University of Minnesota, MN Nano Center
Standard Operating Procedure

Equipment Name:	Rapid Thermal Annealer		
Badger Name:	K1 RTA RTP600S	**Revision Number:**	10
Model:	RTP-600S	**Revisionist**:	Lage von Dissen
Location:	Keller Hall, Bay 1	**Date:**	6/21/2021

1 Description

The rapid thermal annealer consists of a small, quartz-lined chamber which is rapidly heated by high intensity, tungsten-halogen lamps. A single wafer loaded into the chamber can be heated to temperatures of 1150 ^{o}C. The RTA is often used for surface repair following ion implantation, stress reduction, ohmic contacts, and more.

2 Safety

a Do not open chamber unless below 200 ^{o}C.

b Be aware that the thick quartz table will stay hot much longer than a Si substrate.

3 Restrictions/Requirements

a Must be a qualified user on “K1 RTA RTP600S”.

b Pyrex glass can only be used with processes that are 450 ^{o}C or less

c Not allowed: Organics/polymers, carbon, SiC, DLC, etc.

4 Required Facilities

a Compressed air, 60psi, 5 SCFM

b Process chilled water, >2 GPM

c N2, 0-30 SLPM

d 5% H2/N2, 0-10 SLPM

e Ar, 0-10 SLPM

f 10% O2/N2, 0-10 SLPM

g N2O, 0-10 SLPM

h O2, 0-10 SLPM

5 Definitions

a Thermocouple: A bi-metal junction which has been calibrated for temperature given the thermo-voltaic change in that junction. Wire leads from the junction should not be shorted against a metal (i.e. chamber door) or semiconductor (wafer substrate), as this will cause an offset in the voltage reading, and may lead to significant errors in the temperature reading. The junction should press firmly against the material being measured so as not to under-estimate the temperature of the substrate, which leads to over-heating of the chamber.

b Pyrometer: Solid state detector (photo-diode) which has been calibrated for temperature given the infra-red emission of silicon. Will only work accurately for silicon. Will not work for glass or sapphire substrates! Highly reflective metals on the back of the wafer will cause problems (especially aluminum).

5 Definitions [cont.]

Real Temperature (when within 40 ºC of the Model Temperature): the temperature as measured by the TC or the pyrometer.

Real Temperature (when NOT within 40 ºC of the Model Temperature): the temperature as measured by the TC or the pyrometer.

Model Temperature: the temperature the system is trying to achieve.

Lamp intensity: relative scale, from 0 to 100% power.

Gas Flow: represents the current gas flow rate, relative to the maximum possible flow rate for that particular gas (i.e. max flow = top of the graph). Each gas is represented with its own color (only one is shown here).

6 Operating Instructions

a LOGGING ON

1. Enable the **"K1 RTA RTP600S"** in Badger.
2. Fill out the log book (user info, date, etc.).
3. Press the **"Power On"** button (located on the RTA control panel). This will turn on the compressed air which cools the chassis and electronics.

b PROGRAMMING A PROCESS (if this is not needed, please proceed to step 'C')

1. From the Main Menu, press **F3** to access the **"Recipe Menu"**.
2. If you wish to write a brand new recipe, press **F6** (New). If you prefer to edit an existing recipe instead, use the arrow keys to select the appropriate recipe, and then press **Enter**.

NOTE: If you selected F6 above (to create a new recipe), the computer may give a message stating "NONE.rpd exists! Overwrite it?" If this happens, please press the **'Y'** key to answer 'Yes'.

3 Fill out the various fields at the top of the screen as needed. Use the arrow keys to move from one field to another. See below for more details. If you'd like to look at the manual for the RTP-600s, for more information on any parameter, press **F1** (Help) to access the manual.

File Name: this should be 8 characters or less and should have the extension '.rpd' at the end (for example, "Si_1000C**.rpd**") to ensure that the recipe is saved into the proper directory.

Pyro Cali: this should always be set to **"SYS_PYRO.WFR"**.

Lamp Cali: this should always be set to **"SYS_LAMP.WFR"**.

Engineer: this is where you can enter the recipe author's name.

Wafer Type: this should always be set to **"WAFER"**. If this is currently set to "SUSCEPTOR", press the **Space Bar** to toggle this parameter to "WAFER". This ensures that recipes that make use of the pyrometer temperature sensor will have an accurate temperature measurement.

Temp sensor: pressing the **Space Bar** toggles this parameter between THERMOCOUPLE and PYROMETER. This will determine which temperature sensor the system will use/monitor when running this recipe. The thermocouple (TC) will work for processes between 150-800 °C. The pyrometer will work for processes between 500-1150 °C.

Control Mode: this should always be set to **"Close-loop"**. If this is currently set to "Open-loop", press the **Space Bar** to toggle this parameter to "Close-loop". This ensures that the temp. sensor will provide feedback to the lamp power output, which is absolutely essential.

Title: this can be used to provide some more info or a short comment pertaining to the contents of the recipe (e.g. temperature, gases used, etc.).

Factor1-8: these are PID control factors (default values are 1.00), which affect how well the recipe performs. If you are having problems with temperature overshoot, instability or oscillation, etc., these factors can be further optimized to improve the recipe performance. To toggle which factors are displayed in the recipe (Factors1-4 or Factors5-8), press **F3**.

See pages 27-30 in the manual for more details on what these factors are used for.

4 Create/Edit your recipe by programming a sequence of step numbers (**Step No**.). See below for more details.

Step Function: this is the basic purpose or function of the step. There are five commands to choose from: Idle, Hold, Ramp, and Stop. These are abbreviated I, H, R, and S on the keyboard.

Idle: this ensures that the lamps are turned off while maintaining any specified gas flows. It is generally used at least twice in any recipe: during an initial step, to purge any atmospheric gases from the oven using an inert gas; and as the final step, effectively stopping the recipe. If you plan to change the gas flow rate for the heated portion of your run, you should program an additional "Idle" step beforehand that uses that particular gas flow rate (to stabilize the gas flow before heating).

Ramp: this selects how much time it will take to reach a particular temperature. Most users program their desired process temperature in this step. For example, a user may want the oven to heat up from room temperature to 450 °C, over a time interval ("Ramp" step) of 5 seconds.

Hold: this selects how long a particular temperature and gas flow rate(s) will be maintained, often used after you've ramped up to that particular temperature. This is a steady-state process step (i.e. the total time to anneal, reduce, oxidize, etc., at any particular temperature and gas flow).

Stop: this ends the entire recipe, and is generally used after a final "Idle" step. This step should contain nothing but zeroes in every field.

Time (sec): this is the duration of the step, measured in seconds. See "Temp vs. Time" matrix (page 8), to ensure that you do not exceed the maximum time allowed for any particular temperature used.

Temp (°C): this is the temperature setpoint of the step, measured in degrees Celsius.

Gas 1-6 (SLPM): these are the gases that can be programmed to flow during this step. They are measured in SLPM (standard liters per minute). See first page of this SOP for maximum flow rates. **Total gas flow rate (for all gases used at the same time) should NOT exceed 30 SLPM, or the quartz tube can be damaged.** See next page for more requirements.

Gas 1-6 (SLPM) continued:

Non-inert gases come in two types: oxygen-based (O2, O2/N2, N2O) and hydrogen-based (H2/N2). Inert gases include N2 and Ar.

Before running any step with non-inert gases, the system should be **purged with an inert gas (N2, Ar) for a total of 600 SLPM*seconds** (e.g. 30 seconds @ 20 SLPM, 40 seconds @ 15 SLPM, 60 seconds @ 10 SLPM, etc.). If the same type of non-inert gases are being flowed in several adjacent steps, you do NOT need a separate purge in-between each of these steps. However, if the type of non-inert gas is going to change in a subsequent step (e.g. from O2-based to H2-based), then a purge step with an inert gas is needed in between these steps.

After running your last step containing any non-inert gas, **repeat the purging requirement listed above (600 SLPM*seconds)**.

Before the end of the recipe (i.e. before the "STOP" step), you should **run a purge with an inert gas (N2, Ar) for a total of 1800 SLPM*seconds** (e.g. 60 seconds @ 30 SLPM, 120 seconds @ 15 SLPM, 180 seconds @ 10 SLPM, etc.).

5 To save and validate the recipe, do the following from the **Command** field:

Press **F10** (Validate) to see if the recipe is valid. If the validation is not successful, you will need to edit the recipe in order to satisfy any missing validation criteria (e.g. correcting gas flow rates or times for certain steps). If the validation is successful, it should prompt you to "Press any key to continue". Press the **Enter** button.

Press **F2** (Save). If you are prompted with the message: "Overwrite?", you can press **Y** to proceed with overwriting the recipe.

Press the **Esc** button if needed, to return to the Recipe Directory. Press the **Esc** button again if needed, to return to the Main Menu.

C RUNNING A PROCESS

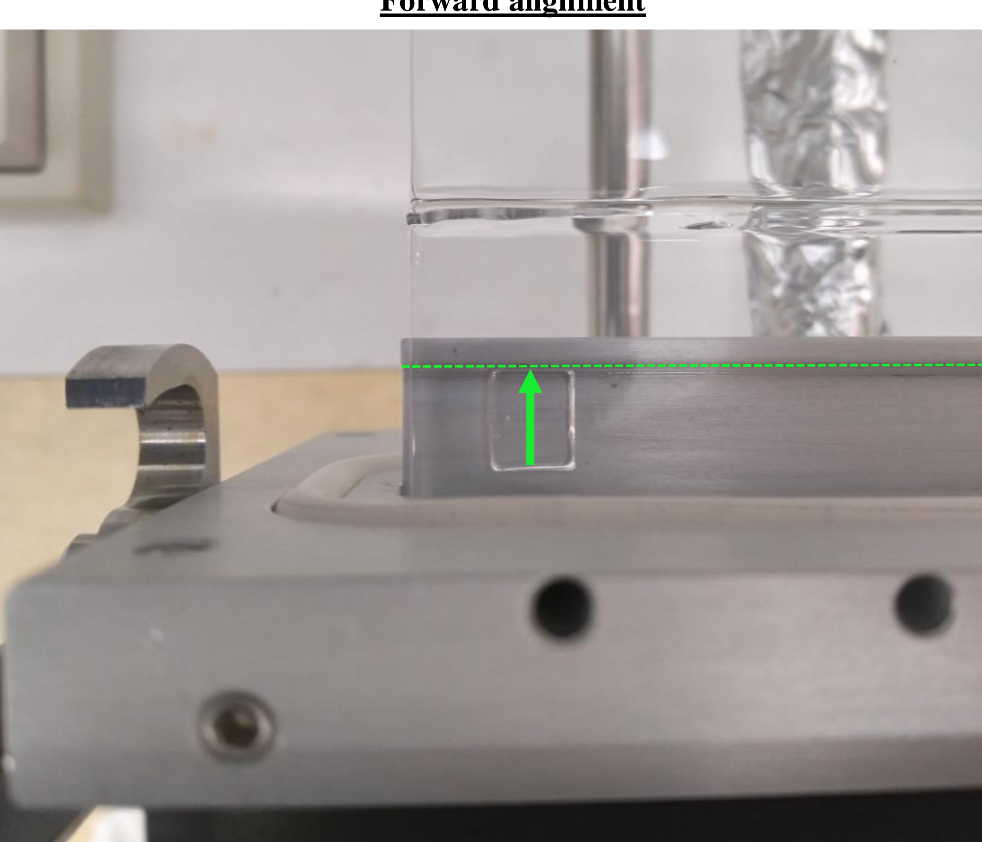
1 Open the chamber door by lifting up on the metal handle with your fingers, while using your thumbs to slowly but firmly pry the door seal from the chamber flange. Open the door slowly and carefully.

2 Based on the temperature requirements of your process, decide whether the TC (150 - 800 ºC) or the Pyrometer (500 -1150 ºC) will be used. If the TC is not installed, the software will use the Pyrometer by default. If you'd prefer to use the TC instead, plug it in to the socket on the inside of the chamber door. If the TC is used, please **DO NOT BEND THE WIRES** unless absolutely necessary (see next page for more details).

NOTE: For correct polarity of the TC signal, the heads of the screws on the TC connector must be **FACE DOWN** (nuts facing up). If this is installed incorrectly, the temperature will read out as a negative number, which could cause catastrophic damage to the system if a process is run.

3. Place wafer on the three points of the quartz tray. If you have small pieces to process, place a carrier wafer on the quartz tray and then place your pieces on top.
4. Prior to closing the chamber door, you will want to check for proper alignment of the quartz tray to ensure that it does not hit anything (like the door flange or the inner walls of the oven). For the tray alignment, you will need to verify the "forward alignment", "centering" and the "tilt" (see images below):

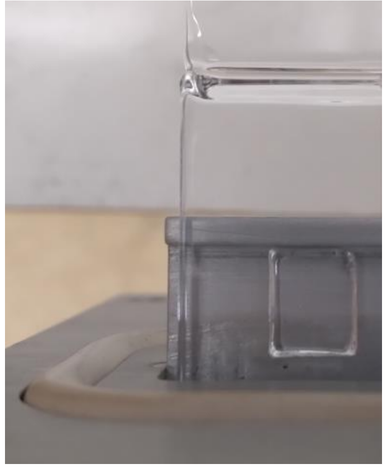
Forward alignment



Verify that the two square bumps on the bottom of the quartz tray are resting up against the aluminum support lip (as shown above). There are two quartz bumps that you need to check. There is one bump on the left side (as shown above), and one located on the right side (not shown).

If either bump is not in contact with the support lip, please ask for help from the proper MNC staff.

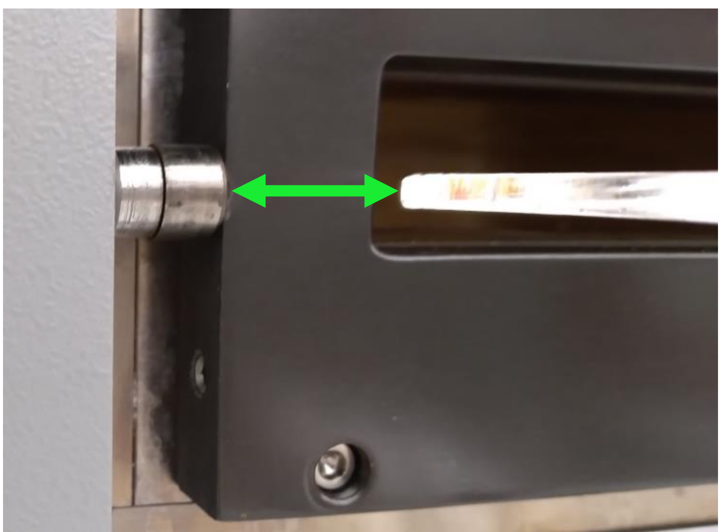
Centering



Verify that the quartz tray is well centered on the aluminum support lip by inspecting the left and right sides of the support lip (as shown above). This ensures that the tray is not positioned too far to the left or right, which will help to prevent the tray from hitting the door flange or the inner walls of the oven.

If the tray is not centered adequately (it does NOT need to be perfect), please ask for help from the proper MNC staff.

Tilt



Finally, you will want to verify that the tray's tilt is adjusted properly. One easy way to do this is to inspect the back edge of the tray and ensure that it is roughly level with the center of the door latch pin (as shown above).

If the tilt needs to be adjusted, please ask for help from the proper MNC staff.

5 Close the chamber door slowly, and press the metal handle down to make the seal on the door press firmly against the metal flange.

6 When you are ready to run the process, from the Main Menu, press **F4** or **F5** (Run Process) depending on which type of process you'd like to run:
F4 = Thermocouple process, F5 = Pyrometer process.

7 Highlight the recipe you would like to run. Press **Enter** to run.

NOTE: There are usually 5 to 7 pages of recipes with 15 recipes/page. At around 100 recipes (when the 7th page is filling up) the computer will give a warning that the directory is full. Contact staff for help in moving some recipes from the directory if needed.

8 Allow recipe to run until completion. Process parameters will be displayed on the screen. If needed, see definitions section (page 2) for an explanation of each colored line shown on the graph.

If you want to abort the process, press the **Esc** button. If you choose to abort the process, the system will show a message stating that it needs to purge for 60 seconds. Once the purge is complete, press the **Enter** button to return to the "Recipe Data File Directory".

9 When the process recipe has finished running, a message will appear that says "Process Over". If you do not automatically return to the "Recipe Data File Directory," press the **Enter** button. Press the **Esc** button to return to the Main Menu. Allow temperature to cool to ≤ 200 ºC before opening chamber door to remove your wafer/samples. When you are finished processing all your samples, remove the TC (if it was used) and close the chamber door.

d LOGGING OFF

1 Allow the system to cool for at least 5 more minutes, and then press the **Power Off** button to turn off the compressed air.

2 Fill out any remaining process details in the log book.

3 Disable the **"K1 RTA RTP600S"** in Badger.

7 Problems/Troubleshooting

Problem	**Possible Solution**
Temperature LCD display shows a negative number.	This is generally caused whenever the thermocouple (TC) has been installed backwards. When installing the TC, the screw heads should be facing down on the white TC connector (nuts facing up). If this does not resolve the problem, contact MNC staff and **do not** use the system.
Temperature LCD display appears to be unresponsive (e.g. it does not decrease after a process is over).	This most often happens if you aborted a process, and are still on the screen showing the process graph. Return to the "Recipe Data File Directory" by pressing the **Enter** button. See if the temperature display is now updated. This could also be caused by a TC sensor board malfunction. If the above doesn't solve this problem, contact appropriate MNC staff.
Process recipe validation is NOT successful.	Ensure that the gas purging requirements have been met (top of page 5 in this SOP). If needed, contact MNC staff for more details.

Temperature vs. Max Time Allowed

Process Temp (°C)	Max Time (seconds)
1150	50
1100	75
1050	80
1000	90
950	100
900	110
850	130
800	150
750	180
700	225
650	300
600	450
550	900
500	1125
450	1350
400	1575
350	1800
300	2025
250	2500
200	2500
150	2500