FOM
TECHNOLOGIES

FOM nanoRC

OPERATION & MAINTENANCE MANUAL

Rev. 1.0 - June 2023

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1. Introduction

This document serves as the operation and maintenance manual for the FOM Technologies Nano Roll Coater, abbreviated as FOM nanoRC. The FOM nanoRC is a benchtop slot-die coating machine specifically designed for use with flexible substrates. With its ability to deposit thin films composed of a wide variety of solution-processed precursor materials onto various flexible substrates, the FOM nanoRC offers a miniaturized demonstration of industrial-scale roll-to-roll manufacturing technologies. Equipped with user-friendly features such as easy control over coating speed and substrate heating, this machine is perfectly suited for lab-scale materials research environments.

1.1. Revision history

Table 1: Revision history

Rev.	Date	Change	Valid for (serial number)
1.00	27.06.2023	Creation	FOM20-1S and successive

This version of the manual only applies to the latest version of the machine (see the last line of Table 1), Should you require a manual for a previous version of the machine, please, do not hesitate to contact us.

1.2. Equipment specifications

Table 2: Equipment specification

Parameter	Value
Dimensions: (WxHxL)	530 x 350 x 230 [mm]
Mass	19 [kg]
Supply voltage	110-220 [V] AC / 50-60 [Hz]
Power rating	2500 [W]
Drum temperature rating	RT - 160 [°C]
Coating speed	0.1-2 [m/min]
Coating width	≤ 100 [mm]
Coating length	≤ 500 [mm]
Slot-die head compatibility	FOM SD 25 to FOM SD 100
Integrated syringe pump	No

The compact size and weight of the Nano Roll Coater make it easy to place, maneuver and store, while its standard power requirements allow for easy plug-and-play setup. The stated temperature rating and coating speed are ideally suited to achieve stable coating of a wide range of materials with thicknesses on the order of 1 micron to several tens of microns.

1.3. Dimensional drawings

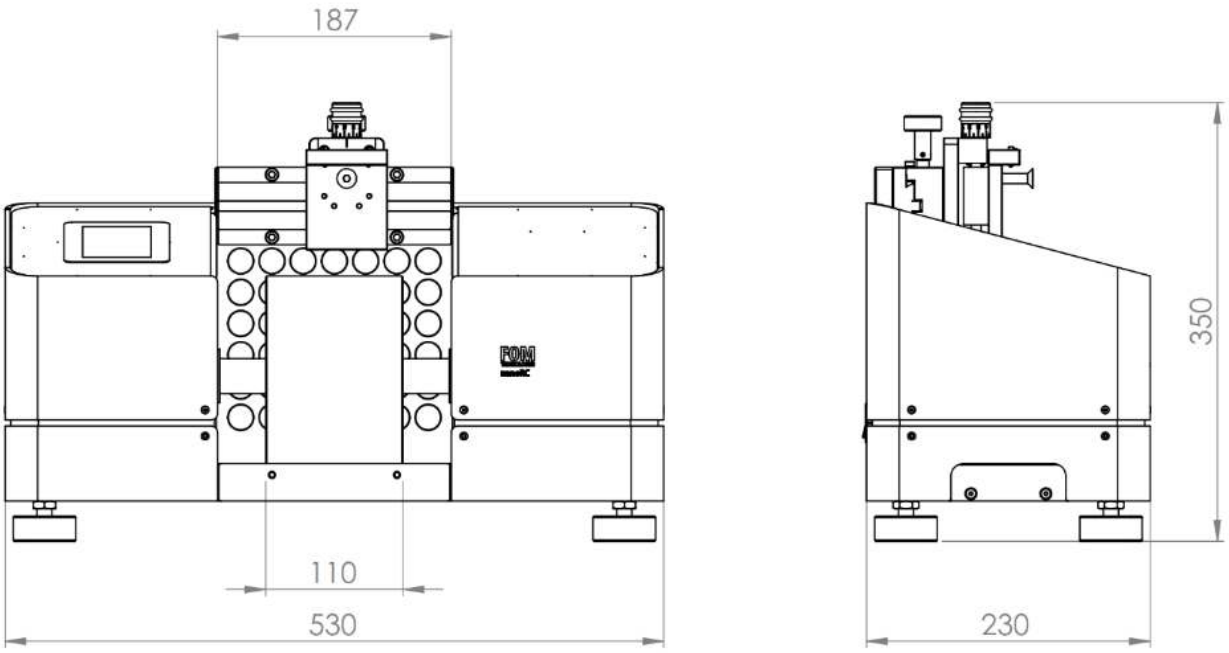

Figure 1-1: Dimensional drawings of the nano RC. Front view (left) and side view (right).

1.4. Standards and normative

CE

FOM Technologies declares that the product is manufactured in compliance with EN 60204-1 and ISO 13849-1 standards, meeting the health and safety requirements necessary for the CE marking. This certification aligns with the "Certificate of Quality Directive 2006/42/EC Annex II B, Declaration of conformity of machinery".

1.5. Disclaimers & equipment hazards

To ensure the successful operation of the FOM nanoRC and prioritize the safety of all lab users, operators, trainees, and maintenance personnel should read and thoroughly understand this manual before initiating any coating experiments or tool maintenance. It

is imperative that operators are in a state of sound mind and body when operating this equipment. The usage of this equipment should be restricted to authorized personnel and not extended to the general public.

It is recommended that new users receive proper training in the use of this equipment from experienced operators. Any deviation from the instructions provided in this manual may lead to personal and material damage, for which FOM Technologies A/S cannot be held responsible.

Before operating the device, the user must endure the functional safety and the proper conditions of the machine and accessories. The device must not be operated if there is any visible damage.

1.5.1. Risks and hazards

<u>IMPORTANT:</u> The FOM nanoRC machine can be switched off at any time in an emergency using the main power switch on the rear of the machine; this will NOT cause any damage to the machine.

The following table provides an overview of the risks and hazards associated with the operation of the FOM nanoRC machine.

Table 3: Risks and hazards associated with the use of the FOM Nano Roll Coater

Hazard	Preventive measures or action plan
Burn	Operators should exercise caution and refrain from touching the heating parts when they are hot, as the temperature can reach up to 160 °C. It is important to note that even after the equipment has been shut down, the heated parts will remain hot for some time, posing a burn risk to operators even when power is not supplied to the tool. A warning symbol and text will show up on the LCD display if the drum temperature is higher than 50 °C.

Crushing/pinching	Machinery in motion poses a risk of injury as it can strike and harm individuals. To ensure safety, operators must avoid placing their fingers, any other body parts, or loose clothing in the path of moving mechanisms. Potential damage to both objects and individuals may occur if caught in the motion paths of the drum or shafts. The FOM nanoRC Machine can be switched off at any time in an emergency using the main power switch on the rear of the machine; this will NOT cause any damage to the machine.
Electric shock	While the main power is being supplied, operators should refrain from touching the cables and plugs located at the rear of the machine. It is important to connect the power cable to the machine and the main AC supply only when the main switch is in the 'OFF' position.
Chemical exposure	The coating processes involving certain inks and solvent evaporation have the potential to expose operators to hazardous chemical substances. Operators should be fully aware that they bear sole responsibility for understanding the risks associated with the use of these chemicals. It is strongly advised that operators consult the safety data sheet for each chemical substance and conduct a comprehensive chemical risk assessment.

1.5.2. Intended use

The equipment should be exclusively used for slot-die coating experiments in accordance with the instructions provided in this user manual. Engaging in unintended applications or making aftermarket modifications to the equipment not only carries the risk of equipment damage but also poses a threat to operator safety. It is important to note that such actions will void the warranty provided for the equipment.

2. Description of equipment

The FOM Nano Roll Coater is a compact slot-die coating machine with a simple, user-friendly design.

The exterior of the machine consists of the following parts (see Figure 2-1 and Figure 2-2):

1. **Touch display:** The touch display serves as the control panel for the machine, enabling operators to adjust drum speed, temperature, and rotation direction.
2. **Slot-die mounting gantry:** This part securely holds the slot-die head in place and allows for precise control of its position over the substrate. Detailed schematics of the gantry and its functioning will be provided in subsequent sections of the manual (see Figure 3-2).
3. **Adjustable feet:** The machine is equipped with adjustable feet, enabling easy leveling by adjusting the height of each foot individually. This feature ensures stability and proper alignment of the machine.
4. **Removable drip tray:** Positioned beneath the coating area, the removable drip tray collects any excess ink that may drip down during the coating process. It can be easily removed for convenient cleaning and maintenance.
5. **Substrate support drum:** The substrate support drum is responsible for holding, moving, and heating the substrate during the coating process. Its design ensures optimal coating performance and uniformity.
6. **Ventilation ducts:** The machine incorporates ventilation ducts to ensure efficient cooling of internal components. It is essential to position the machine in a manner that allows unobstructed airflow through these ducts for optimal performance and longevity.
7. **Power socket and switch:** The power socket and switch provide the means to connect the machine to the mains power supply and control its operation. The

physical power switch, located on the machine itself, is the designated method for turning the machine on and off, as there is no software-based switch.

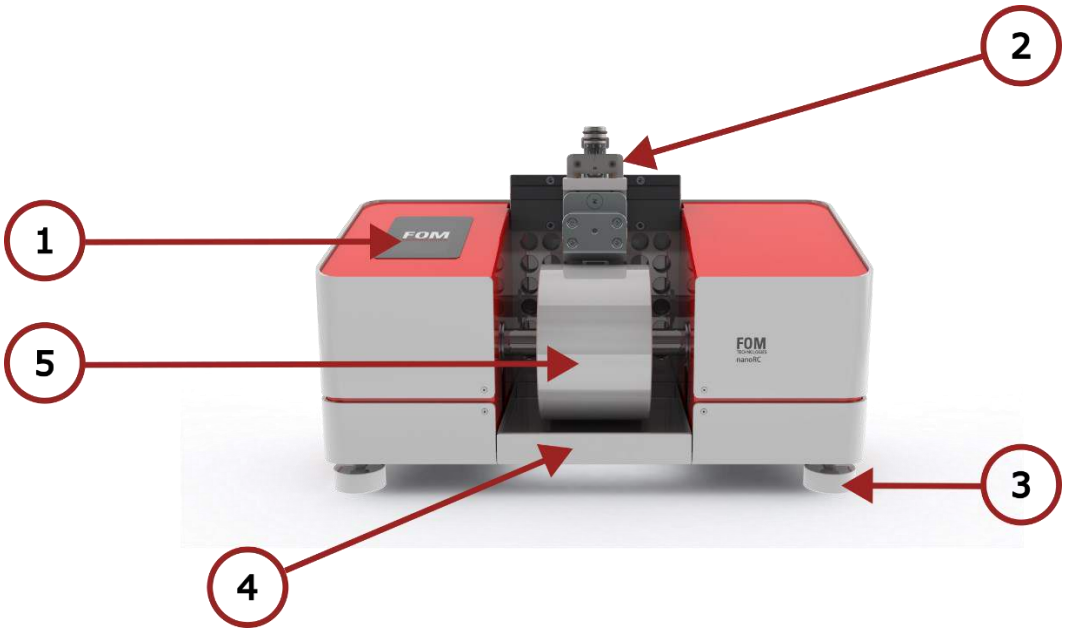

Figure 2-1: Labeled render of the Nano Roll Coater and its respective components (front). (1) Touch display, (2) Slot-die mounting gantry, (3) Adjustable feet, (4) Removable drip tray, (5) Substrate support drum.

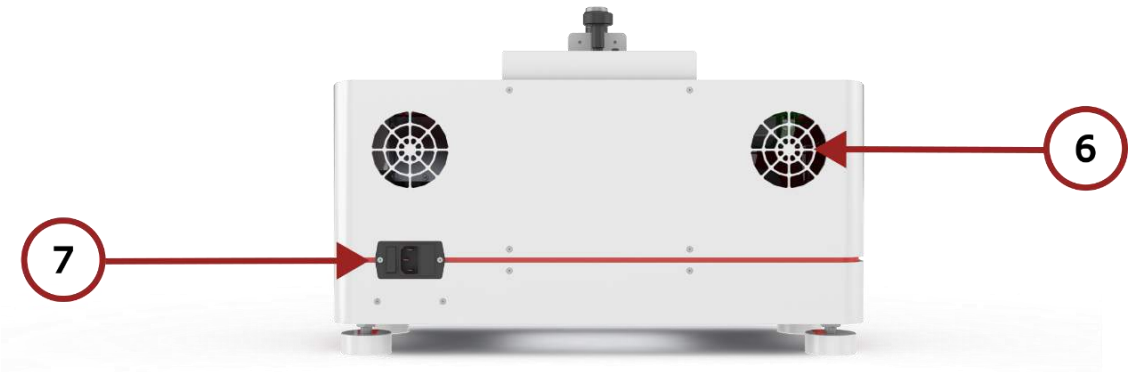

Figure 2-2: Labeled render of the Nano Roll Coater and its respective components (back). (6) Ventilation ducts, (7) Power plug and switch.

2.1. Syringe pump

The FOM nanoRC does not come equipped with an integrated syringe pump. However, FOM Technologies provides the option to combine the Nano Roll Coater with a standalone and programmable syringe pump, available in two versions: standard pressure and high pressure. For more details and inquiries, please reach out to FOM Technologies A/S.

2.2. Touch display interface

The FOM Nano Roll Coater has a simple, user-friendly interface that allows for easy control over all the machine core functions. The interface consists solely of two parameter input screens for quick control over the temperature set point, drum speed set point, direction of rotation, and start/stop functionality. It should be noted that the touch display interface does not allow for control of the syringe pump, which must be separately controlled through its own interface. Users should refer to the dedicated syringe pump manual for detailed instructions on its operation.

The functions of the touch display interface are outlined below (see Figure 2-3):

1. **Start/stop buttons:** Initiates or halts the rotation and heating of the substrate support drum at the displayed setpoints.
2. **Drum direction toggle:** Controls rotation direction of the substrate support drum. Pressing this button will toggle the direction of rotation towards or away from the operator. Please note that heating is only activated when the drum rotates towards the operator.
3. **Drum speed up/down:** Allows dynamic adjustment of the drum rotation speed setpoint.
4. **Drum temperature up/down:** Enables dynamic adjustment of the drum temperature setpoint. It's important to remember that the drum can only heat and does not have active cooling capabilities.

5. **Drum speed and temperature setpoints:** Displays the current temperature setpoint and speed. Pressing the temperature field takes the user to the Temperature Input Screen or Speed Input Screen.
6. **Temperature input screen and keypad:** Allows the user to input a desired temperature setpoint (Room Temperature - 160 °C).
7. **Accept temperature input:** Applies the new desired temperature setpoint and then returns the user to the Home Screen.
8. **Cancel temperature input:** Discards the new desired temperature setpoint and then returns the user to the Home Screen.

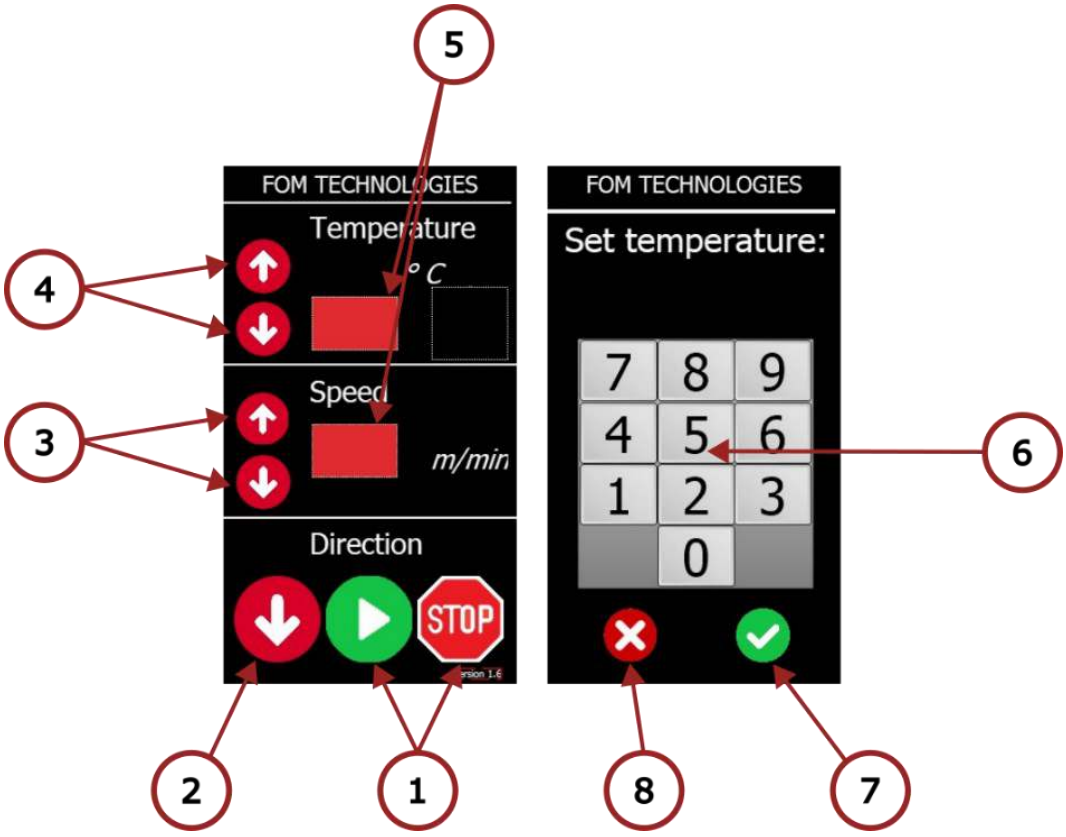

Figure 2-3: Touch display interface of the Nano Roll Coater, featuring the Home Screen (left) and Temperature Input Screen (right). Key components: (1) Start/stop buttons, (2) Drum direction toggle, (3) Drum speed up/down, (4) Drum temperature up/down, (5) Drum speed and temperature setpoints, (6) Temperature Input Screen and keypad, (7) Accept temperature input, (8) Cancel temperature input.

3. Operating instructions

The following sections describe the recommended procedure for safe installation and operation of the FOM Nano Roll Coater.

3.1. Safety precautions

Before beginning any work with the FOM nanoRC, operators should ensure that they have taken the following safety precautions:

- Familiarize yourself with the contents of this user manual and ensure a comprehensive understanding of its instructions.
- The equipment should be exclusively used for slot-die coating experiments in accordance with the instructions provided in this user manual. Engaging in unintended applications or making aftermarket modifications to the equipment not only carries the risk of equipment damage but also poses a threat to operator safety. It is important to note that such actions will void the warranty provided for the equipment.
- Operators must wear appropriate personal protective equipment (PPE) when operating the tool, including safety glasses, a lab coat, safety gloves (such as nitrile gloves), a laboratory cap, and any additional PPE as dictated by the materials and applications used (e.g., anti-static coat for hazardous nanomaterials or clean room work).
- Refrain from operating the machine while wearing loose clothing, wristbands, or having long, unrestrained hair, as they may become entangled in the moving parts of the tool.
- Position the machine in a well-ventilated area to prevent operator exposure to volatile solvents and aerosolized materials. Suitable options include a fume hood, laminar flow housing, or glove box, depending on the specific requirements.
- Ensure that no objects obstruct the path of any moving components at any time, as this could compromise both the machine's functionality and operator safety.

3.2. Installation

The FOM Technologies Nano Roll Coater has been designed to allow for a quick, simple plug-and-play installation process. The following steps will ensure a simple, successful installation.

1. **Position the machine:** Position the machine in a well-ventilated area, such as a fume hood or glove box, to prevent operator exposure to volatile solvents and aerosolized materials. Ensure there is enough space to accommodate an external syringe pump (or other ink delivery equipment) near the nanoRC.
2. **Connect the machine to the AC power supply:** Ensure that the power switch is set to “off” Insert the provided power cable into the power socket on the back of the machine. Plug the opposite end of the power cable into a standard wall socket.
3. **Adjust height and level of the machine:** Before proceeding with any coating trials, ensure the nanoRC is reasonably level. Use a precision spirit level measurement tool across the slot-die mounting gantry and level the machine until reaching a tolerance of ±0.05 mm/m. To adjust the height of a foot, gently loosen the nut and twist the foot clockwise or counterclockwise to raise or lower it, respectively.
4. **Remove the protective packaging:** Remove any protective foil or foam present around the substrate support drum before starting any work with the nanoRC.
5. **Power on the machine:** Flip the power switch at the back of the machine to the “ON” position. The FOM Technologies Nano Roll Coater will power on, and you will see the control interface appear on the touch display.

The FOM Technologies Nano Roll Coater has been successfully installed and is now ready to be mounted with a slot-die head and connected to a pump to begin coating. These processes will be described in the following sections of this manual.

3.3. Slot-die head installation

The following sections describe the steps for assembling and mounting the slot-die head, connecting the pump, and mounting the substrate onto the support drum to prepare for coating.

3.3.1. Assembling the slot-die head

Before mounting the slot-die head onto the coater, it is necessary to assemble its components. This section provides instructions related to the FOM Technology Slot-Die 25 – Steel Series for reference. Careful attention should be given to aligning the components accurately and securely fastening them together with the recommended torque. For detailed instructions on specific slot-die heads and tubing/syringe connections, please consult the dedicated FOM Operation & Maintenance Manual.

The slot-die consists of the following components (see Fig. 3.1):

1. **Front plate:** This part includes the ink inlet port and the ink reservoir.
2. **Shim:** This metal sheet has a cut-out channel that allows to internally guide the ink to the slot-die lip.
3. **Meniscus guide:** A metal sheet with a protruding edge that optimized the rheology of the ink.
4. **Back plate:** The back plate includes the mounting hole which allows the slot-die head to be mounted onto the gantry.
5. **Mounting bolt:** This bolt holds the slot-die head in place when mounted onto the slot-die mounting gantry.
6. **Securing bolts:** These bolts are used to secure the front plate, shim, and meniscus guide to the back plate.
7. **Alignment pins:** These precision pins ensure the exact alignment of the shim, meniscus guide, front plate, and back plate.
8. **Pin extractors**: These tools help for the removal of the alignment pins,

Before using the slot-die head, it is suggested to clean its components using a cotton cloth or soft paper tissue and isopropyl alcohol (2-propanol). Additionally, the user may choose to clean all the slot-die head parts using the same solvent used in the ink or slurry employed in the coating process. It is advisable to use gloves for the cleaning and assembling procedures.

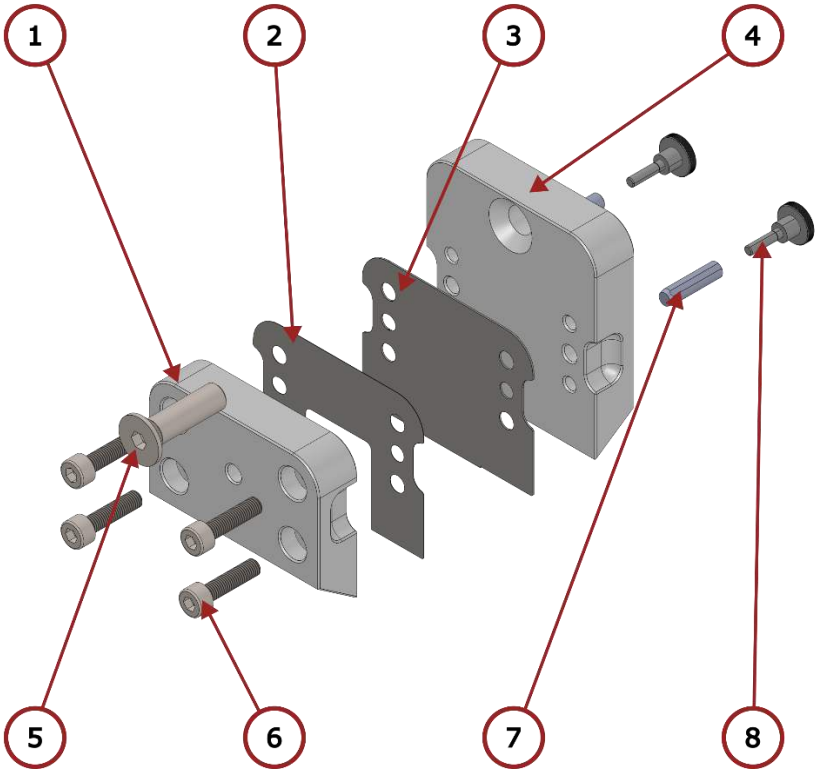

Figure 3-1: Components of a standard FOM Technologies slot-die head. (1) Front plate, (2) Shim, (3) Meniscus guide, (4) Back plate, (5) Mounting bolt, (6) Securing bolts, (7) Alignment pins, (8) Pin extractors.

To assemble the slot-die head, place the back plate, face-up, on a flat and stable surface. Gently insert the two alignment pins into the dowel-holes of the back plate, ensuring they go in halfway. Avoid applying excessive force. Use the alignment pins as guides to stack the meniscus guide on top of the back plate, followed by the shim(s). Press down gently on the meniscus guide and shim(s) until they are in perfect contact with the upper face of the back plate.

Next, with the front plate face-down, carefully align its dowel-holes with the alignment pins. Slide the front plate into place with minimal pressure. Ensure there are no gaps between the various layers. Finally, secure all the components using the securing bolts. It is important to tighten the bolts in the designated order and torque, refer to the specific slot-die head manual for precise instructions.

Important: If excessive force is required, verify the alignment, and clean the slot-die head to remove any possible residues of coating ink. Exercise caution to avoid scratching the inner surfaces of the slot-die head during assembly and cleaning.

To disassemble the slot-die head follow these steps: place the slot-die head with the front plate facing down on a flat and stable surface. Then, use the pin extractors tools to remove the alignment pins from the rear of the back plate. Carefully flip the slot-die head over, so it is face-up. Next, remove the securing bolts by unscrewing them. Once the securing bolts are removed, gently lift the front plate to separate it from the rest of the assembly. Proceed in the same manner for the shim and meniscus guide. Lift each component carefully and separate them from the slot-die head. Handle each part with care to avoid any scratches and other damage.

Important: Disassemble the slot-die head shortly after the completion of the coating session and before the ink inside has a chance to dry. This practice ensures optimal maintenance and prevents the risk of clogging.

Important: The two SDH plates are machined together and specifically paired. It is not possible to interchange plates between SDHs of the same size. Make sure the part numbers on the side notch of both plates are matching.

3.3.2. Slot-die mounting & positioning

The Nano Roll Coater slot-die head mounting gantry provides precise and reliable slot-die positioning capabilities. The following components are involved in the positioning of the slot-die head when mounted on the gantry (see Figure 3-2):

1. **Mounting bolt:** The mounting bolt secures the slot-die head to the mounting gantry.
2. **Tilt control screws:** These screws enable adjustment of the tilt angle of the slot-die head, allowing for precise alignment and parallelism with the substrate.
3. **Vertical positioning knob:** The vertical positioning knob allows for fine adjustment of the slot-die head's height.
4. **Horizontal positioning knob:** The horizontal positioning knob facilitates precise lateral positioning of the slot-die head.
5. **Slot-die head:** This is how the slot-die head should look when it is correctly installed onto the NanoRC machine.
6. **Top bracket of the mounting gantry:** The top bracket of the mounting gantry houses the tilt control screws. Press the slot-die head against the tilt control screws, then fix it in position.
7. **Back plate of the mounting gantry:** Press the slot-die head against this surface, then fix it in position.

To mount the slot-die head onto the machine, start by placing the slot-die head back plate against the mounting gantry. Insert the mounting bolt through the mounting hole of the slot-die head and screw it into the threaded hole of the machine mounting gantry. While applying slight pressure to the slot-die head, ensure it is in perfect contact with the back plate (see Figure 3-2 detail 7) and the top bracket (see Figure 3-2 detail 6) of the mounting gantry. Fully tighten the bolt to securely fix the slot-die head in place. The slot-die head has now been successfully mounted onto the Nano Roll Coater.

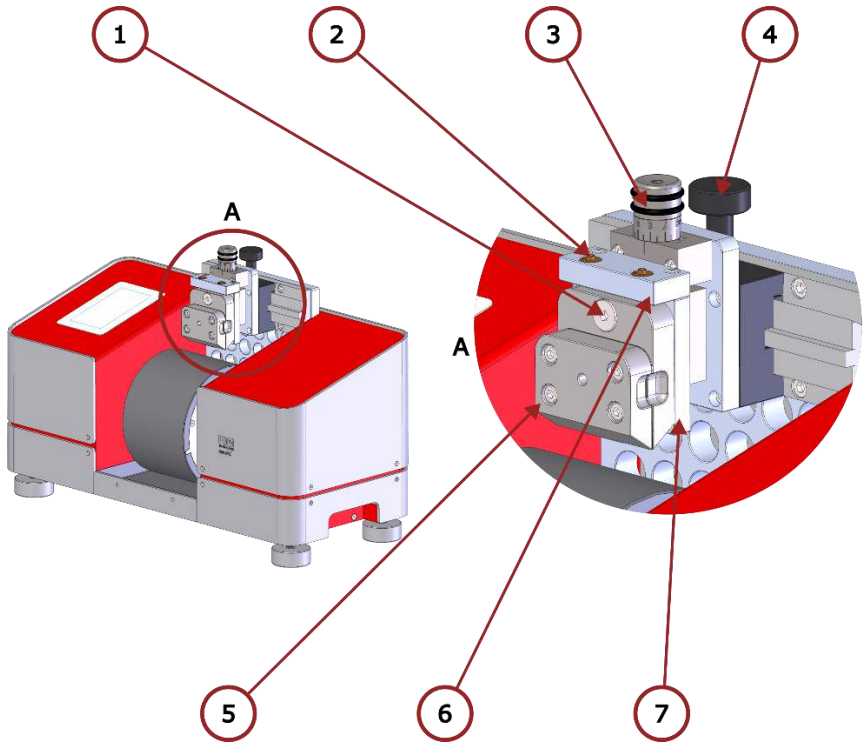

Figure 3-2: Schematic of the Nano Roll Coater (left) and a detail view of the die positioning and adjustment mechanism (right). (1) Mounting bolt, (2) Tilt adjustment screws, (3) Vertical positioning knob, (4) Horizontal positioning knob, (5) Slot-die head, (6) Top bracket of the mounting gantry, (7) Back plate of the mounting gantry.

3.3.3. Adjusting the parallelism of the slot-die head

To adjust the tilt angle of the slot-die head and ensure parallelism with the substrate, follow these steps:

Begin by using the vertical positioning knob to bring the slot-die head close to the substrate support drum. Then, use a feeler gauge to measure the distance between the slot-die head lip and the drum surface. Note down which side is high and which is low. Next, move the slot-die head to a safe position and slightly loosen the mounting bolt. Locate the tilt screws (refer to Figure 3-3, detail 1) and use appropriate hexagonal keys to release the small lock screw-nut (Figure 3-3 detail 2) and then adjust the tilt screw (turn the tilt screws clockwise to lower the corresponding side, or counterclockwise to raise it). Re-secure the head with the mounting bolt making sure that it is in contact with the tilt screws.

It may be necessary to repeat these steps, making incremental adjustments, until the desired parallelism between the slot-die head and the substrate is achieved. Once a parallel position has been reached, the slot-die head can be fixed in place by tightening the 0.9 mm hexagonal lock nut.

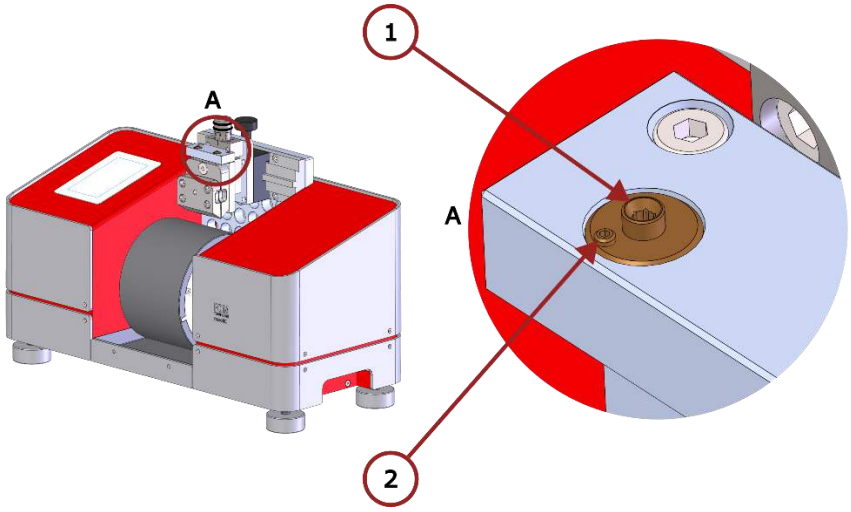

Figure 3-3: Tilt screw (1) and lock nut (2) for parallelism adjustment.

3.4. Substrate installation

The FOM Nano Roll Coater is designed to accommodate a diverse range of flexible substrates. It is advisable to mount the substrate onto the machine by securely attaching it to the substrate support drum using heat-resistant tape, such as Kapton, at both ends. Ensure that the substrate is tightly pulled against the drum to create sufficient tension. This practice guarantees a flat coating surface, yielding optimal coating results.

To facilitate easy mounting, it is recommended to prepare a rectangular strip of substrate not larger than 100x500 mm, as shown in Figure 3.3 (i). Begin by fixing one edge of the substrate to the drum using tape. Carefully wrap the substrate around the drum, taking care to avoid any wrinkles or folds. Finally, secure the second end of the substrate with tape to ensure it remains in place during the coating process.

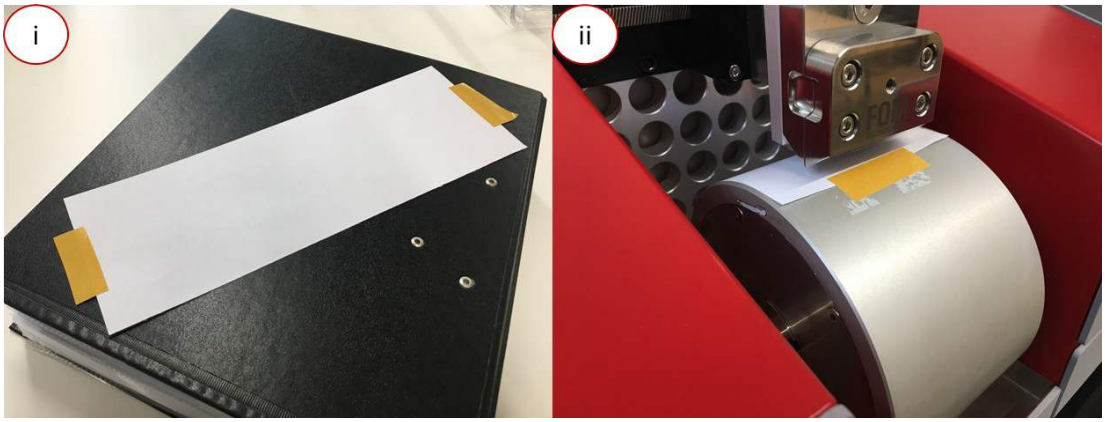

Figure 3-4: A strip of paper serves as an example substrate, showing (i) mounting tape affixed at both ends of the substrate, and (ii) the substrate mounted on the drum on the drum ready to begin coating.

3.5. Getting started with slot-die coating

3.5.1. FOM Technologies workshops on slot-die coating

FOM Technologies offers extensive workshops on coating technologies and techniques, specifically focusing on slot-die coating. Our workshops provide new users with a hands-on introduction to all aspects of precise, continuous, and scalable thin-film production via slot-die coating, allowing them to jump-start their knowledge in this field. In addition, experienced users can benefit from these workshops by sharpening their skills, filling knowledge gaps, and discussing their most pressing challenges with world-leading instructors. We have partnered with leading institutions worldwide to provide access to unrivaled training facilities and instruction. For further information, please do not hesitate to contact us.

3.5.2. Slot-die coating with FOM nanoRC

To begin coating trials with the FOM Nano Roll Coater, ensure that the machine is installed and that the slot-die head is assembled, mounted, and aligned properly. Also, make sure the syringe pump is connected to the slot-die head, and the substrate is securely affixed to the support drum.

Before starting the coating process, it is important to make the following final preparations:

1. **Drum Temperature:** Set the drum temperature to the desired level (this may take several minutes). Note that the drum will only heat if the drum is in rotation.
2. **Slot-die Head Position:** Lower the slot-die head to a position slightly above the substrate, maintaining an approximate distance of 5 mm.
3. **Substrate Positioning:** Position the drum in such a way that the initial portion of the substrate stripe is placed underneath the slot-die head lip. Leave a margin of at least 5 mm from the lip to the substrate edge.
4. **Syringe and Tubing Preparation:** Prepare the syringe pump or any suitable ink delivery system and connect the tubing line to the slot-die head.

Once these preparations are complete, it is possible to begin a coating process: initiate the flow of the ink by starting the pump at the desired rate. Gradually lower the coating head lip towards the substrate without making any contact. Allow time for the meniscus to form. Start the NanoRC machine at the desired coating speed. Adjust the height of the slot-die head to optimize the quality of the coated film.

Notice that, while adjusting the height does have an impact on the overall coating quality, it is not the primary factor governing the wet film thickness of the coated layer. The wet thickness primarily relies on three main factors: the rate of fluid pumping, the speed of the substrate, and the width of the coated stripe. By decreasing the pump speed, increasing the substrate speed, or widening the coating width, the wet thickness can be effectively reduced. Conversely, adjusting these parameters in the opposite direction will result in an increase in wet thickness.

Important: Unlike some other coating methods, the slot-die head is never in contact with the surface of the substrate. Therefore, it is crucial to avoid any touch between the slot-die head or meniscus guide and the surface of the substrate or support drum. Such interaction not only fails to improve coating results but can also lead to damage to the meniscus guide and slot-die lip, compromising the quality of future coatings.

4. Service and maintenance

If used in accordance with the intended purpose, the device is maintenance-free. In the event of a failure, please contact FOM Technologies A/S to coordinate the necessary actions. Opening the device should only be done by authorized personnel from FOM Technologies A/S or their authorized service staff. Any unauthorized attempts to open or repair the device may void warranty claims.

It is recommended to dismount and disassemble the slot-die head for cleaning at the end of every coating session. Additionally, the dip-tray should be removed and thoroughly cleaned from any residues of ink.

When cleaning the machine, including the substrate cylinder, use a soft cloth damped with a small amount of detergent or ethanol, avoid any liquid dripping inside the machine enclosure.