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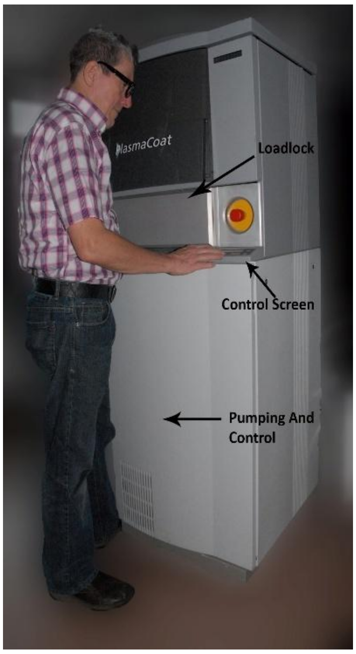
**Technology ● Process ● Design ● Outsourcing ● Training**

# Small Batch High Throughput Plasma Activated Magnetron Sputtering System

# 3-Magnetron New Build Plasmacoat Sputter System (PSS) Including DC Plasma Source Assist (DCPSA)

# Specification
# Plasmacoat 200-4 Port -010725

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**Overview**

Magnetron sputtering has a number of advantages over conventional physical vapour deposition techniques such as electron beam and thermal evaporation. For example, the kinetic energy of the sputtered atoms is typically 10 times higher than that of evaporated species, this results in much harder and much more adherent coatings. The energy of the process also removes the need for substrate heating during deposition which is of specific benefit when coating plastic substrates or other temperature sensitive substrate materials. This means that deposition is carried out at room temperature allowing different materials such as glass and plastic to be coated even in the same batch. Compact magnetron sources are also capable of high deposition rates which result in fast process cycle times.

The metal-oxide materials used in multilayer optical coatings are good electrical insulators and while it is possible to sputter insulators using radio-frequency power, the deposition rates are too low to be economical. To overcome this problem, following early work by Schiller et al [1], Scobey et al [2] and Howson [3], and subsequent work by Alajiani et al [4] McKinlay et al [5] Gibson et al [6] techniques have been developed in which a few monolayers of metal are deposited using dc sputtering in one zone of a vacuum chamber and the metal is then oxidised in another zone as the substrates rotate. This technique is illustrated schematically in *Figure 1*

The method uses zone separation, ensuring process stability of the metallic surface being maintained in the deposition zone. The metal-oxide deposition rate is determined by the efficiency of the metal oxidation on the substrate surface. Partial or incomplete oxidation results in optical absorption in the film. In these systems, a plasma source is required to activate the oxidation process. A small-scale chamber configured for the process as described in this paper is shown in– pumping is single turbo pump above plasma source port.

The Plasmacoat utilises load-lock delivery system for the loading of substrates into the deposition chamber. This ensures main deposition chamber is always maintained under vacuum. The machine configurations consist of two or three magnetrons with metal targets with a separate plasma source as shown in *Figure 2* and *Figure 3* (*figure 1 shows chamber three magnetron ports and figure 2 shows system with 2 magnetron ports with additional port in each chamber for plasma generation)*.

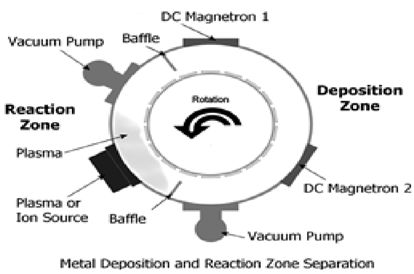


*Figure 1*

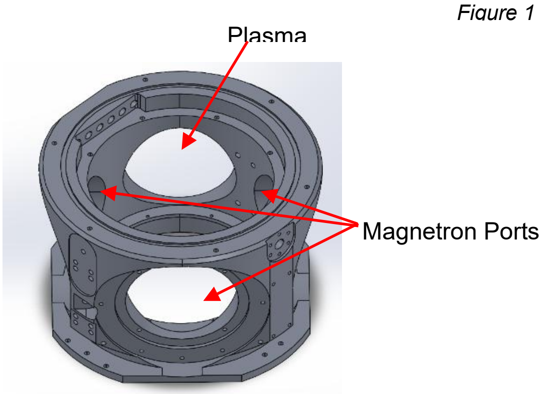


*Figure 2 (used on Plasmacoat-200 4-port system)*

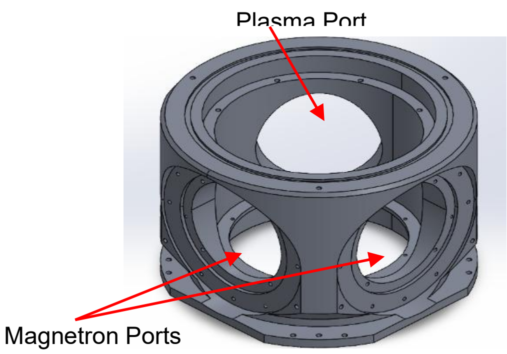


*Figure 3 (used on Plasmacoat-200 3-port system)*

Plasmacoat uses reactive magnetron sputtering process to produce dense optical coatings with outstanding durability. Coatings can be applied to mineral, glass as well as to a variety of plastics including hard-coated CR39 and polycarbonate. The machine is usually supplied for deposition of multilayers incorporating two materials. Silicon dioxide is the low index material and zirconium oxide is supplied as the high index material. However other materials such as niobia, titania, hafnia and tantala are available. These materials are ideal for precision optics and photonics applications.


*Fig 4 Plasmacoat with load-lock door open and tooling carousel in place*

Once load-lock is pumped out the rotor lifts the substrate carousel into the deposition chamber (deposition chamber configuration shown in *Figure 1*). A gate valve separates load-lock and deposition chamber ensuring deposition chamber is always maintained under vacuum. The system is ready to deposit in less than 10 minutes after pump down is initiated.

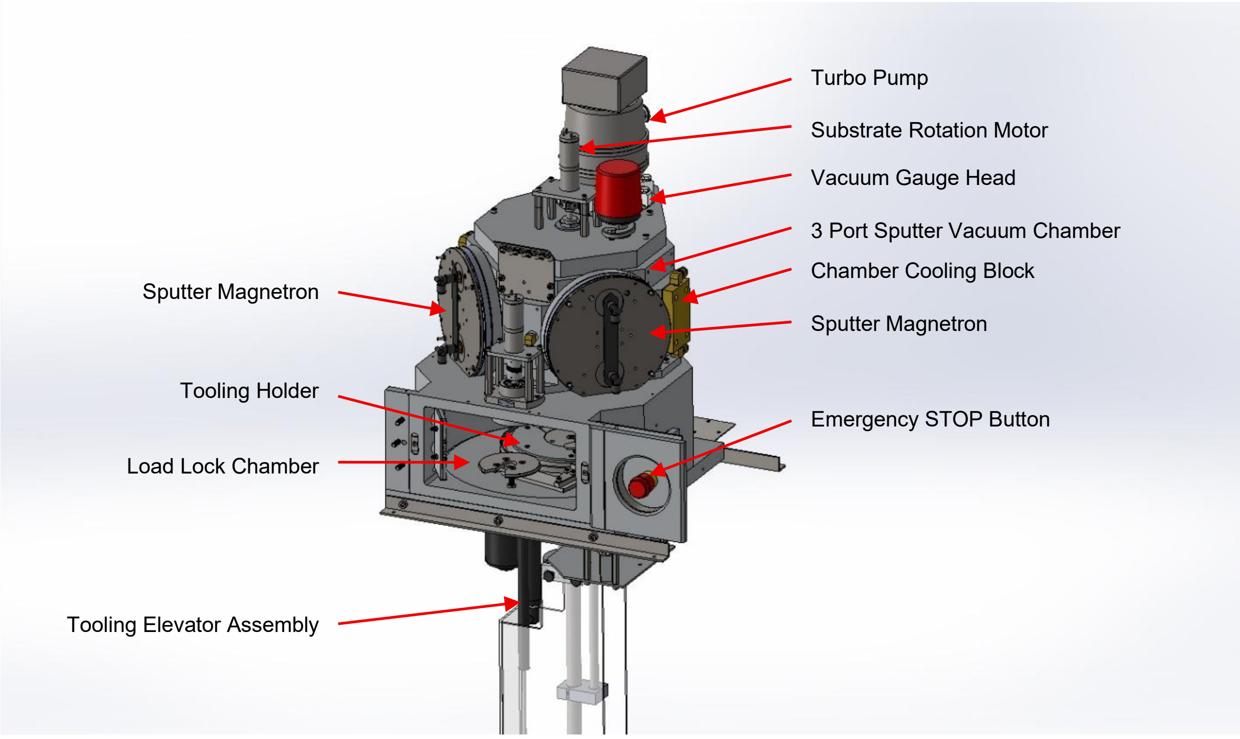


*Fig 5 Chamber and Tooling Lift Assembly (3-port version shown)*

# 1 System Specification

## 1.1 Chamber & Load-lock Chambers

The sputter chamber and load-lock chamber are single walled vertical axis aluminium chambers The sputter chamber has 4 main ports, 3 for sputter targets and one for the DC plasma source port (see figures 2). The chamber cooling is achieved via two water cooling blocks mounted to the side of the chamber (see fig 5 above).

The load lock chamber is fitted with a manually operated door (see fig 4 above). The door is interlocked to avoid inadvertent operation

### 1.1.2 Chamber and load-lock dimensions and specifications

| Description | Unit | Plasmacoat 200 |
|---|---|---|
| Sputter Chamber Diameter (Internal) | mm | 244 |
| Sputter Chamber Height (Internal) | mm | 190 |
| Chamber Diameter (external) | mm | 250 |
| Chamber Height (external) | mm | 828 |
| Load-lock Chamber height (external) | mm | 180 |
| Load-lock Chamber Max width & depth | mm | 420 X 420 |
| Load-lock Chamber diameter (Internal) | mm | 380 |
| Magnetron Positions | | 3 |
| Microwave Position | | 1 |
| Ultimate Chamber Vacuum (Clean, dry & empty) | mbar | >5X10$^{-6}$ mbar |
| Chamber Leak Testing (Clean, dry & empty) | mbar | 1X10$^{-8}$ mbar l/sec |
| Load-lock Pump Down Time 2X10$^{-2}$ mbar (clean, dry & empty)* | min | <10 min |
| Base Vacuum (clean, dry & empty)* | mbar | >6X10$^{-6}$ |

## 1.2 Magnetron Sputter Sources

1.

Three (3) magnetron positions are available in the walls of the vacuum chamber. Three magnetrons are supplied as standard. The magnetrons are directly cooled to enable efficient coating deposition and are designed to produce intense ion bombardment of the substrates during deposition.

The magnetrons are powered using pulsed DC or DC with a DC plasma source located remotely from the sputter targets.

The magnetic arrangement and strength of the magnetrons are optimised for each system.

The systems enable coating deposition to be carried out using a high density of low energy bombarding ions at room temperature. This results in deposition of very dense, amorphous coating structures with low internal stresses.

The magnetrons are housed in a metal frame that allows for easy implementation for the magnetron(s) to be removed to ease target material replacement. Target material is bonded onto a copper backing plate, which is then mounted onto the magnetron body.

The system will be supplied with 3 targets as advised by the customer .. Typical configuration shown as follows -

| Magnetron Position | Material |
|---|---|
| 1 | TBA by Customer |
| 2 | TBA by Customer |
| 3 | TBA by Customer |

### 1.2.1 Magnetron Specifications

| Description | Unit | Plasmacoat 200 |
|---|---|---|
| Magnetron Diameter | mm | 225 |
| Magnetron Target Diameter | mm | 150 |
| Max Power * | kW | 1.5 |
| Water Colling minimum | ltr/min | 3 |
| Max differential Pressure | Bar | 4 |

** Max Power of magnetron determined by material being sputtered*

## 1.3 Substrate carrier

The Plasmacoat systems are equipped with a precision single axis carousel (normally with 6 coating positions) with fixturing to accommodate a range of substrate sizes. The is removable, via the load-lock door. The substrates are rotated by means of a DC controlled motor giving speeds of typically 30-60 rpm. This ensures <±1% thickness uniformity over the central drum surface. Coupling of the motor to carousel is automatics when the load-lock door is closed and the elevator is in the coating position.

*Figure 6 – 6 station carousel*

(*above picture shows standard Plasmacoat tooling*)

*Note: Tooling for coating of 3-dimensional parts is included. Final design to be agreed by end user and Thin Film Solutions Ltd*

## 1.4 Vacuum Pumps

Vacuum pumping system consists of a dry pump, and turbo-molecular pump. The use of dry pumps eliminates the possibility of hydrocarbon contamination due to back streaming.

### 1.4.1 Vacuum Pump Specifications

| | Manufacturer | Model | Unit | Plasmacoat 200-4 |
|---|---|---|---|---|
| Rotary Pump displacement * | Edwards | XDS 35iC | ($m^3h^{-1}$) | 35 |
| Turbo pump* | Edwards | *n*EXT 85D | (l/sec $N_2$) | 86 |
| Turbo Pump flange connection | | | ISO | 100 |

**Pump data based on standard pump configurations (Edwards pumps) @50Hz.*
*** Pump model types/suppliers subject to change without notice*

## 1.5 Vacuum Gauges

Pressure is monitored by a Penning/Pirani combination with an Edwards active gauge controller with digital display.

An Edwards Pirani Gauge is fitted to the backing line to monitor the backing pressure of the turbo pump

| | Manufacturer | Model | Unit | Range |
|---|---|---|---|---|
| Chamber Pressure | Edwards | WRG-S Active | mbar | Atm – $1X10^{-9}$ |
| Backing Pressure | Edwards | APG200 | mbar | Atm – $4X10^{-4}$ |

** Supplier and model number subject to change without notice*

## 1.6 Vacuum Valves

Electrically operated valves are used to facilitate pumping and venting of the system.

## 1.7 Magnetron Power Supplies

The three magnetrons are powered by two off EDF Electronics 1.5KW

Choice of specific power supply configuration is progressed on detailed discussion of customer process requirements.

The power supplies are fully interlocked to prevent operation unless correct chamber vacuum is achieved and all protective covers are in place

### 1.7.1 Specifications

| EDF Electronics™ | Unit | Dual Output |
|---|---|---|
| Max Power Per channel | kW | 1.5 |
| Max Voltage | V | 1000 |
| Max Current | A | 3 |
| Frequency Range | kHz | 10-300 |
| Line Regulation | % | +/- 1 |
| Repeatability | % | +/- 1 |
| Pulsed Regulation Mode | | P, V, I |
| DC Regulation Mode | | P, V, I |

** Make and model number subject to change without notice*


*Figure 7 EDF Electronics Power supply*

## 1.8 DC Plasma Power supply

A DC plasma source is mounted at the rear of the sputter chamber. An argon with reactive gas plasma is created within the sputter chamber

The power supply is fully interlocked to prevent operation unless correct chamber vacuum is achieved, and all protective covers are in place

### 1.8.1 Specifications

| | Unit | Range |
|---|---|---|
| Output Power (max) | W | 500 |
| Output Voltage (max) | V | 600 |
| Ripple | % | 2 |
| Output Ripple (max) @ 300Hz | %p-p | 2 |

** Supplier and model number subject to change without notice*

## 1.9 Process Gas Control

Process gases are controlled via MFC's (Mass Flow Controllers) All gas lines are stainless steel and incorporate Nupro electro-pneumatic closure valves. Gas lines connections are made via a gas connection manifold located at the rear of the system using Swagelok™ ¼" inch connections. Two stage regulators (end user supplied) must be used for the process gasses. Regulators must confirm to local health and safety requirements.

Process gasses **must** be high purity electronic grade minimum 99.998%

Reactive gas flow is maintained at the appropriate rate by a gas controller monitoring magnetron. The number of reactive gas lines can be extended on request. This system is used to control the exact composition and stoichiometry of reactively deposited coatings.

3 off MFC's supplied.

### 1.9.1 MFC Specifications

| | Unit | Range |
|---|---|---|
| MKS | Model | GE50 |
| Range ($N_2$ equivalent) | sccm | 0 - 200 |
| Repeatability | % | +/- 0.3 |
| Typical accuracy | % | +/- 1 |
| Resolution (FSD) | % | +/- 0.1 |
| Warm up time | min | <30 |

** Make and model number subject to change without notice*

### 1.9.2 Process Gases

All process gases must be research grade, high purity, otherwise coating performance will be affected. The gas can be supplied via a bulk gas feed line or by individual cylinders. If cylinders are used, then the gas regulator MUST be a two-stage regulator. For gases, such as Oxygen and hydrogen, these must meet local health and safety standards for use with these gases.

| Process Gas | Input Range |
|---|---|
| Argon* | 20 - 40 PSI (1.4 – 2.8 bar) |
| Nitrogen* | 20 - 40 PSI (1.4 – 2.8 bar) |
| Oxygen* | 20 - 40 PSI (1.4 – 2.8 bar) |
| Hydrogen*,** | 0-500 ml/min @ 20°C 15PSI (1 bar) |

* *Research grade gases*
*** Supplied by Hydrogen Generator located at rear of system (hydrogen generator included)*
*Note: All process gases are fully interlocked*

### 1.9.3 Hydrogen Process Gas Generator (include – required for infrared processes)

Hydrogen is provided through the use of a Hydrogen Generator (electrolysis). This generates pure hydrogen through distilled water electrolysis This will be located to the side of the system

| | Unit | Range |
|---|---|---|
| Linde | Model | NM-H2-500 |
| Hydrogen Flow Rate (max) | ml | 0-500 |
| Output Pressure (Max) | Bar | +/- 0.3 |
| Pressure accuracy | % | +/- 0.5 |
| Water Requirements | | Pure/Distilled |

## 2.0 Process Control

The system control is fully automatic and fully interlocked through a PC/PLC. This includes a suite of menus for the various coating types, automatic recording of deposition parameters, status displayed on mimic diagrams, orderly and safe shut down procedures. Existing menus can be easily modified and new menus written with no specialised programming skills. The system can be monitored from the factory by modem link.

The computer fully controls the vacuum system and allows easy writing of coating sequences using the recipe writer section of the program. These coating recipes consist of a series of coating steps, each include all coating parameters (e.g. power supply settings).

Full "Manual control possible when system in "Maintenance Mode". This allows the operator to manual control the vacuum sequencing, MFC gas selection and flow as well as set up magnetron and microwave power supplies. Manual Mode operation is fully interlocked to prevent accidental operation of valves and power supplies

## 2.1 Thickness Control

Thickness Control is achieved via Using Power time method – Deposition using the magneton power for a pre-determined time within a recipe

## 3.0 System Utility Requirements

### 3.1 Electrical

| | Range |
|---|---|
| Voltage (single phase) | 200-250 VAC |
| Current (Max) | 50 |
| Power (kW)** | 11 (220VAC) |

** Alternative voltages are available but must be confirmed at time of order*
*** Assumes 0.95 power factor correction*

### 3.2 Water

| | Unit | Range |
|---|---|---|
| Cooling Water Flow (l/min) | l/min | 10-20 |
| Inlet Temperature Non-condensing | °C | 18-25 |
| Inlet Pressure (Bar) | Bar | 2-3 |
| pH | | 7-8 |
| Conductivity (minimum Ω/cm) | | 1500 |
| Maximum Chloride Content (mg/Kg) | | 150 |
| Hardness | | <7 milli-equivalent/$dm^3$ |

**Note**
It is the end users responsible for ensuring that all service are available close to the installation point of the system. Including a water chiller.

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