.

## 8.13 Configuration

The *Configuration* screen displays a range of indicators that show how the nanoETCH system is configured.

The *Back* button returns the user to the *About* screen.

## 9. Maintenance

The system is designed to require minimal maintenance. In cases where it is suspected that serious maintenance is required, users should contact the manufacturer.

Routine maintenance procedures that can be carried out periodically by users include:

- Chamber interior: Use an inert dusting gas canister to gently blow out any debris that may have collected.
- Chamber door o-ring seal: Ensure this is kept free of dirt/debris by wiping with a lint-free cloth wetted with isopropanol. Remove and replace cracked/extremely dirty o-rings



- (contact manufacturer for specifications).
- Chamber door: Watching for loose connections or feedthroughs (contact the manufacturer should loose connections be identified).
- Backing pump: Ensure pump is adequately maintained. Refer to pump-specific manual supplied with the system for instructions.
- Turbomolecular pump: Refer to the pump-specific manual supplied with the system for maintenance instructions.
- Etching stage: Inspect for cleanliness and ensure any loose material is removed from the vacuum chamber.
- DC PSU: Ensure that vents on the front panel of the DC PSU are clear and free of obstruction. Refer to specific manual supplied with the system for maintenance instructions.
- Touchscreen: Remove dirt/grease by periodically wiping with a damp non-scratching cloth (do not apply solvents).
- Rear ventilation slots: Ensure that slots are clear and free of obstruction.
- Case: As for touchscreen.

Warning—never attempt to modify, repair or open the system without first consulting the manufacturer! Such activities may lead to hazardous situations.

Warning—chamber internal components may be hot! This may also apply to substrates and substrate stages. Avoid direct contact with all chamber internal surfaces (use tweezers).

Warning—chamber interior components are delicate! Do not apply excessive force.

## 10. Troubleshooting

When an error occurs, the touchscreen displays a dialog box that informs them that this is the case. For further information regarding the nature of the error, users should visit the *System Log* screen. For each error, this screen will name the category of the error and provide a letter error code. The different error categories are as follows:

- Pressure: Error related to pumping performance and pressure control.
- Temperature: Error related to the heater assembly and heating performance.
- Controller: Error related to the control electronics.
- Gas delivery: Error related to operation of the on-board MFCs and purge valve.
- Water: Error related to the chilled water flow.
- Process: Error related to a process being carried out.

When an error occurs, the system will automatically respond by taking appropriate action. For minor errors, this may simply involve displaying the error dialog box and writing an error message to the *System Log* screen. For more serious errors, and those that could cause a hazardous situation to arise, the system may take more severe action such as terminating any running process and preventing processes from being started.

The specific meanings of each letter code for each category, together with an explanation of responsive actions taken by the system are provided in the table below:



Category	Letter Code	Explanation	System Response
Pressure	A	Chamber door interlock timeout during pump routine	Error message displayed; chamber vent routine initiated; prevent initiation of pump routine
	B	Chamber pressure rises above door interlock setpoint while in pumped state	
	C	Chamber pressure rises above door interlock setpoint while process is in operation	Error message displayed; running processes are terminated; chamber vent routine initiated; prevent initiation of pump routine
	D	Chamber low-vacuum interlock timeout during pump routine	Error message displayed; chamber vent routine initiated; prevent initiation of pump routine
Controller	A	Error in core control electronics	Error message displayed; running processes are terminated; chamber vent routine initiated; prevent initiation of pump routine
Gas delivery	A	MFC1 error	Error message displayed
	B	MFC2 error	
	C	MFC3 error	
Water	A	Water flow failure while pumping system is active	Error message displayed; running processes are terminated; chamber vent routine initiated; prevent initiation of pump routine
	B	Water flow failure while process is running	
	C	Chamber pump routine initiated without water flow	
Process	A	Attempt to start process while uncleared error(s)	Error message displayed; process operation prohibited

The following table provides a list of suggested action to be taken by users in the event of errors occurring:

Category	Letter Code	Suggested Action
Pressure	A	Check chamber door o-ring is clean and sealing correctly; check chamber door is fully closed before starting pump routine; check for obvious leaks around vacuum system; contact manufacturer with diagnostic codes if issue persists

	B	Contact manufacturer with diagnostic codes
	C	
	D	Check chamber door o-ring is clean and sealing correctly; check chamber door is fully closed before starting pump routine; check for obvious leaks around vacuum system; contact manufacturer with diagnostic codes if issue persists
Controller	A	Examine system for obvious malfunctions; contact manufacturer with diagnostic codes
Gas delivery	A	Check MFC1 process gas supply pressure is in range of 20–25 psi; if supply pressure to system recently changed, allow 30 minutes to settle before using; re-calibrate zero offsets; contact manufacturer with diagnostic codes if error persists.
	B	Check MFC2 process gas supply pressure is in range of 20–25 psi; if supply pressure to system recently changed, allow 30 minutes to settle before using; re-calibrate zero offsets; contact manufacturer with diagnostic codes if error persists.
	C	Check MFC3 process gas supply pressure is in range of 20–25 psi; if supply pressure to system recently changed, allow 30 minutes to settle before using; re-calibrate zero offsets; contact manufacturer with diagnostic codes if error persists.
Water	A	Check for obvious malfunctions in chilled water supply; contact manufacturer with error codes if issue persists
	B	Check for obvious malfunctions in chilled water supply; contact manufacturer with error codes if issue persists
	C	Check for obvious malfunctions in chilled water supply; contact manufacturer with error codes if issue persists

Errors can be cleared through the *Diagnostics* screen. Here, users can press *Clear* buttons to clear all errors in corresponding categories. Note that it is not possible to clear continuously occurring errors. Recurring errors must be cleared each time they occur. Clearing errors may allow the user to continue using the system for process operation.

The *Diagnostics* screen also displays a list of numeric error codes for all error categories. These error codes are intended to aid the manufacturer in diagnosing any faults.

For serious errors, e.g., controller errors, remedial action must be taken. Further information regarding errors and remedial action is available from the manufacturer.

## 11. Warranty

The nanoETCH system is shipped with a 12-month warranty valid from date of installation or 2 months following date of shipment, whichever date is earliest.

Warranty extensions and service contracts are available. Please contact the manufacturer for details.

## 12. Manufacturer Contact Details

The manufacturer of nanoETCH systems is Moorfield Nanotechnology Limited.

The manufacturer's address is:

Unit 1 Wolfe Close,  
Parkgate Industrial Estate,  
Knutsford,  
Cheshire,  
WA16 8XJ.  
United Kingdom.

Telephone number: +44 (0) 1565 722609

Fax number: +44 (0) 1565 722758

Email address: [sales@moorfield.co.uk](mailto:sales@moorfield.co.uk)

Websites: [www.moorfield.co.uk](http://www.moorfield.co.uk)