

SCREEN PRINTER P200S



STANDARD OPERATING PROCEDURE (SOP) 2018 (v.2)



NCPRE FABRICATION LAB

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INTRODUCTION

P2000S is a semi-automatic screen printer bought from Haikutech, Netherlands under NCPRE for

the metallization process of c-Si solar cells. Typically front side (Ag) and back side (Al) will be deposited using the printer, while the cell size can vary from 50mm x 50mm to 156mm x 156mm.

1.1 System Description

Various components of the Printer P2000S indicated in figure 1 are as follows:

1. **Computer Interface** - Control Panel to operate and control various printing process steps and avoid false operations.
2. **Printing Table** - To hold and transport the substrate for screen-printing.
3. **Squeegee and Scrapper** - To spread and print the metal pastes on the solar cells.
4. **Screens** - To print the desired pattern on solar cells.
5. **Printing Station**- Houses components like screen, squeegee, scrapper and drives up/down movement control for the entire stage.
6. **Fiducial Cameras**- For manual alignment of the cells before printing.
7. **Emergency Stop Button** - To stop the printer in case of an emergency.
8. **Squeegee Pressure Monitor and Control** - To vary and monitor the squeegee pressure during printing operation.

Important features of the screen printer are shown in table 1.

Table1. Important Features of Screen Printer P2000S

Feature	Specification
Screen in-out handling	Screen slides in and out from side
Squeegee standard	Squeegee + flood blade 25mm x 5mm x 220mm
Minimum Size	50mm x 50mm (with custom designed fixing)
Maximum printing area	250 x 250mm (with custom table)
Electrostatic elimination	The printing table moves under an ionization bar when entering the machine

Print Speed	Squeegee movement by servomotor 2 -320mm/sec, free adjustable
Print Force	0 - 200N adjustable by precise pressure regulator
Snap off	Adjustable 0 - 5mm, Light for easy snap off detection is installed at the back side of the screen
Alignment	Screen to substrate repeatability ± 5 microns (mechanical, if environment temperature in range ± 1 degr C)
Cycle Time	Typical 4-10 sec (table in, print, table out)
Product Changeover	Set Up <10 minutes

2 System Operation Details

2.1 Powering Up the Printer

Before powering up the printer, always ensure that CDA supply is turned ON and close to 60psi. If it is less, the printer will raise an 'Alarm' upon start up. The CDA pressure should always be maintained close to this value during the entire operation to avoid abrupt stops during the process. Then switch on the main supply switch of the printer located on the back-side of the printer by rotating it clock-wise to the ON position as shown below.



Figure 2. Turning ON the main supply of the printer.

Once the power is turned ON, the computer system will automatically start and load the control interface. Ensure that no alarms are indicated on the control panel. Also the printer will automatically adjust and align the printing station to its upper position. The squeegee pressure can then be varied from the front panel and value of more than 0.1 MPa should be selected. Typically the value will be around 0.14 MPa (70N) for front and back side metal paste printing.

2.2 Fixing Squeegee and Scrapper

Once the system is powered up properly, the squeegee and scrapper should be installed in the printing station. This is to be done first to prevent any damage to screen during installation. First, squeegee and scrapper should be thoroughly cleaned with IPA and lint-free cloth to remove residual paste particles if present. The squeegee head then should be moved to 'UP' position via the switch present near the printing station shown in figure 3. The scrapper is to be installed by moving it from left to right from the back side to fit in the slot and then tighten it by the screw. Similarly the squeegee is then fixed on the front side. It should be ensured that they are installed tightly and are not loose.



Figure 3. Squeegee Head Control Switch.

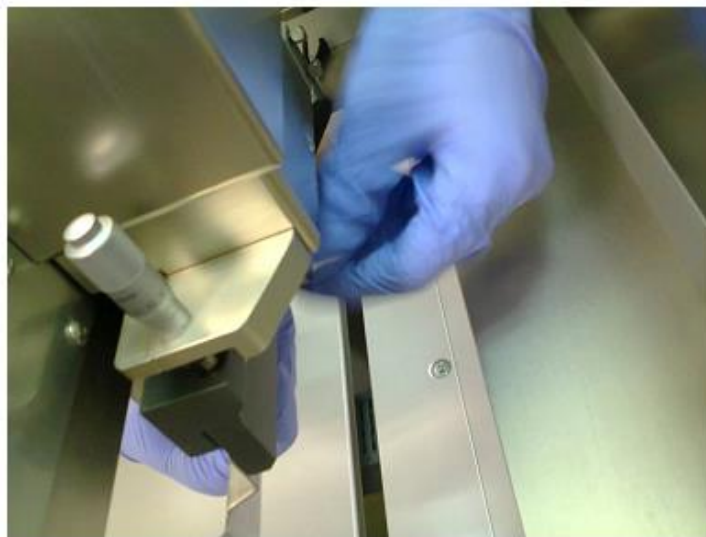


Figure 4. Back side view during scraper installation



Figure 5. Front view of squeegee and scraper installed in the printing station

2.3 Cleaning and fixing the screen

Cleaning the screen thoroughly with IPA before the printing process is important. If there is dust or contaminating particles on the screen, it can adversely impact the printing process. The cleaning process should be gentle on the screen and performed only in the chemical wet bench. Ensure that the print area is free of contaminants by seeing the screen against bright light. Once the cleaning is done, ensure that the squeegee button is in 'UP' position. Also ensure that the screen lock is turned 'OFF'. The printing table should be positioned to 'UPPER' position, this will help to load the screen with some space from the bottom.

The required screen then should be mounted on the frame and **with the screws tightened well**. If the screen is not fixed well; it might vibrate during the printing process and lead to unstable printing. Once tightened, the screen should be loaded from the front side slowly in the screen holding slot. It should be ensured that the aluminum plate structure sides of the frame should be held by the screen fixing cylinders on either side. Once placed properly, turn 'ON' the screen fixing and ensure that the screen is firmly held.

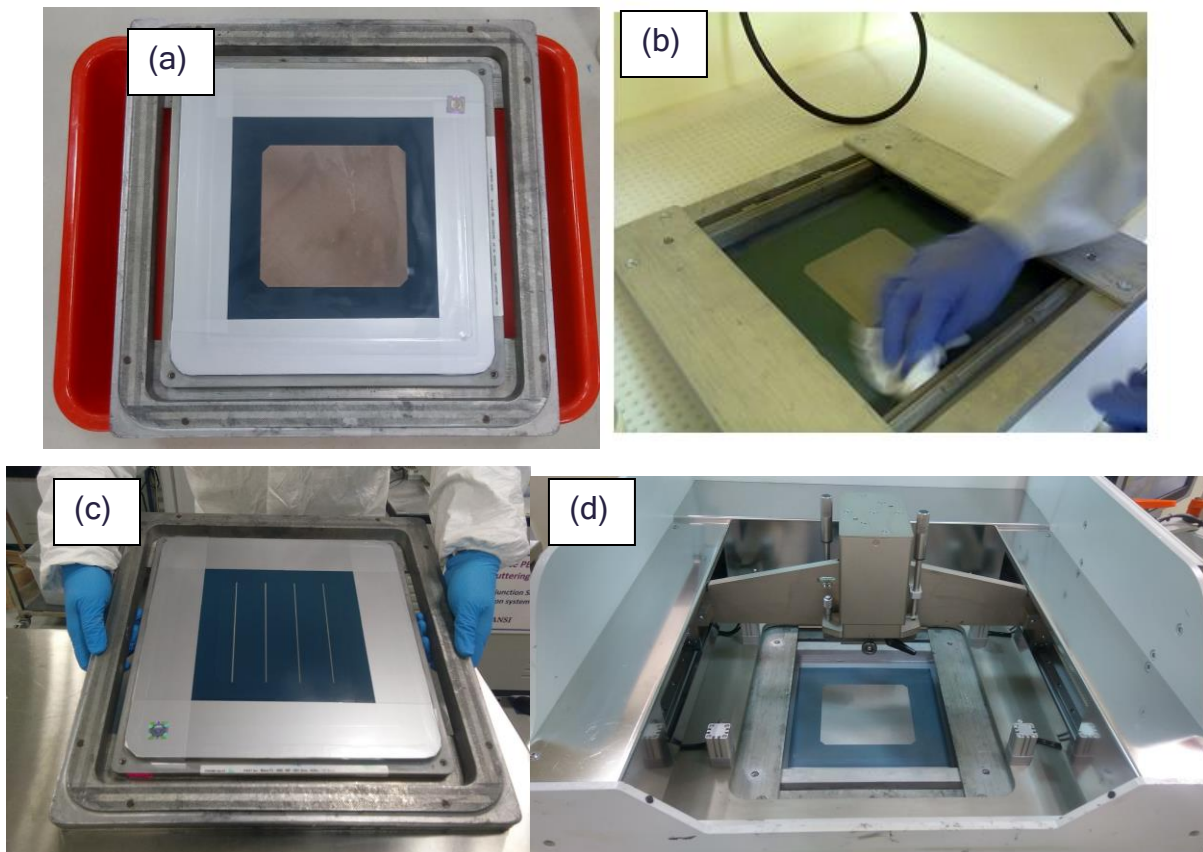


Figure 6. (a) Back side Al printing screen with screen frame (b) Cleaning of screen prior to printing in the chemical wet bench (c) Front side Ag printing screen (d) After screen fixing in printer

2.4 Setting Zero for the screen

After the squeegee and screen are installed, the next step is to define 'Zero' level for the screen with respect to the substrate. This is an important step as it will determine the effectiveness & correctness of the printing process and ensure no unintended damage to the solar cell. Keep the squeegee in 'UP' position during this step as well. To move the screen up/down, the printing stage is to be manually controlled from the 'LIFTING' section as indicated in figure 7. The 'LIFTING' section has buttons with respectively function indicated in table 1. **Before moving the substrate under the screen, take the printer head to 'Upper' position by clicking on the 'TO UPPER' button.** The entire stage will then gradually move up. A dummy substrate (thickness pretty much same as the actual substrate) or the actual substrate is then place on the vacuum chuck and held tightly by pressing the 'VACUUM' button in the 'MANUAL' section of the control panel. The cell then needs to be moved under the screen using the In-Out button in the 'MANUAL' section. Now the cell is under the screen and we have to determine the 'Zero' setting. Move the head to middle position via 'TO MIDDLE' button and observe the stage coming down. At this point, there should be noticeable distance between the screen and substrate as indicated in figure 8. Then move the cell to snap-off via 'TO SNAP OFF' button. At this position, the distance between the screen and substrate should be around 1mm. **From here onwards, changes in distance are to be made via INDEX UP/DOWN buttons only to avoid damage to the substrate.** Gradually move the screen down till the screen is almost touching the cell as shown in figure 9. This step will require experience and good judgment which will come after few runs.

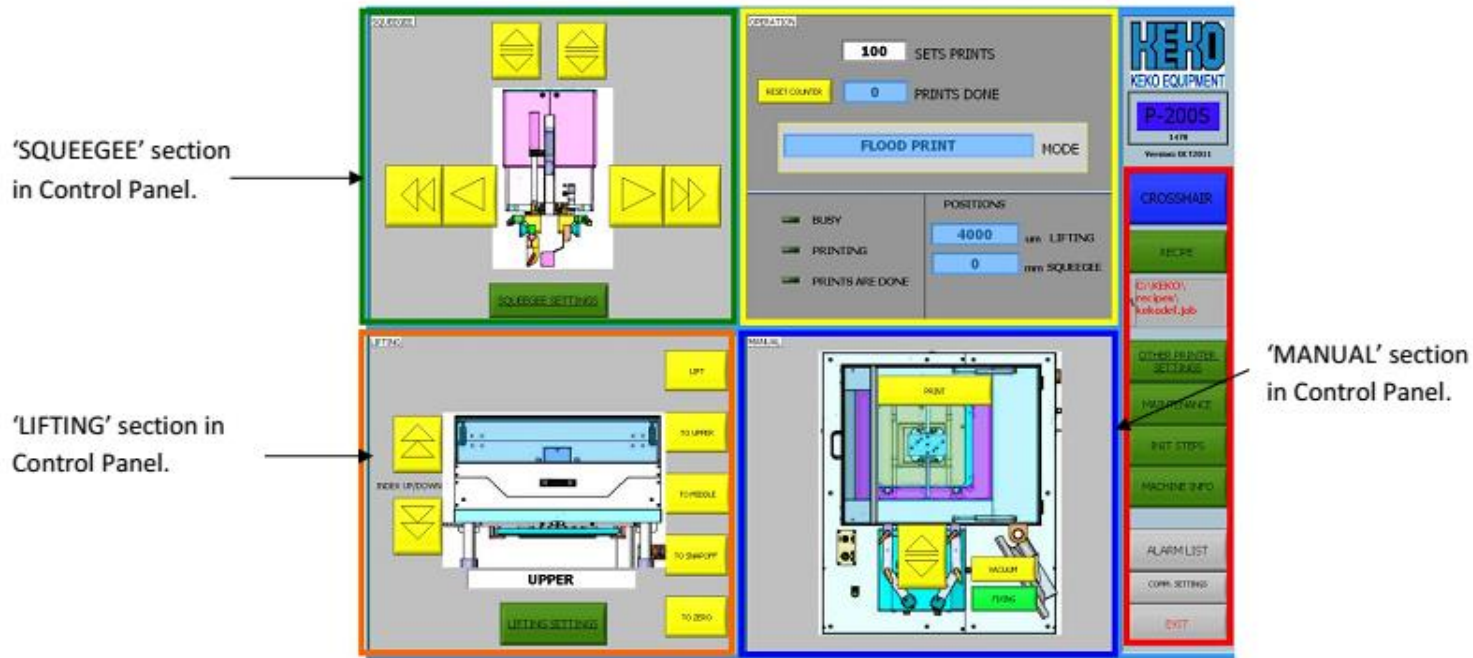


Figure 7. Various control section in the control panel

Table 2. Functionalities of the buttons in section for screen up/down movement

Button	Functionality	Comments
Printer Up	Lifts the printer head up by pre-determined step(0.1mm)	Used during 'Zero' setting of the head
Printer Down	Moves the printer head down by pre-determined step(0.1mm)	Used during 'Zero' setting of the head
To Zero	Moves the head to 'Zero' position	To check whether the head is in contact with the substrate. But do not use it unless 'Zero' setting is done.
To Snap Off	Moves the head to 'Snap Off'	To move the screen to Snap Off before the printing process
To Middle	Moves the head to 'Middle'	Used to move the screen away from Zero or Snap Off
To Upper	Moves the head to 'Upper' position	Used to move the screen away from Zero or Snap Off
Lift	Lifts the head to highest upper position	Used to move the screen away from Zero or Snap Off



Figure 8. Screen at middle position with sufficient distance from the chuck

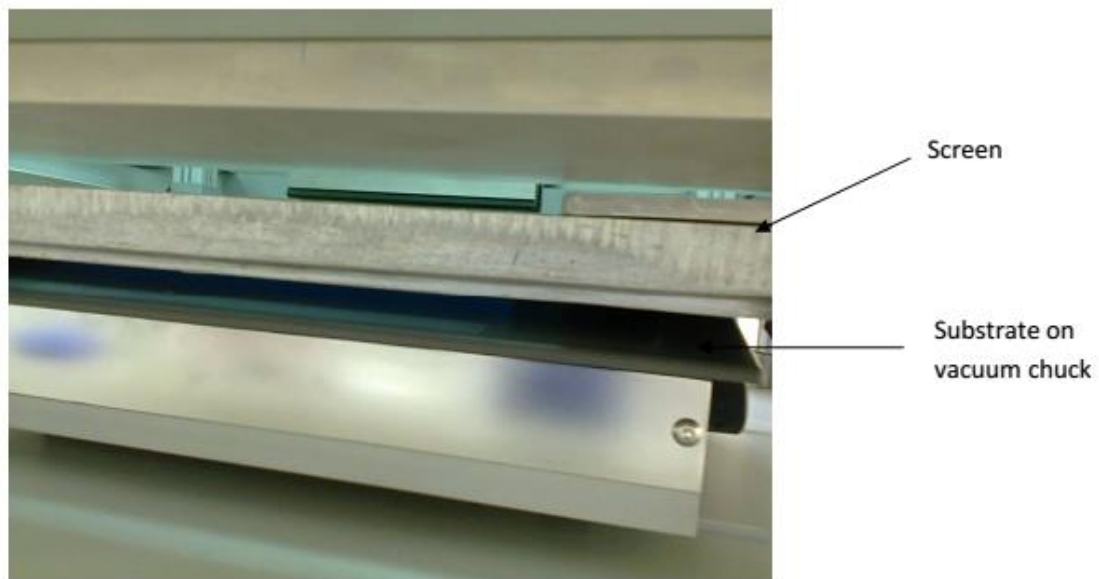


Figure 9. Screen almost at zero location with respect to the substrate

Once the screen zero is determined, the current location should be set to 'Zero' by clicking on 'LIFT SETTINGS' in 'LIFTING' settings and then selecting the 'Set current printer position to zero'. A warning will appear indicating change in printer zero position,

select 'Yes' for the same. The snap-off value will be 1mm above the zero value and will be automatically readjusted.

2.5 Squeegee and Scrapper settings

Subsequently, the squeegee and scrapper settings are to be tuned with respect to the screen. The squeegee should be moved to 'DOWN' position via the switch, while the screen should be maintained at snap-off position. With the printing table under the screen, a dummy substrate should be kept to avoid possible damage to the sample. The squeegee controls are located at top left corner as shown in figure 7. The bottom set of control within the box can be used to move the squeegee to forward/backward positions or incremental steps. The top right and left control buttons are for moving the squeegee and scrapper respectively to down positions during the printing process. Figure 10 shows the upper and down positions for the squeegee and scrapper. At the up position, **there is sufficient clearance from the screen, while on the down position the scrapper should be 0.1-0.3 mm above the screen.** This is to facilitate proper spreading of the paste before the actual printing on the solar cell. Likewise, **the squeegee is 0.5-1 mm below the screen to ensure proper transfer of the paste onto the substrate.** Initially the scrapper is lowered, and the distance from screen can be checked by inserting a paper. If the paper can freely move in and out then it means that the distance is more than 0.3 mm. The scrapper position can be adjusted with the help of knob on left side of scrapper indicated in figure 10. Moving the knob clock-wise will move the scrapper up and vice-versa. The alignment of the scrapper with respect of screen can also be adjusted if needed by the help of another knob on opposite side as shown in figure 4. This should be adjusted to ensure uniform pressure distribution while spreading the paste on the screen. Similar setting should also be made for the squeegee with the difference being in the distance from the screen. **The above indicated settings for squeegee and scrapper should be checked at forward, back and middle position to ensure uniformity across the screen during printing process.** Another aspect related to the printing process to set the forward and back position of squeegee and scrapper. These settings are important to obtain complete paste coverage on the screen and ensuring complete substrate coverage by the squeegee. These can be altered via the 'SQUEEGEE SETTINGS' option in the squeegee control section.

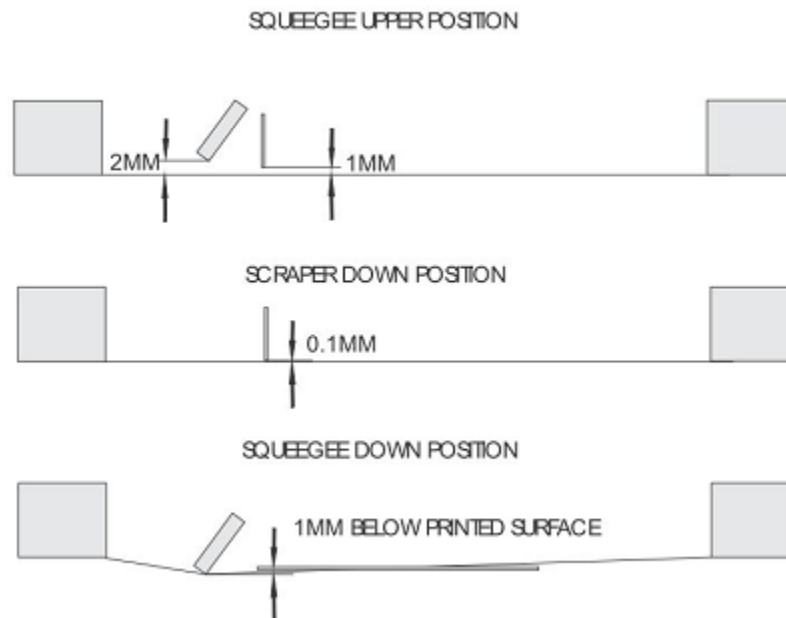


Figure 10. Upper and lower position for squeegee and scraper



Figure 11. Micro-height adjustment knob for scraper

2.6 Paste Stirring and Application on the screen

After all the settings are done, we are ready to start the actual printing process. Before we deposit the paste, it has to be thoroughly mixed to ensure uniform distribution of various paste constituents and solvents. Due to storage, the constituents tend to segregate. **Typically the paste should be stirred vigorously with a cleaned stainless steel spatula for 3 minutes** as indicated in figure 12. **Once stirred, the paste should be deposited on the screen without much delay.** It is important to have an idea about the amount

of paste to be applied based on the quantity to be used per sample and number of samples to be printed.



Figure12. Stirring of metal paste prior to printing

The paste should be applied close to the actual pattern on the screen so that it can spread by the scraper during the printing process. It should be ensured that the paste is not directly applied on the patterned area. Once the paste is applied, printing process should be started without delays as the drying paste may coagulate and block the screen openings. **The paste should be applied near the home position of squeegee and flood.** This will ensure uniform spreading of the paste during the printing process. **Please read step 2.6 before depositing the paste onto the screen.**



Figure13. Paste application on the screen

2.7 Dummy Run, Alignment and Printing on actual substrates

It is always recommended to do initial 1 or 2 runs on dummy substrates, preferably of the same size as that of the actual substrate. This is required to ensure the alignment of the printed paste on the substrate. **Before step 2.6, it is recommended to do an initial coarse alignment by moving the dummy substrate under the screen and making manual adjustments to the vacuum chuck so that the sample looks pretty much aligned under the screen.** When the coarse adjustment is to be done, the printer head should be at snap-off position. The substrate can then be moved under the screen by clicking 'Table In/Out' button in the 'MANUAL' control section highlighted in figure 14. This will help to obtain macro alignment of the substrate, while further micro alignment adjustments can be done with the help of cameras. Once the manual alignment is done, bring the printer back outside by clicking on the same button. The substrate should be held on the chuck by clicking on vacuum option indicated in figure 13.

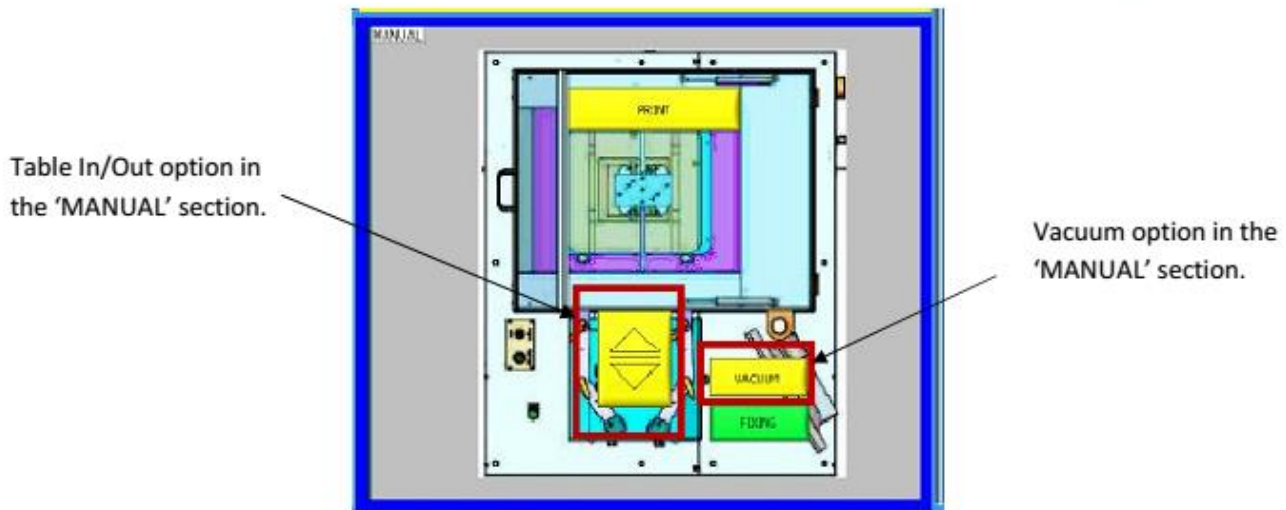


Figure 14. MANUAL control section in the control panel

Once the substrate is manually aligned and paste deposited on the screen, the printing steps are as follows:

- Ensure the substrate is held by vacuum, this should already be done while doing the initial manual alignment under the screen. So the vacuum need not be broken.
- Ensure the printer head is at 'Snap Off'.
- Ensure the squeegee is at 'Down' position.

- Ensure fixing of the substrate is indicated by green color of 'FIXING' icon as shown in figure 14.
 - The print process can then be initiated by simultaneously pressing the right and left 'PRINT' push buttons. The print buttons are present on either side of the vacuum chuck as shown in figure 15.
 - Once the printing is done, the chuck will automatically come back to the out position. Figure 16 shows a test printer done on a dummy substrate.
 - Perform cross-hair alignment of the cursors as discussed in sub-section ahead.
 - Place a second dummy sample and align with respect to previous cross-hair cursors and print.
 - If the alignment is satisfactory, proceed with printing on actual substrate or continue with dummy samples till desired accuracy is obtained.
 - Once the printing process is started, subsequent prints should be done without delays and the alignment should be performed for each sample.
- Also ensure that sufficient quantity of paste is always present on the screen. Insufficient amount of paste may lead to regions without or insufficient paste after printing.



Figure 15. Mechanical 'PRINT' buttons on either side of the vacuum chuck



Figure 16. Printing done on a dummy sample

2.7.1 Fine alignment using cameras

Fine alignment of the printing process can be done using the cameras as indicated in figure 1. There are two cameras which focus on diagonally opposite ends of the substrate. The cameras are located at the upper position of the printer head which is 4000 μ m and their positions should not be swapped. Steps for alignment using cameras are as follows:

- Move the camera in range of the printed areas being visible. Remove 'FIXING' by clicking on the MANUAL control panel button so that it turns to yellow. Go to 'CROSSHAIR' section on the top right side as shown in figure 18. On clicking this option, the camera view for both ends will be visible as shown in figure 16. Now vary the camera position to clearly view the edges and require feature. **Don't vary the camera height during the process.** This should be done using the arms of the cameras. **Once done, don't alter the camera position during subsequent prints.**
- After the first dummy print, **align one of the pair of cursors (green or red) along the corner features like grid line and save them.** Figure 18 illustrates alignment of red cross-hairs with the diagonal edges of the cell after a print. **This will serve as reference for alignment during subsequent prints and should be done for both the cameras.**
- When the actual substrate is then placed, align the cell manually on the chuck with help of knobs on the stage as indicated in figure 19. Knob 1 is for movement in X-direction parallel to the movement of stage into the printing area, while knob 2 will move the stage in Y-direction. Tilt control can be done using knob 3. Before adjusting

the tilt, ensure that center of holder is aligned with the 'Middle' of the chuck indicated in figure 19. Ensure that the alignment of the feature is within the desired limit before the print.

- Close the 'CROSSHAIR' menu and turn on 'FIXING' of the stage.
- Now print step can be given and the print should be well aligned.



Figure 17. Cross-hair view of cameras with the two set of cursors for respective views

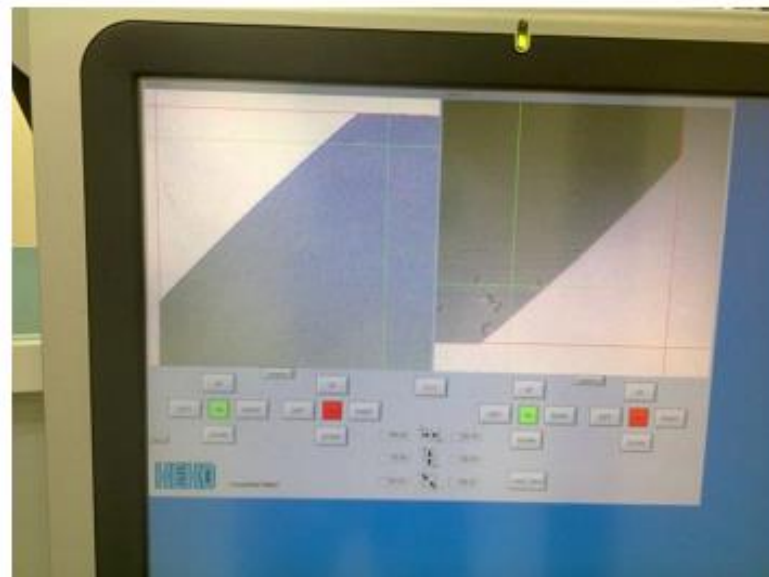


Figure 18. Cross-Hair alignment with edges of print on substrate

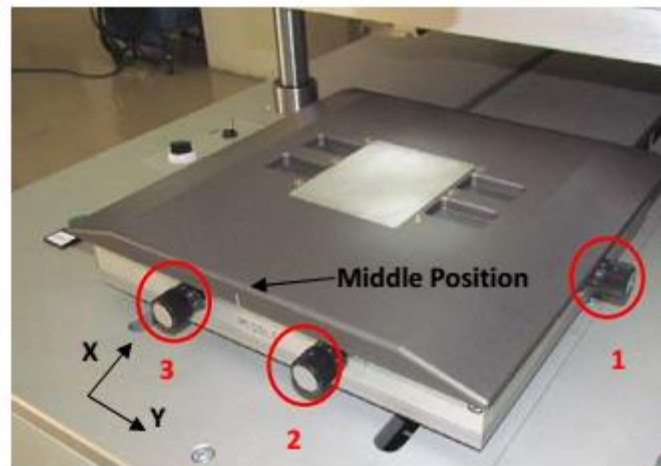


Figure 19. Knob for micro alignment of substrate before printing

3. Emergency Shut Down

Emergency shut down is used under an unusual condition and is activated by pushing the emergency stop button near the computer screen as shown in figure 1. When the emergency stop button is pushed, an “EMERGENCY STOP!” alarm will be displayed. CDA supply to all motors except squeegee will be turned off and the PLC will remain on. Once the emergency stop button is deactivated, the printer will come to its home position. The emergency stop button should be pressed under the following conditions:

- **Squeegee Servo Error:** In this case there can be a ‘BUSY’ or ‘ERROR’ alarm for squeegee movement which will be indicated by the corresponding alarm “ERROR SQUEEGEE SERVO!”. The emergency stop button should be pressed and servo driver error code should be checked.

4. Trouble shooting for non-uniform printing and related issues

The following points should be checked for ensuring good printing:

- Check parallelism of squeegee and printing table and correct it if necessary.
- Ensure proper squeegee down stop position.
- When the squeegee is fixed to the squeegee holder, the edge has to be straight to ensure uniform pressure throughout the length.
- The snap-off distance can be increased if a prominent separation sound is present after printing. It should be in the range of 1-1.5 mm.
- For reduced deposited paste, the squeegee pressure can be increased.
- Check paste quantity and apply more if insufficient quantity is present.

- Clean the screen if clogging seems to be leading to non-continuous prints.
- Check screen quality if non-uniform printing or pre-mature paste application is observed.

5. Common Issues and Solutions

The following are common issues that the operator might face during operation.

1. **Blank error message after each print:** This problem comes after 100 prints are completed in a run as indicated in figure 20. This is not an actual alarm regarding any process step and simply resetting the counter after 100 prints will avoid the problem.



Figure 20 .blank alarm after 100 prints is completed

2. **Printer too low Alarm:** This alarm comes when the screen is at zero position i.e. Touching the substrate and the operator tries to withdraw the chuck. Since the screen is touching the substrate it might damage it and hence the error. After clearing the alarm, the operator should move the screen to snap-off or higher position and then withdraw the chuck.

6. Cleaning Procedure for Screen-Printer

As per the NCPRE cleaning schedule, weekly cleaning of the system is mandatory. Cleaning is to be done gently with lint-free cloth and IPA. Baring the indicated components, the entire printer should be cleaned. The components not to be cleaned or touched during the cleaning process are:

- Cameras above the substrate holder and associated arms. The height of the cameras should not be altered.
- Inside chambers on either side of the printer below the main stage.

- Care should be taken to avoid damage to the squeegee and associated settings during the cleaning.

7. Category Semi-clean PV

8. References

1) P2000S Operating Manual, Haikutech.

9. Revision Details

1) Version 1.0(15/2/2013)- Initial Draft of the Manual prepared by Mehul C. Raval and Sudhir Lone.

2) Version 1.1(14/6/2013) - Modifications to fine-line alignment section, added the cleaning procedure section and updated trouble-shooting & other sections.



Front view of cell after Ag printing