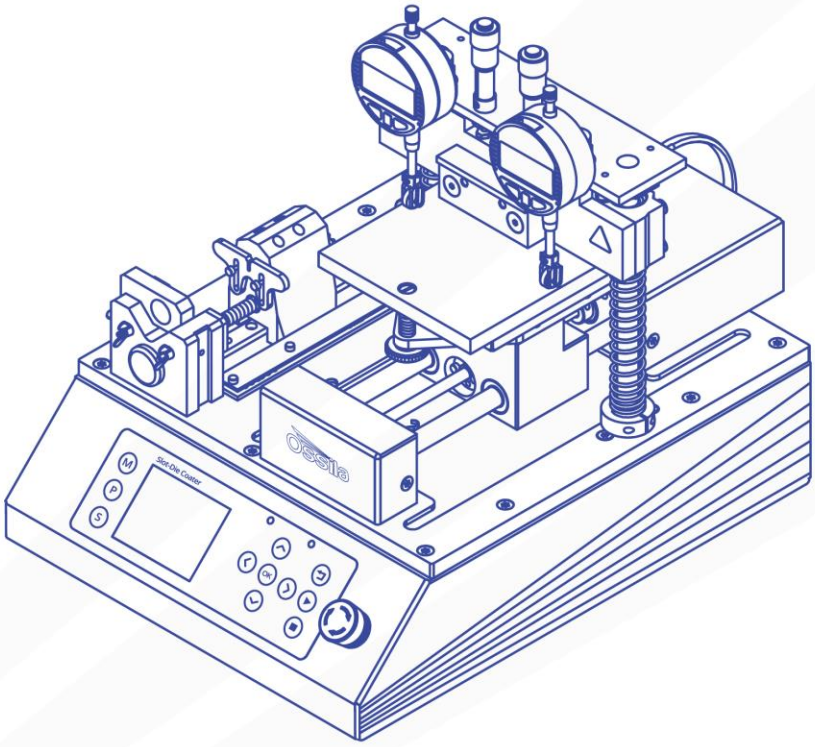
SLOT-DIE COATER
USER MANUAL

Manual Version: 1.0.K

Product code: L2005

Product Version: 1.0

Software Version: 1.0



Ossila.com

Contents

1. EU Declaration of Conformity (DoC)

We

Company Name: Ossila BV

Postal Address: Biopartner 3 building, Galileiweg 8

Postcode: 2333 BD Leiden

Country: The Netherlands

Telephone number: +31 (0)71 3322992

Email Address: info@ossila.com

declare that the DoC is issued under our sole responsibility and belongs to the following product:

Product: Slot Die Coater (**L2005A1**)

Serial number: L2005A1- xxxx

Object of declaration:

Slot Die coater (**L2005A1**)

The object of declaration described above is in conformity with the relevant Union harmonisation legislation:

Machinery Directive 2006/42/EC

EMC Directive 2014/30/EU

RoHS Directive 2011/65/EU

The following harmonised standards and technical specifications have been applied:

BS EN ISO 12100:2010 Safety of machinery-General principles for design-Risk assessment and risk reduction

Signed:

Name: Dr James Kingsley
Place: Leiden
Date: 16/11/2021

Декларация за съответствие на ЕС
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2. Overview

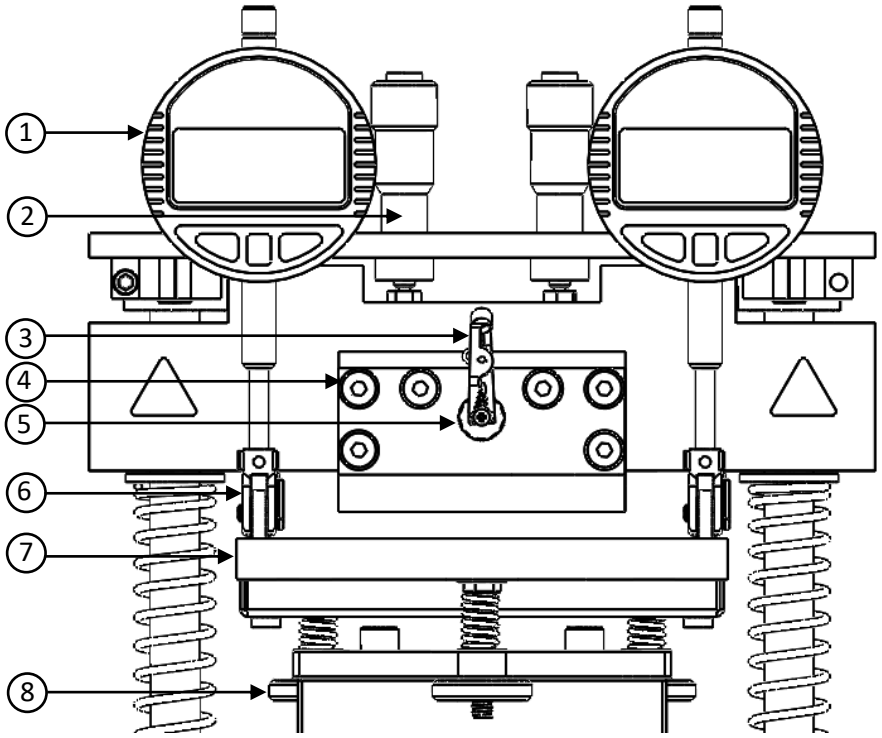
Slot-die coating is an advanced thin-film deposition technique that is compatible with large-scale manufacturing processes such as roll-to-roll and sheet-to-sheet deposition systems. The technique is part of a class of coating techniques called 'metered coating techniques', in which the thickness of the deposited layers is solely dependent upon the rate of solution flow and the speed at which the substrate moves.

Figure 2.1 An Ossila slot-die coater

This compact slot-die coating system is aimed at research and development teams who are looking to transition away from techniques that are incompatible with large-scale processing, such as spin coating. The Ossila Slot-Die Coating System has been designed for simple operation, easy maintenance, and affordability. An integrated high-precision Syringe Pump allows for accurate and reproducible flow rates, which are essential for controlling thin-film thicknesses.

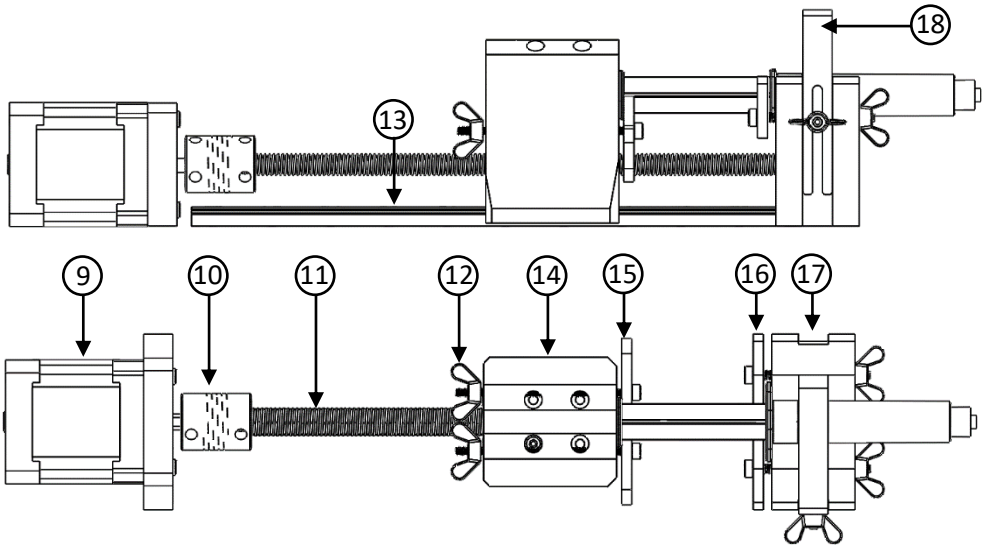
The substrate stage is levelled using a simple three-point levelling system combined with high-precision digital height gauges. Additionally, the stage incorporates a heating element allowing substrates to be heated up to 120°C.

The slot-die head is made from stainless steel, ensuring compatibility with a wide range of chemicals. The internal design of the head uses a simple 'coat hanger' manifold to distribute the solution evenly across the coating width, resulting in minimal thickness variation.



1	Digital Height Gauge	5	Luer Lock Adapter
2	Manual Micrometer	6	Gauge Roller
3	Safety Clip	7	Heated Stage
4	Slot-Die Head	8	Thumb Screw

Figure 2.2 Slot-die coater gantry schematic.



9	Motor
10	Coupling
11	Lead Screw
12	Wing Nut
13	Rail Guide

14	Plunger Pusher
15	Plunger Clip
16	Flange Clip
17	Syringe Holder
18	Barrel Clamp

Figure 2.3 Slot-die coater syringe pump schematic

3. Specifications

The Slot-Die Coater specifications are shown in **Table 3.1** and **Table 3.2**.

Slot-Die Coater	Specifications
Maximum Hotplate Temperature	120 °C
Maximum Travel Length	100 mm
Minimum Stage Speed	100 µm s^{-1}
Maximum Stage Speed	50 mm s^{-1}
Minimum Syringe Dispense Rate	0.021 µL/s for a 1mL syringe
Maximum Syringe Dispense Rate	1 mL/s software limit
Maximum Substrate Thickness	13 mm
Stage Surface Flatness	<20 µm*
Stage Surface Roughness (RMS)	3 µm*
Stage Levelness	< 50 µm*
Power Supply	Input: 90-264 VAC 50/60Hz Output: 24 VDC, 6.25 A
Dimensions (Depth x Width x Height)	360 mm x 280 mm x 190 mm
Weight	<10 kg

Table 3.1 Slot-Die Coater specifications

*Values determined at a stage temperature of 21°C.

Slot-Die Coater	Specifications
Slot-Die Head Material	Stainless Steel
Slot-Die Head Coating Width	50 mm
Slot-Die Shim Thickness	100 µm
Luer Lock Adapter	Stainless Steel M5 to Luer Lock Adapter
Tubing and Connector Material	PTFE Tubing, high density PP Luer lock connectors

Table 3.2 Slot-Die Coater head specifications

4. Warranty

The Slot-Die Coater is covered by Ossila's two-year warranty. There are no user-serviceable parts in this unit other than the fuse (which is accessible externally). Any modification or alteration may damage the equipment, cause injury, or death. It will also void your equipment's warranty. If servicing or repair is needed, please contact Ossila to organise a return. Our service department will also quote for any repairs to faults that occur outside the 2-year warranty period.

4.1 What the 2-year Ossila Warranty includes

- Free return shipping
- Repair, spare parts, and replacement (at Ossila's discretion) of defective products due to faulty materials or workmanship
- If any part is no longer available, Ossila will replace it with a functional replacement part

4.2 What the 2-year Ossila Warranty does not cover

- Normal wear and tear, including parts that might wear out over time
- Damage from external sources such as weather, electrical outages, or power surges
- Equipment that has been modified or serviced by anyone other than an Ossila engineer
- Equipment that has been subjected to chemical damage through improper use
- Equipment that has been operated outside the usage parameters stated in the User Manual associated with the equipment
- Equipment that has been used to process any type of biological materials (viruses, bacteria, bodily fluids, etc.) due to not being able to handle items contaminated with biological waste
- Equipment that has been rendered inoperable through accident, negligence, carelessness, misuse, contamination, improper maintenance, modification, or other external causes

5. Unpacking

5.1 Packing List

The items included in the Slot-Die Coating System are:

- Slot-Die Coater
- Power supply and power supply cord
- Slot-Die Coater Head and connecting screws
- (x5) 25 mm coating width 100 µm thick shims
- (x5) 50 mm coating width 100 µm thick shims
- Luer Lock to M5 thread adapter
- PTFE tubing with Luer Lock adapters
- Tube clip
- (x2) LR44 batteries
- User manual

5.2 Damage Inspection

Upon receiving the unit, examine the components for evidence of shipping damage. If damage has occurred, please contact Ossila directly for further action. The shipping comes with a shock indicator to show if the package has received an impact during transportation.

6. Safety

Warning

- **Only use the 24V power adapter and power cord supplied with the unit**
- **If using flammable or hazardous solvents, users are expected to be trained in their usage and carry out a risk assessment**
- **Keep the area around the machine clear, 1 m clearance above and 30 cm to the sides**
- **Keep clear of the machine while it is in operation**
- **If using hazardous solvents always use within a fume hood or controlled environment**
- **There are pinch points when in operation, keep hands clear of moving parts**
- **Hot plate temperatures can result in severe burns, use caution when operating at elevated temperatures. The LED will blink when the hotplate is heating up and will remain on once it has reached set temperature**
- **Do not use in an explosive atmosphere**

6.1 Use of Equipment

This Slot-Die Coater is designed to be used as instructed, which is under the following conditions:

- Indoors in a laboratory environment (pollution degree 2)
- At altitudes up to 2000 m
- At temperatures between 5 °C and 40 °C; and a maximum relative humidity of 80% at 31 °C

The Slot-Die Coater is supplied with a 24 V DC / 6.25 A power adapter with a power cord for the country of purchase. This is in accordance with European Commission regulations and British Standards. Use of any other electrical power cables, adapters, or transformers is not recommended.

6.2 Hazard Icons

The following symbols can be found at points throughout the rest of the manual. Note and read each warning before attempting any associated operations associated with it:

Symbol	Associated Hazard
	General warning or caution, explained within the accompanying text
	Electrical shock
	Pinch point, or entanglement hazard
	Hot surface

Table 6.1 Hazard warning labels used in this manual.

6.3 General Hazards

When installing or operating the Slot-Die Coater, there are several health and safety precautions that must be considered.

WARNING: Improper handling when operating or servicing this equipment can result in serious injury. Pay attention to the following hazards when operating this equipment.

Pinch point and entanglement hazards are present during operation of the syringe pump and stage. As a precaution, users should avoid handling or leaning over the equipment during operation to avoid possible crushing or entanglement of hair and/or clothing. The unit weighs approximately 10 kg. Care should be taken when handling or moving the unit

In the event of an emergency, the unit can be disabled by disconnecting the power cord from the power supply. Make sure that the power outlet for this cord is readily accessible to the operator.

Servicing should only be performed by an Ossila engineer. Any modification or alteration may damage the equipment, cause injury, or death. It will also void your equipment's warranty.

6.4 Emergency Stop

The slot-die coater is fitted with an emergency stop button that can be pressed in the event of emergencies e.g. the trapping of objects within pinch points. When pressed, the emergency stop button cuts off the power to the system and a buzzer will turn on to indicate that the button has been pressed. The emergency stop button will remain pressed until the button is rotated clockwise and released. Once released, the system can be restarted by turning the unit off and on again using the on/off switch at the back of the unit. The emergency stop button should not be used for powering down the system after use and should only be used in emergency situations.

Figure 6.1 The emergency stop button mounted to the front of the slot-die coater.

6.5 Tube Clip

A tube clip has been provided with the system. The clip chain attaches to the slot-die head using a simple washer. The clip itself can then be attached to any PTFE tubing that is connected to the system. This ensures that if the polypropylene connector becomes damaged during operation, the tubing is held in place and solution does not escape the system. The clip should be attached whenever the system is used.

Figure 6.2 The slot-die coater tube clip and chain is used to secure the tubing

6.6 Operational Safety

Any procedure involving the slot-die coater should have a suitable operating procedure, risk assessment and COSHH form(s) to ensure that the user is aware of the potential hazards inherent to the work they are undertaking. The following are safety points that should be noted by the user before any procedure is undertaken with the slot-die coater.

6.6.1 Pinch Points

Both the syringe pump and the moving stage present the risk of pinch points to the user. It is recommended that any loose articles of clothing and hair are tied back and secured before using the system. In addition, we recommend that users do not place their hands near the moving sections when programs are running or when there is manual movement of the syringe pump or the stage.

6.6.2 Hot Plate

The hot plate can be programmed to reach temperatures as high as 120°C. When the temperature is above 50°C, extreme care should be taken when placing and removing substrates. In addition, risk assessments should consider potential fire hazards that can occur when heating solvents to high temperatures. Many common solvents used within laboratories have a flash point below 120°C, leading to the risk of ignition. Adjust experimental parameters to reduce risk of solvent combustion.

6.6.3 Sources of Ignition

Solvents can often be heated beyond their flash point, where any source of ignition can ignite the solvent. To minimize this risk users should ensure that no sources of ignition are placed close to the slot-die coating system.

6.6.4 Fire Hazard

In the unlikely situation where solvents on the hotplate have ignited, the system is designed to contain any solvents either on the hotplate itself or on the baseplate below. This is to stop the spread of fire. Users are also recommended to leave at least 30 cm of space surrounding the entire system, and 1 m above the system, free from any other objects to reduce the possibility of the fire spreading.

7. Maintenance

7.1 Cleaning

Maintenance consists of periodic cleaning. The exterior of the instrument can be wiped with a clean, dry cloth to remove any oil, grease or dirt. Small amounts of solvent can be used to clean the stage and head once it has cooled to room temperature.

7.2 Repair & Service

Periodically, the rail guide and the lead screw should be lubricated with synthetic grease or oil to ensure smooth motion. Repairs or servicing not covered in this manual should not be performed. Contact Ossila if you have issues with your system.

8. Installation

The following procedure should be followed when setting up the unit for the first time.

1. Place the unit on a solid, level surface. If necessary, the feet can be rotated to adjust their height and level the unit. Ensure the area is free from vibrations, temperature extremes and highly flammable or explosive materials. Keep the area surrounding the machine clear, with approximately 1 m clearance above the machine and around 30 cm clearance on the sides.
2. Remove the cable ties that secure the gantry during shipping.
3. Before plugging in the Slot-Die Coater, ensure the power switch on the unit is switched to the ‘0’ position (off).
4. Connect the power supply connector to the Slot-Die Coater (shown in **Figure 8.1**).
5. Insert one LR44 battery into each digital height gauge by removing the cap (shown in **Figure 8.2**).
6. You may wish to turn the digital height gauges off when not in use to conserve battery life. This is done by pressing the ‘OFF/ON’ button. The digital height gauges are not powered or charged by the mains supply.

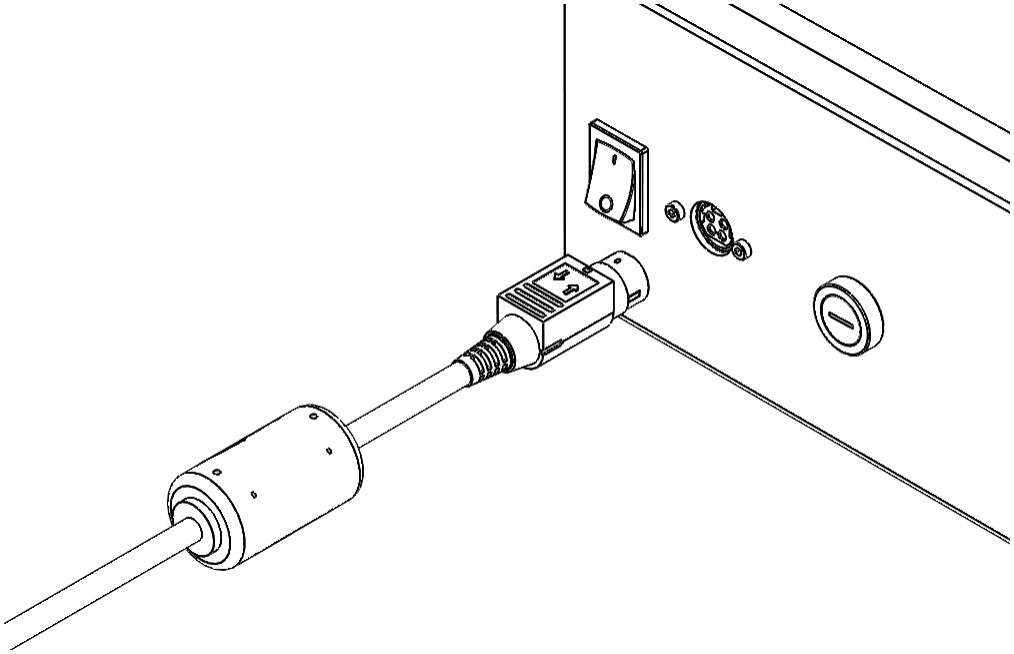


Figure 8.1. Installation of the Slot-Die Coater by plugging in the power supply cable.

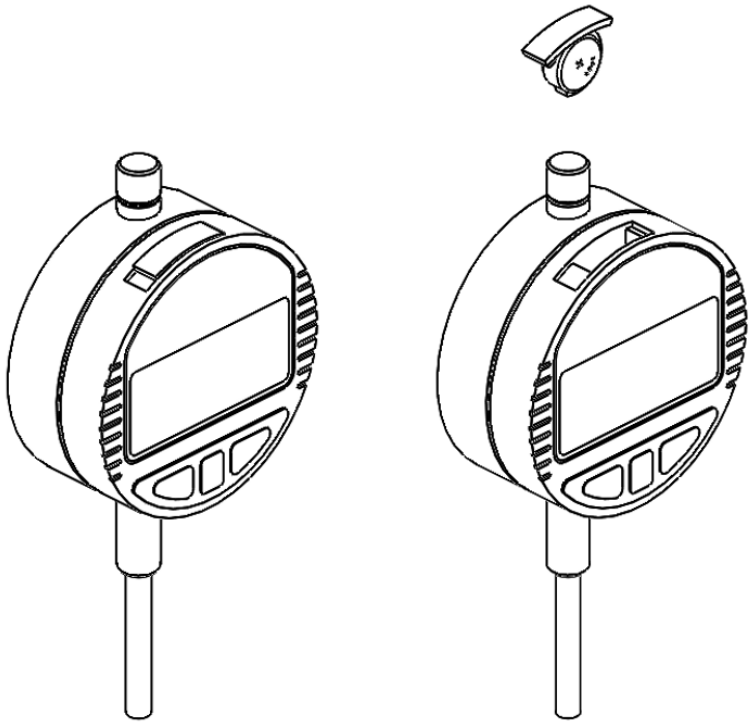


Figure 8.2. Each digital height gauge should be fitted with one LR44 battery by removing the cap.

9. Operating the Slot-Die Coater

9.1 Slot-Die Coater User Interface

The control panel of the Slot-Die Coater is shown in **Figure 9.1.** It consists of an LCD display, 11 control buttons and 2 indicators. The functions of the buttons are described in **Table 9.1**.

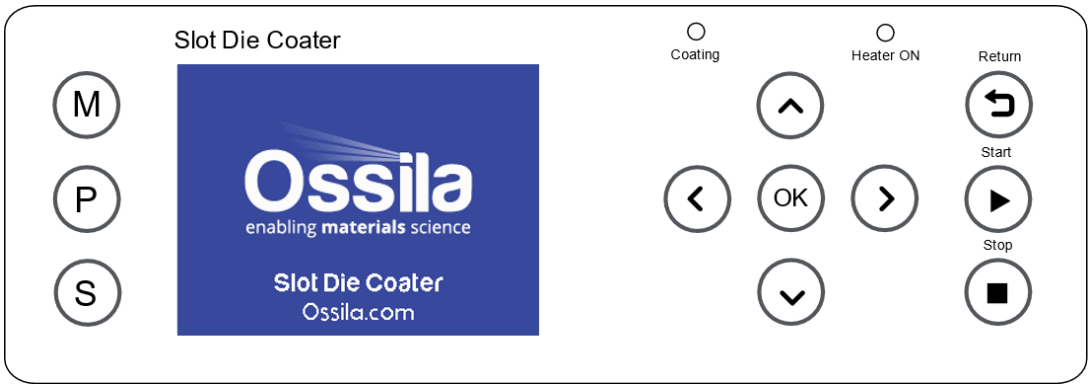


Figure 9.1 Slot-Die Coater LCD display and keypad.

Button	Name	Function
M	**Manual**	Enter **Manual Mode** where the syringe driver and the slot-die stage can be moved
P	**Program**	Enter **Program Mode** where saved programs can be selected and/or edited
S	**Settings**	Enter **Settings Mode**, where syringe properties can be defined, and hotplate temperature offsets can be added
^	**Up**	Navigating Up through menus; increasing selected values by 1; increasing unit size
v	**Down**	Navigating Down through menus; decreasing selected values by 1; decreasing unit size
>	**Right**	Navigating Right through menus, changing current program or step
<	**Left**	Navigating Left through menus, changing current program or step

OK	**OK**	Press to select, edit, or accept changes
■	**Stop**	Stop current running program
▶	**Start**	Run currently selected program
↩	**Return**	Return the stage to the home position

Table 9.1 Operational buttons and their associated functions.

9.2 Program Operation

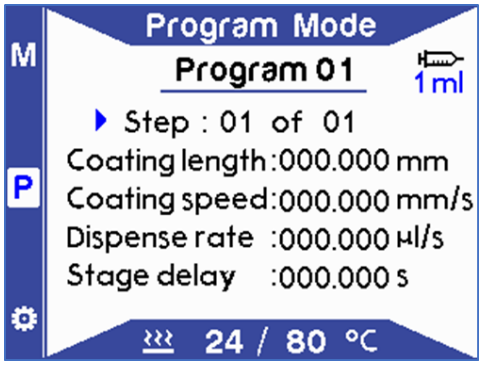
9.2.1 Turning the unit on

1. Turn the Ossila Slot-Die Coater power switch **ON** (position '1'). The bootup screen will show.

2. After the bootup, reset the stage to its 'home' position by pressing (OK). This will move the stage to the furthest back point.

3. Whilst the stage is moving to the 'home' position, the following message will be shown.

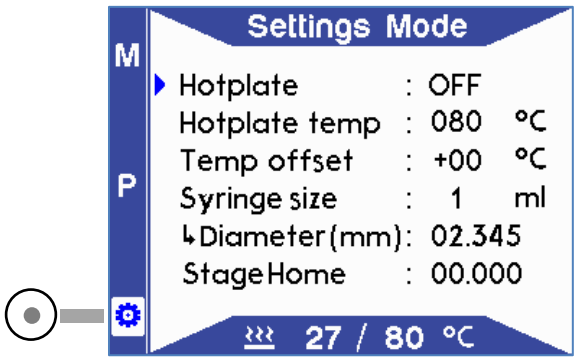
4. Once the system is at the 'home' position, the **Program Mode** page will be prompted.



9.2.2 Settings Mode

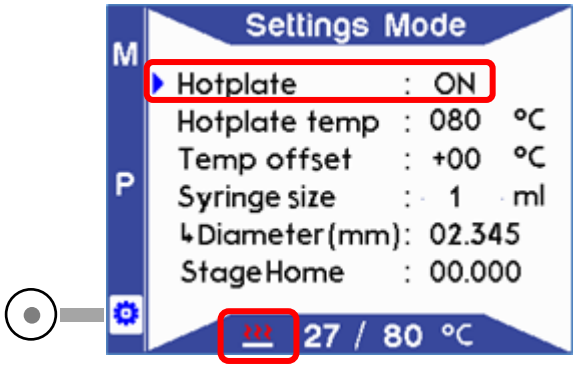
The **Settings Mode** allows the user to input parameters related to the hotplate operation, syringe properties and stage homing. Edit mode can be entered by pressing (OK) on the required line. Entering edit mode on any parameter will turn the text of the parameter red.

1. Press (S) to enter **Settings Mode**.

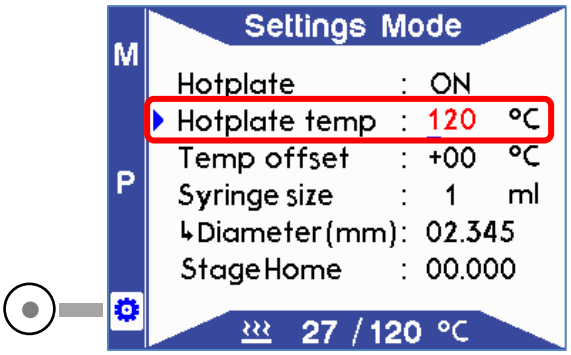


2. To switch the hotplate **ON**, navigate to the 'Hotplate' line and press (OK) to switch **ON** the hotplate. The 'Heater' LED will blink ON/OFF whilst the hotplate is heating and remain **ON** when it reaches the set temperature. You can switch **OFF** the hotplate by pressing (OK) again.

Note: The Hotplate icon on the screen will blink RED while the hotplate is switched ON.



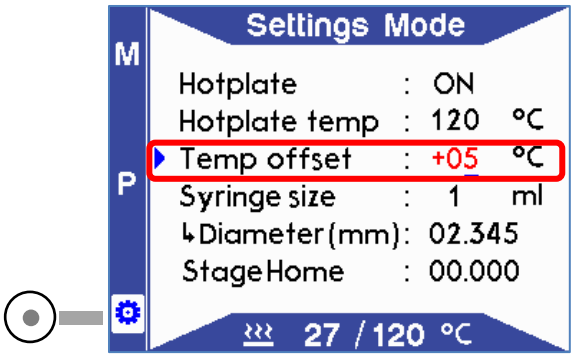
3. The hotplate temperature is set by navigating to the 'Hotplate temp' line and pressing (OK) to edit the value. To navigate between the digits, press the (<) or (>) buttons. To change the value of the selected digit, press the (^) or (v) buttons. Press (OK) again to exit the edit mode. The maximum set value allowed is **120°C**.



4. The surface temperature of the hotplate may differ slightly from the displayed reading. To set the exact temperature value on the surface, a temperature offset can be applied by navigating to the 'Temp offset' line and pressing (OK) to edit. You can set the temperature offset by **±10 °C.** To change the sign for 'Temp offset', navigate to the sign and press (^) or (v) to change it.

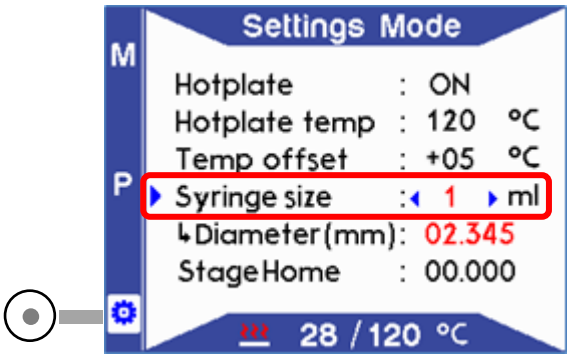
Note: An external temperature sensor is required to measure the surface temperature (not supplied).

Note: The displayed temperature has the offset applied and therefore will appear higher than the set point temperature when a positive offset is applied.



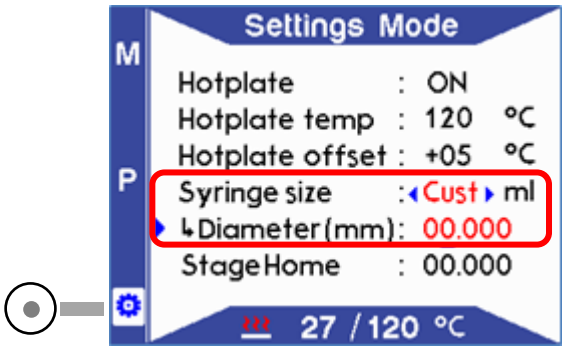
5. To change the syringe size, navigate to the 'Syringe size' line and press (OK) to enter edit mode. To change to different sizes of the syringe, press (<) or (>) to scroll between the pre-set sizes. Press (OK) again to exit the edit mode.

   *Note: The selected syringe size is displayed in the upper right corner within **Program Mode**.*



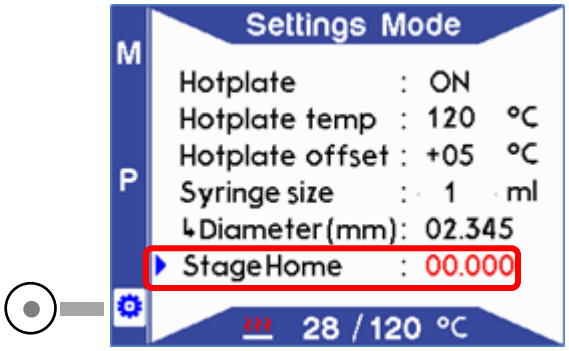
6. A custom syringe size can be entered by selecting 'Cust', which allows the syringe diameter to be manually entered.

   Note: If the diameter value is not set, a warning will appear on the screen to notify the user.



7. The stage position is tracked across the slot-die coater operation. The user allows to set new HOME position for the system during current operation. To set the new stage home position, navigate to the 'Stage Home' line and press (OK) to edit. Press (↩) to set the new Home position based on the stage's current position. Press (OK) again to exit the edit mode.

   *Note: To change the stage position manually, go to **Manual Mode**.*



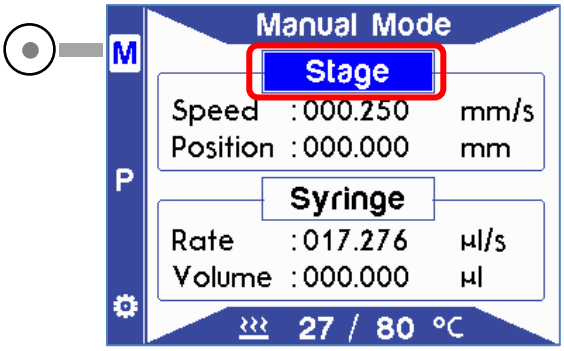
9.2.3 Manual Mode

Manual Mode allows direct control over the syringe pump and stage positions. Entering edit mode on any parameter will turn the text of the parameter red.

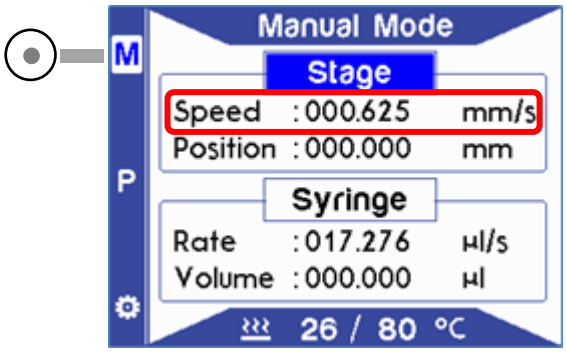
WARNING: Pinch points and entanglement

The rotation of the lead screw/coupling and the movement of the plunger pusher present entanglement and pinch hazards. Care should be taken when the system is running.

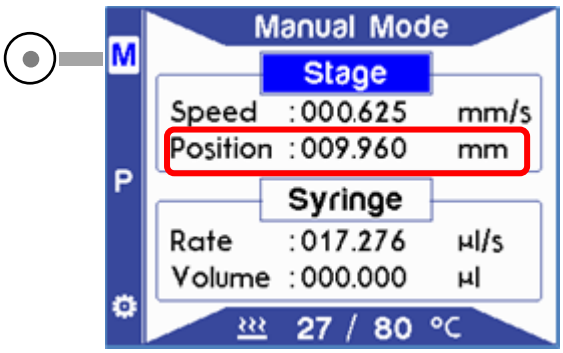
1. To enter **Manual Mode**, press (M) located at the top left-hand side of the screen. The stage is pre-selected in **Manual Mode**. Press (^) to select Stage (if not already selected).



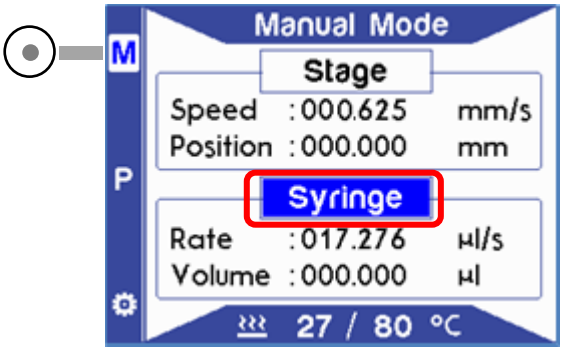
2. The stage has pre-set speed values of **0.062 mm/s, 0.250 mm/s, 0.625 mm/s and 1.250 mm/s.** To change the speed, press (OK) to choose the desired speed for **Manual Mode**.



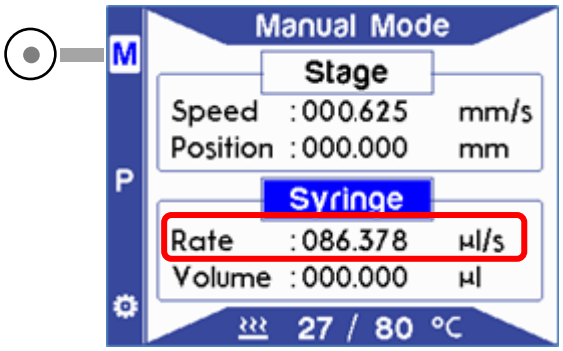
3. To move the stage position manually, press (<) or (>) while 'Stage' is highlighted. The current position display will be updated automatically.



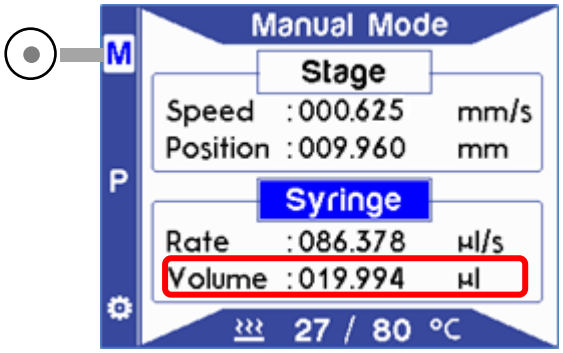
4. Press (v) to select the 'Syringe'.



5. The manual dispense rate of the syringe is calculated based on the selected syringe size in **Settings Mode**. Press (OK) to cycle through preprogramed values.



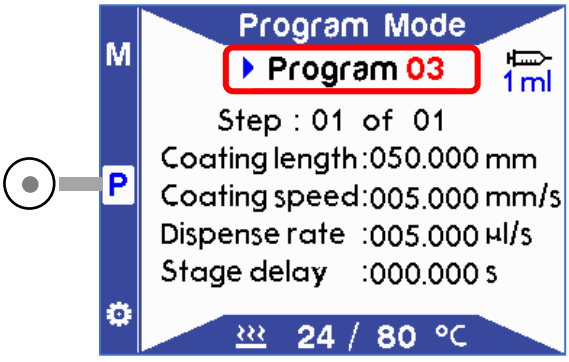
6. To dispense the solution manually, press (<) or (>) to move the syringe plunger position. The volume of solution dispensed will be automatically calculated and displayed.



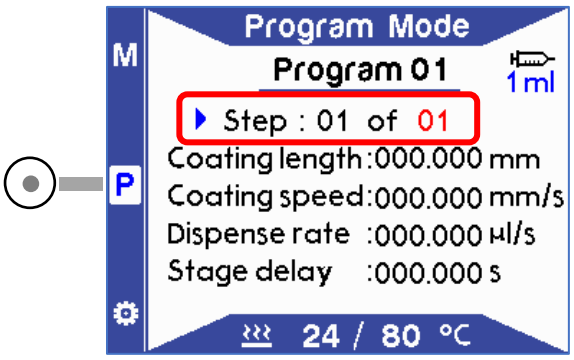
9.2.4 Program Mode

Program Mode allows the user to set up a coating process by defining several parameters. Press the (P) button to enter **Program Mode**. Entering edit mode on any parameter will turn the text of the parameter red.

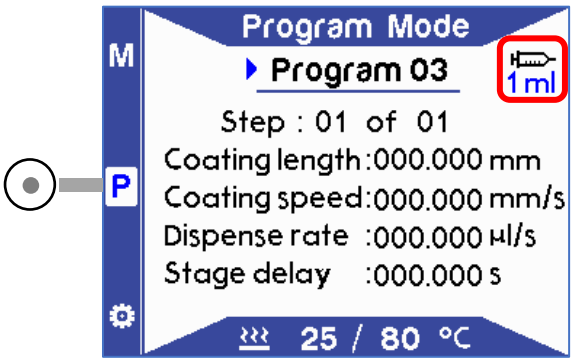
1. The unit can store up to 20 programs in memory with up to 50 steps in each. The current program can be changed by navigating to 'Program' with the (^) button. Press (OK) to enter edit mode and press (^) or (v) to change the program number. Press (OK) to exit edit mode. Program number can also be changed using (<) or (>) without entering edit mode.



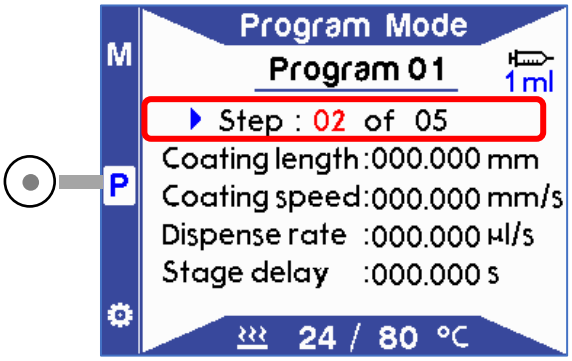
2. To change the number of steps in the program, navigate to steps line and press (OK) to edit the value. Press (^) or (v) to change the value. Press (OK) to exit edit mode.



3. The size of syringe that has been selected in the **Settings Mode** appears in the top right corner. This value can be edited from the **Settings Mode** (see **Section 9.2.2**).

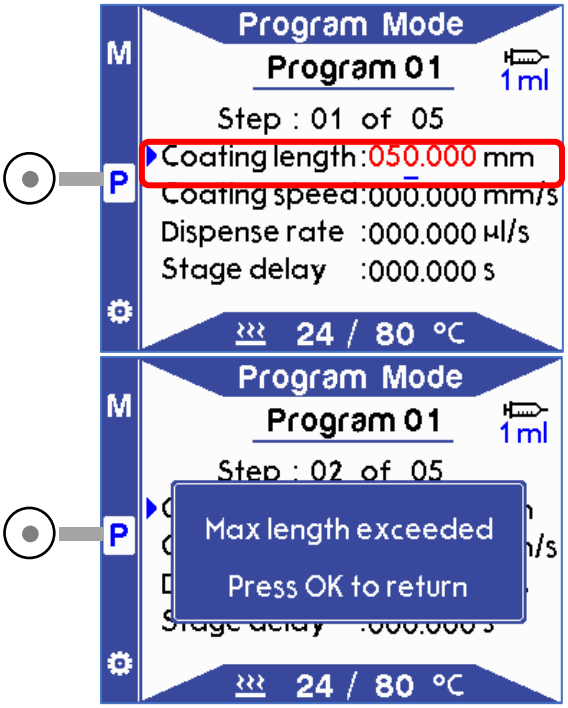


4. To change individual step parameter values, navigate to the 'Step' line. Press (OK) to enter edit mode and press (^) or (v) to change the value. Press (OK) again to exit edit mode. You can press (<) and (>) to change which step number is selected when not in edit mode.

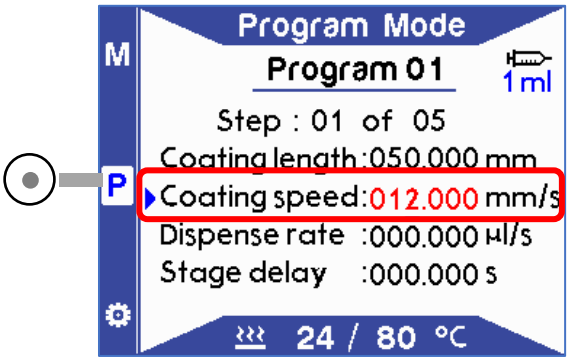


5. The coating length, coating speed and dispense rate can be set for each step. To edit the coating length, navigate to the 'Coating length' line and press (OK) to edit. The digit cursor will appear under the number.

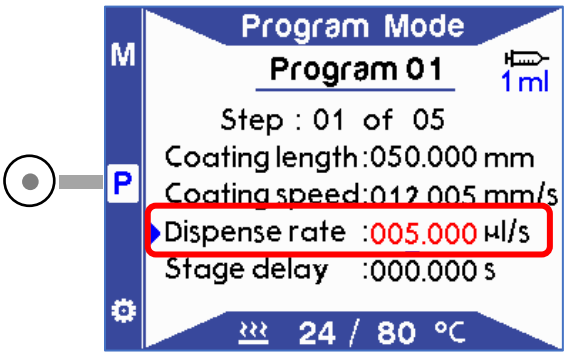
   Note: If the coating length is set above the maximum length allowed (100 mm), a warning will appear to notify the user. The system will automatically calculate the remaining allowed length and set it in the current step.



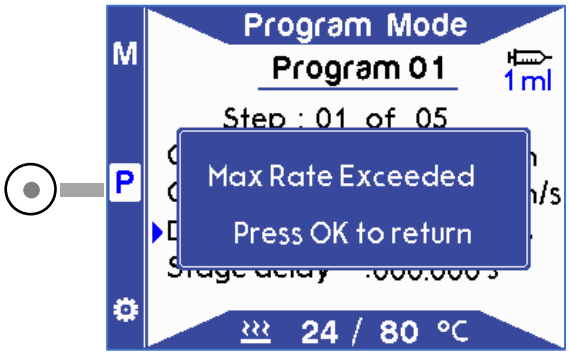
6. To change the **Coating Speed** for the current step, navigate to the 'Coating speed' line and press (OK) to edit. The maximum coating speed allow is **50 mm/s**. Coating speeds will round to the nearest value that the stepper motor can achieve.



7. To change the **Dispense Rate** for the current step, navigate to the 'Dispense rate' line and press (OK) to edit.

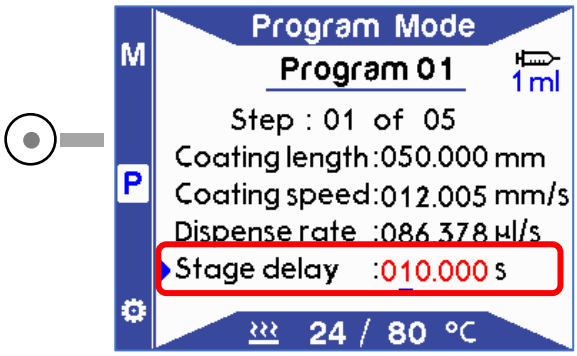


8. If the dispense rate is set above the maximum allowed rate of the syringe, a warning will appear on the screen. Press (OK) to continue, and the system will autocorrect the rate to the maximum allowed rate value for the selected syringe size. (To see the minimum and maximum rates for each syringe, refer to **Section 12.1**)



9. To include the delay in the current step, navigate to the **Stage delay** and press (OK) to enter edit mode. The digit cursor will appear under the number. Users can navigate between the digits by pressing (<) and (>) buttons. To change the value of the selected digit, press (^) and (v) buttons. Press (OK) again to exit the edit mode.

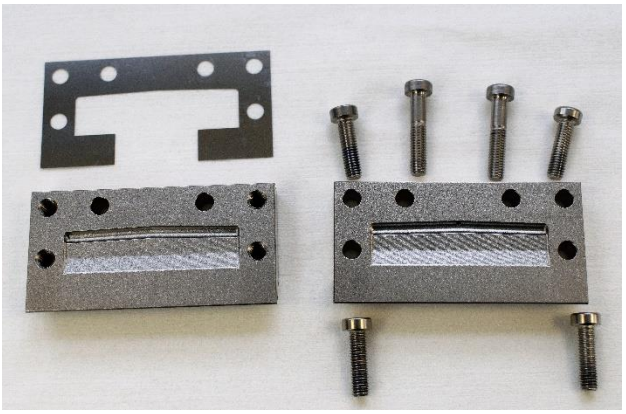
   Note: The stage delay is used to delay the coating at the beginning of the step but allow the syringe to still dispense at the set rate.



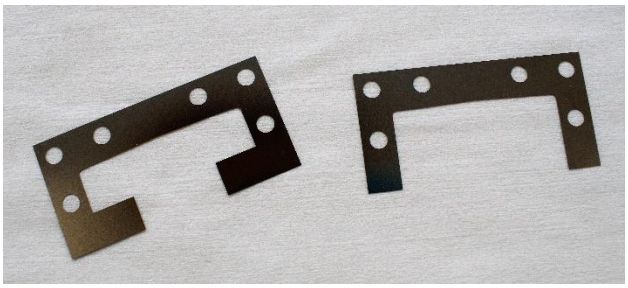
9.2.5 Assembly and installation of the Slot-Die Head

The slot-die head can be assembled and installed while the unit is powered down.

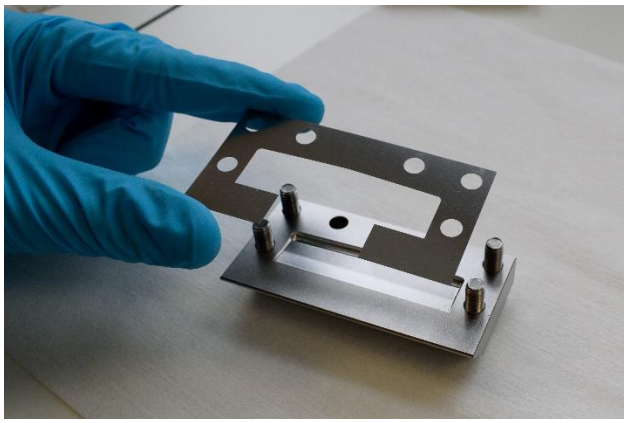
1. Make sure that the stainless-steel heads and are free of dirt or dust before assembling, or there may be defects within the coating. The head should be disassembled and cleaned after each use.



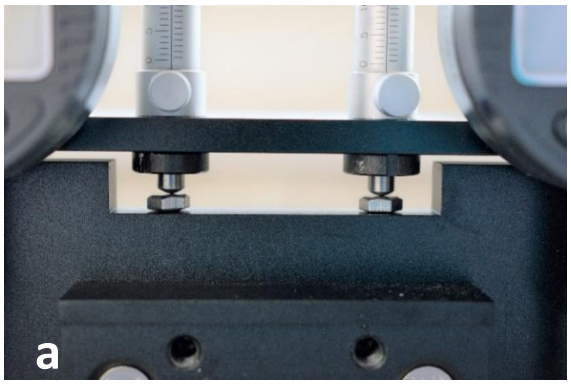
2. Select a shim with appropriate width for the substrate you wish to coat. Add the required number of shims to get the gap thickness required. Each shim is 100 µm thick.

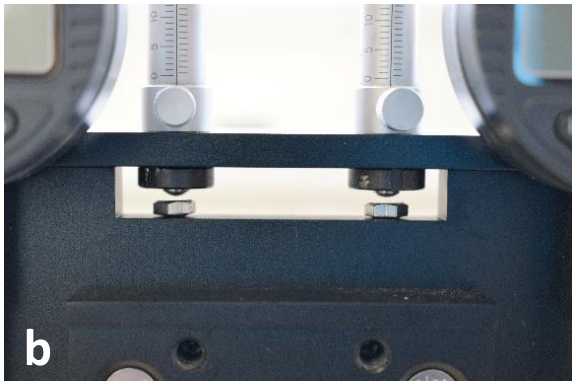


3. Clamp the shims between the two halves of the slot-die head and using the four shorter corner screws to clamp the slot-die head together. The screws should go through the half of the head with the socket for the Luer lock adapter first.



4. If the micrometers are in contact with the gantry (a), retract them by turning anti-clockwise until they are no longer in contact (b).





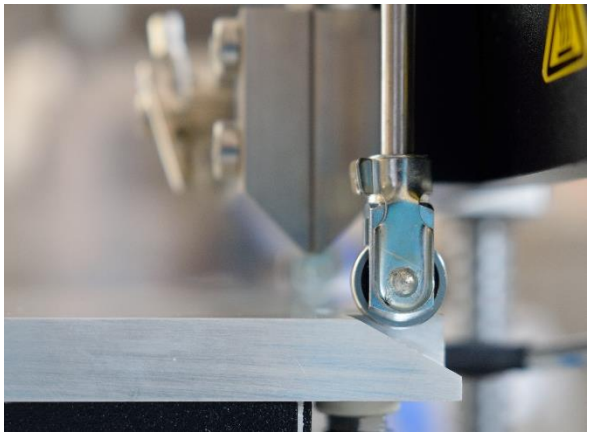
5. Place the slot-die head flush against both surfaces of the mounting bracket. Using the two longer bolt-on screws, attach the slot-die head to the slot-die system via the two gantry threaded holes. The side of the head with the socket for the Luer lock adapter should face outwards.

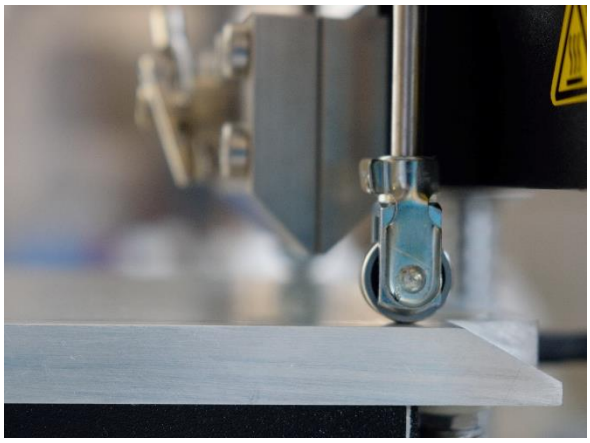
6. Place the Luer Lock adapter through the washer at the end of the safety clip. Attach the stainless-steel Luer lock adapter to the slot-die head. When not attached to the tubing, the safety clip chain should be kept off the stage to prevent it dragging during levelling.

9.2.6 Levelling the Stage

PLEASE NOTE: The digital height gauges used to level the stage have a resolution of 1 µm. It is not possible to level the stage to this accuracy. Recommended levelling parameters are given in the procedure below. If substrate heating is required, the hotplate temperature should be set, the hotplate turned on and the stage allowed to reach the set point temperature **before** levelling the stage.

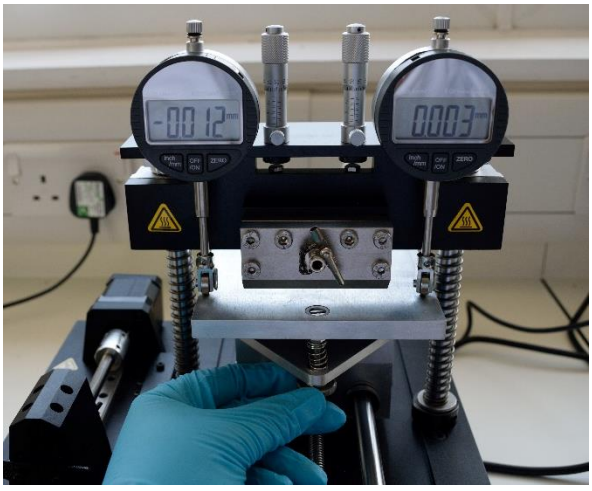
1. Zero height gauges relative to the head:
   - In **Manual Mode**, use the (>) button, move the stage so that the gauge rollers are no longer touching the top surface.
   - Turn the digital height gauges on by pressing ‘OFF/ON’ and set them to zero by pressing ‘Zero’.





2. Level the stage across the width:
   - Using the ⟨ button, move the stage so that the gauge rollers are on the top surface of the stage.

   - Using the left and right adjustment thumbscrews at the back of the stage, level the digital height gauges so that the readings on both dials are within 50 µm of each other. Press the 'Zero' button on both digital height gauges so they both read zero.

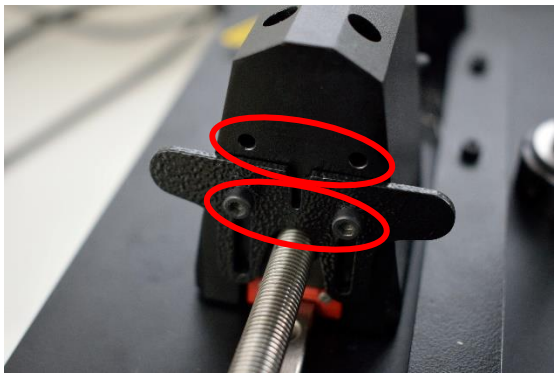


3. Level the stage across the length
   - Using the ⟨ button, move the stage so that the gauge rollers are now situated at the front end of the stage.
   - Using the front thumbscrew, adjust the height of the front end of the stage until the digital height gauges read close to zero on both sides.
   - The difference between either side should be no more than 50 µm.

4. The stage should already be at or close to the stage home position. To ensure this is the case return the stage to the stage home position by pressing the ⮌ button. To increase the accuracy of the levelling, repeat steps 2 and 3.

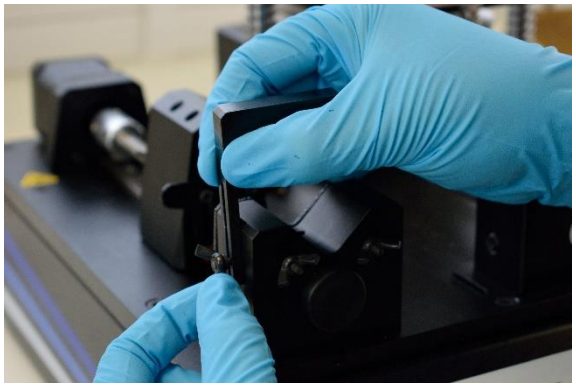
9.2.7 Installing the Syringe

1. There are two sets of holes on the plunger pusher to accommodate different sized syringes. The height of the plunger clip can be adjusted by changing which set of holes the securing screws pass through. The upper pair of holes can be used for large syringes, and the lower pair for small syringes.

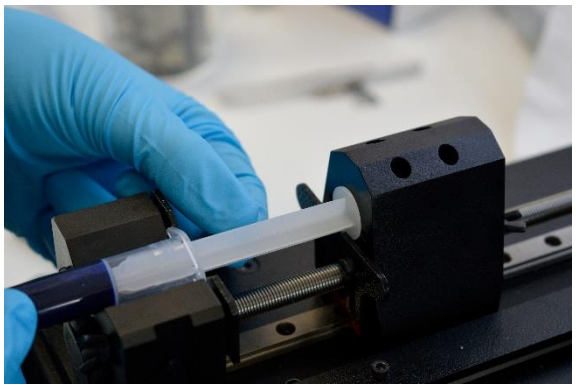


2. Fill your syringe with the desired quantity of solution. Ensure air bubbles are expelled from the syringe.

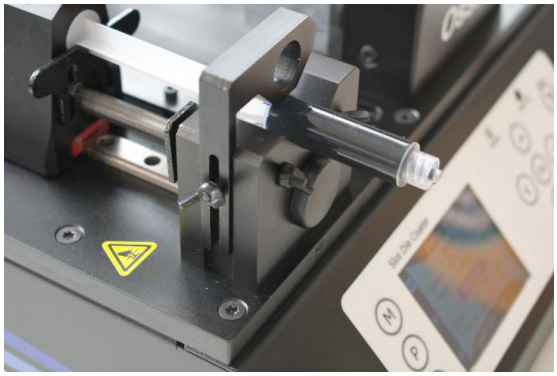
3. Remove the barrel clamp by loosening the wing nut. Place the syringe in the syringe holder



4. In **Manual Mode**, ensure 'Syringe' is highlighted and change the position of the plunger pusher by pressing ⟨ and ⟩ leaving sufficient space between the flange clip and the plunger clip to attach the syringe. Loosen the screws on the flange clip and the plunger clip as much as possible and insert syringe. The plunger clip can be moved vertically to better fit the syringe.

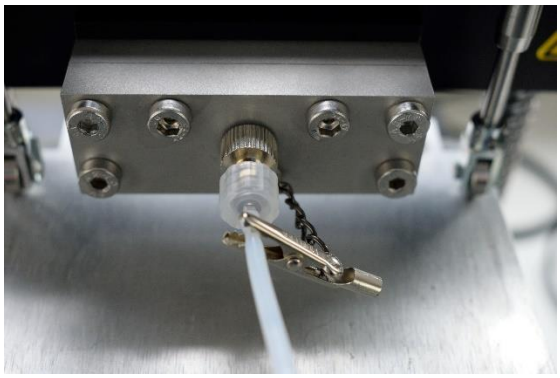


5. Replace the barrel clamp and secure with the wingnut, then tighten the wingnut screws on the flange clip and the plunger clip until the syringe is secure.

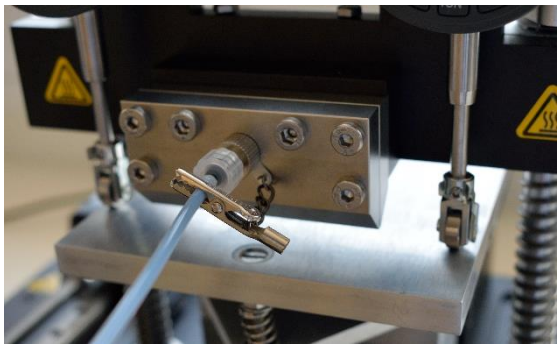


6. Connect the female end of the PTFE dispensing tube to the syringe.

7. Connect the male end of the PTFE dispensing tube to the Luer Lock on the slot-die head and connect the safety clip to the tubing.



8. Pre-load the slot-die head. Using **Manual Mode**, move the plunger to push solution through the PTFE tubing until it reaches the head.



9.2.8 Aligning the slot-die head to the substrate

If substrate heating is required, the hotplate temperature should be set, the hotplate turned on and the stage allowed to reach the set point temperature **before** aligning the substrate (see **Section 9.2.2** for hotplate operation instructions). There is a slight expansion of the stage when heated which may affect the alignment and the readings on the digital height gauges.

WARNING: Hot Surface

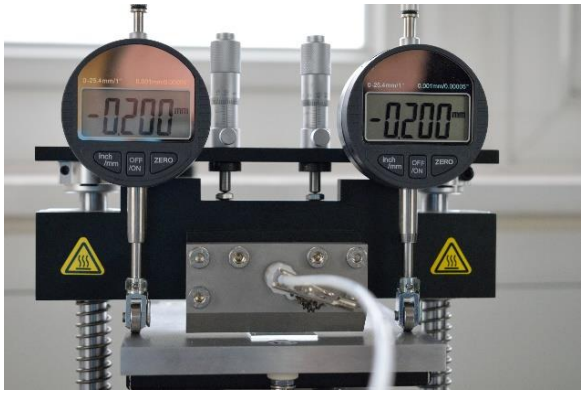
The hotplate is hot when heated and contact with skin can cause burns. Care should be taken when the system is running.

1. Zero the digital height gauges to the top of the substrate.
   - First place the substrate on the stage with the side which will be coated first closest to the front of the unit.
   - Lower the gantry with both the micrometers until there is no longer a visible gap between the head and the substrate. The head should then be slowly lowered a few microns at a time either side, whilst sliding the substrate

side to side. When the movement of the substrate becomes hindered, slowly raise the head a few microns at a time until the substrate is free to move.

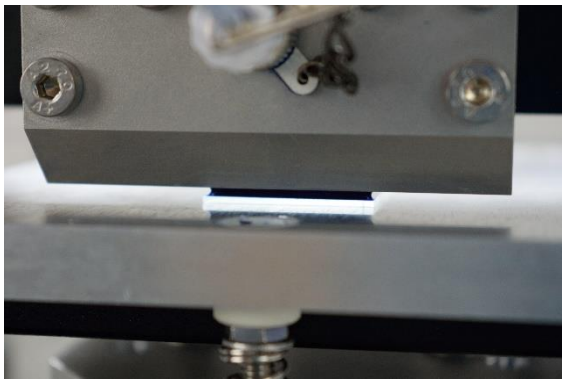
- Repeat for the back of the substrate. Return to the front of the substrate and zero the digital height gauges.

2. Set the gap height. Slowly raise the slot-die head using the micrometers, alternating between them in small steps, until the height gauges show the required gap (see **Section 10.1**).



9.2.9 Forming a meniscus

Before coating, a meniscus of solution should be formed across the width of the substrate by dispensing a small amount of solution in the **Manual Mode**. The slowest dispense rate should be used to avoid dispensing too much solution onto the substrate, which can cause defects. Solution should be pumped until a small amount comes out of the head and forms a meniscus on the substrate surface. Alternatively, a program step can be used to perform this automatically.

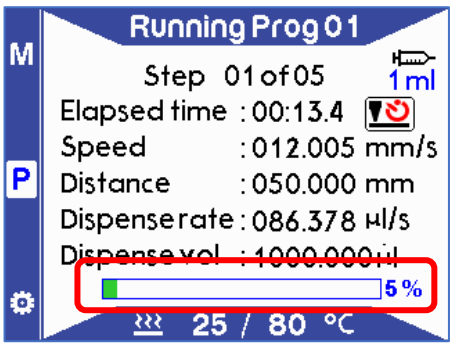


9.2.10 Running a Program

WARNING: Pinch points and entanglement

The rotation of the lead screw/coupling and the movement of the plunger pusher present entanglement and pinch hazards. Care should be taken when the system is running.

1. Once the required parameters have been set in **Program Mode**, and both the slot-die head and syringe have been installed (see **Sections 9.2.5** and **9.2.7** respectively), the program can be run by pressing the ▶ button. A green progress bar will appear showing the overall progress.



Note: If the stage delay is set in the program, the stage delay icon will appear blinking next to the elapsed time until delay time is up.

Stage Delay Icon

Note: If the coating speed has not been set for all off the program steps, a warning will appear to notify the user. Running will be aborted until the speed is set.

2. You can start coating at any stage position by positioning the stage in **Manual Mode**. However, the position is tracked so that it will not exceed the maximum travel distance of 100 mm. Where the total coating length plus the initial stage position exceeds this maximum travel distance, a warning will appear. The stage position should be put closer to the default home position (see **Section 9.2.1**), or the coating length should be reduced.

10. The Coating Process

When using volatile solvents, place the slot-die coater within a fume hood or controlled environment (e.g. a glovebox).

To use the slot-die coater, a general start-up procedure should be followed before coating should begin. There are several stages to this:

i. Installing the slot-die head (**Section 9.2.5**)
ii. Setting the hotplate temperature (**Section 9.2.2**)
iii. Levelling the stage (**Section 9.2.6**)
iv. Installing the syringe (**Section 9.2.7**)
v. Aligning the slot-die head with the substrate (**Section 9.2.8**)
vi. Forming a meniscus (**Section 9.2.9**)
vii. Setting the coating parameters & running the program (**Section 9.2.10**)

10.1 Gap Height

The gap between the slot-die head and the substrate is important to coat a defect-free film. For an in-depth explanation of this please refer to Ossila's "Slot-Die Coating: Guide to Troubleshooting Defects" (https://www.ossila.com/pages/slot-die-coating-defect-troubleshooting).

To know the minimum gap height for coating a stable film you must first know what wet film thickness you are wanting to coat. If you are working from a dry film, you must begin by calculating the percentage volume of solids in solution. This can be done if the mass of the liquid, the mass of the solid, the density of the liquid, and the density of the solid are all known.

$$\text{Volume \%}_{\text{Solids}} = \frac{\frac{\text{mass}_{\text{solid}}}{\text{density}_{\text{solid}}}}{\frac{\text{mass}_{\text{liquid}}}{\text{density}_{\text{liquid}}} + \frac{\text{mass}_{\text{solid}}}{\text{density}_{\text{solid}}}}$$

The needed wet film thickness (t_{wet}) can then be calculated from final desired dry film thickness (t_{dry}):

$$t_{wet} = \frac{t_{dry}}{\text{Volume \%}_{\text{Solids}}}$$

As an initial number to work with, the viscous model approximation can be used. For this gap height (h) should be less than double the wet film thickness:

$$h < 2(t_{wet})$$

It should be noted that the gap height above is only true for solutions with capillary numbers greater than approximately 0.1 to 0.25. For low capillary number solutions, where the viscosity or the speed

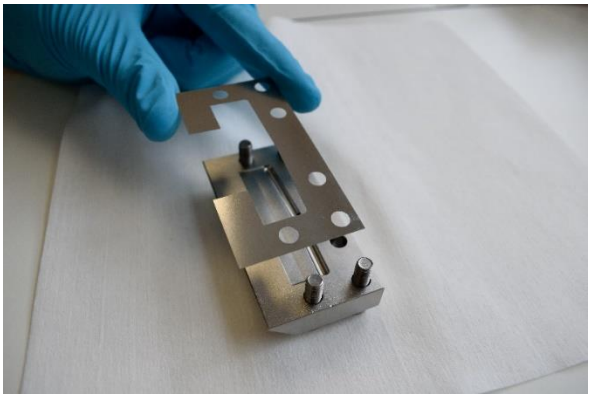
of the stage is low, the minimum gap height is controlled by the equation below, where C_a is the capillary number. This means higher gap heights can be used for low viscosity solutions.

$$\frac{\mathrm{h}}{\mathrm{t_{wet}}} = 0.67.C_a^{\frac{2}{3}}$$

10.2 Worked Example

For this example, a fluorescent dye in 1,1,2,2-Tetrachloroethane (TCE) was used, at a concentration of 20 mg/mL.

i. The slot-die head was first assembled as described in **Section 9.2.5**. A single shim with an outlet width of 2.5 cm was used.

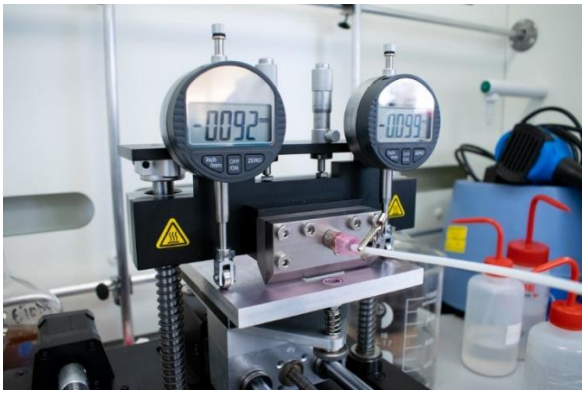


ii. The hotplate temperature was set at 80°C and the heater turned on (see **Section 9.2.2**).

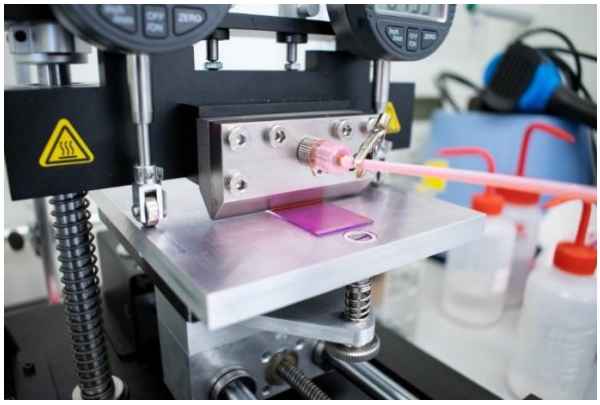
iii. Once the stage had reached its set point temperature, it was levelled following the instructions in **Section 9.2.6** to a levelness of 50 µm i.e. the maximum absolute value seen on either digital height gauge was <50 µm across the length of the stage.

iv. A solution of dye in TCE (20 mg/mL) was prepared and filtered using a 0.45 µm PVDF (hydrophobic) syringe filter to ensure that no contaminants were present that can cause defects in the final film. A 5 mL syringe was filled with the solution and installed on the slot-die coater according to **Section 9.2.7**.

v. The slot-die head was lowered onto the substrate surface and retracted to give a gap of 100 µm. **Experimentation to optimize the gap for a specific solution and substrate combination is strongly recommended.**

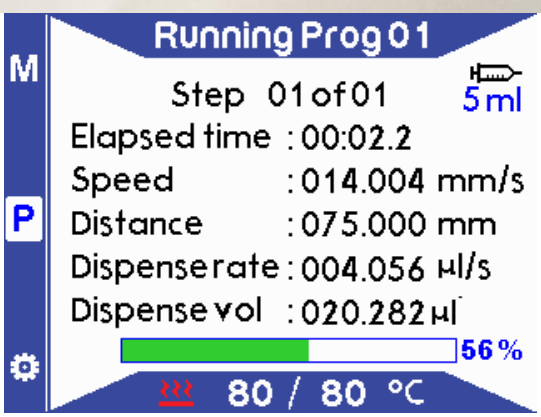


vi. The coating parameters were programmed as described in **Section 9.2.4** and the program run.

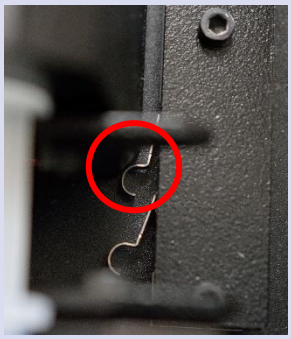


vii. The coated film is shown and achieved a film thickness of ~80 nm. Note that edge defects at the start and end of coating can be minimised by use of 'sacrificial substrates' before and after the main substrate wishing to be coated.

viii. The film shown above used a stage speed of 14 mm/s with a 4 µL/s flow rate.



11. Slot-Die Coater Troubleshooting

Problem	Possible cause	Action
No power / display	The power switch on the unit is in the OFF position	Check the connection and ensure the power is turned ON
	The power supply may not be connected properly	Ensure the unit is firmly plugged in to the power supply and the plug is firmly connected to both the adapter and the working power socket
	The fuse on the rear panel has blown	Ensure the unit is unplugged. Check the fuse on the rear panel. If it has blown, replace with a suitably rated 5A slow blow fuse
	The power supply adapter has a fault	Contact Ossila for a replacement power supply adapter
	No obvious cause	If all the above causes have been considered, there may be a fault on the control board. Please contact Ossila for information
Motor Stalled (Syringe Pump)	Syringe has hit first safety switch	There is not enough solution in the syringe and the moving part of the pump has hit the safety switch. Load more solution into the syringe so the plunger is further back and try again 
Crash Warning	The secondary safety switch has accidentally been triggered	Switch the unit off and on again
	The plunger pusher is triggering the secondary safety switch	Rotate the lead screw by hand to move the plunger pusher closer to the centre of travel
	Internal fault in the secondary safety switch	If all the above has been considered there may be a fault with the secondary safety switch; contact Ossila for more information

Links to further helpful resources for coating and troubleshooting can be found on Ossila's website, including:

- Quickstart Video guide (https://www.ossila.com/products/slot-die-coater)
- Slot-Die Coating: Theory, Design & Applications Article (https://www.ossila.com/pages/slot-die-coating-theory)
- Slot-Die Coating: Guide to Troubleshooting Defects (https://www.ossila.com/pages/slot-die-coating-defect-troubleshooting)

12. Appendix

12.1 Minimum and Maximum Flow Rates

Syringe Volume	Syringe Diameter	Minimum Flow Rate	Maximum Flow Rate
1 mL	4.69 mm	0.021 µL/s	86.4 µL/s
2 mL	9.65 mm	0.087 µL/s	365.7 µL/s
5 mL	12.45 mm	0.145 µL/s	608.7 µL/s
10 mL	15.90 mm	0.236 µL/s	1 mL/s
20 mL	20.05 mm	0.376 µL/s	1 mL/s
50 mL	29.60 mm	0.797 µL/s	1 mL/s

Table 12.1 Minimum and maximum flow rates possible with different sized syringes

13. List of Related Products

Compatible substrates

PV and OLED Scale-Up Substrates (Pixelated & Modules Variants) (S241 + S251)
A 25 X 75 mm ITO patterned glass substrate, available with either modules or pixelated design. Perfect for use in OPV and OLED research.

OFET ITO Scale-Up Substrates (S271)
A 25 X 75 mm version of our popular Interdigitated ITO Substrates for OFET and Sensing.

ITO Coated Scale-Up Substrates (S281)
A 25 X 75 mm unpatterned ITO glass substrate useful for custom patterning and other varied uses.

Quartz Coated Scale-Up Substrates (S261)
These ultra-flat glass substrates have thin (20 nm) layer of synthetic quartz on the surface and are useful for control tests, coating experiments and a variety of other uses.

Related processing equipment

UV Ozone Cleaner (L2002A1)

Ossila's UV Ozone cleaning system is capable of removing contamination on the surface of samples, providing you with ultraclean surfaces within minutes.	

Accessories

	
Slot-Die Heads (L2005A1-E1) Ossila's stainless steel slot-die heads are optimised for even distribution of solution across the head width. Using different heads for different materials can reduce the chance of cross contamination between experiments. Threaded screw to male Luer lock adapter provided.	**Shims (L2005A1-E2)** Ossila's stainless steel slot-die shims can be used to define a wide range of coating widths, altering internal pressure and allowing customisation for different solution viscosities. Available with widths of 25 mm or 50 mm.
	
PTFE Tubing (L2005A1-E3) Ossila's PTFE tubing is pre-assembled with the necessary Luer lock connections for easy use with the slot-die coater. Having separate tubing for each different material reduces the chance of cross contamination and improves the reproducibility of experiments. Available in sets of 5.	**Disposable Syringes (Luer Lock) (C110 – C116)** Ossila's disposable polypropylene Luer lock syringes can be used with the PTFE tubing to connect to the slot-die head. Compatible with a wide range of materials and solvents.

14. Revision History

Rev	Date	Description
1.0.C	06/07/2018	Updated the levelling guide (Section 8.3.1) so that the UP / DOWN arrows are now LEFT / RIGHT arrows
1.0.D	09/08/2018	Updated specification, maximum head to substrate distance changed to 13mm
1.0.E	21/08/2018	Removed Warranty Information
1.0 F	18/08/2018	Edited formatting
1.0 G	22/10/2018	Thorough copyedit for SPG and formatting
1.0 G	24/10/2018	Updated/corrected DoC and altered servicing section (3.6 and 3.8)
1.0 I	10/05/2019	Reformatted instructions for clarity
1.0 J	22/05/2019	Changes to the diagrams to reflect the latest builds and software, and further changes to the instructions for clarity. Re-added warranty information
1.0 K	16/02/2022	Updated DoC