MONTANA STATE UNIVERSITY | Montana Microfabrication Facility

AML Aligner Wafer Bonder

Process Overview

The AML Aligner Wafer Bonder (AWB) is used to bond two wafers together for micro electromechanical systems (MEMS), microfluidic systems, or various other applications. Bonding processes that are possible on the AWB include anodic, adhesive, or eutectic bonding. These processes typically use pressure, force, and heat, together with either high voltages, adhesives materials, and/or annealing to join two wafers. Specifically, anodic bonding relies on high voltage to induce ion migration between a glass and silicon wafer, forming covalent bonds at elevated temperatures. Adhesive bonding utilizes an intermediate adhesive material to form strong bonds between wafers under controlled pressure and temperature. Finally, eutectic bonding typically involves melting a thin layer of material between two wafers at high temperatures, allowing them to join upon solidification, which will form a strong metallic alloy/bond. This equipment offers several advantages over traditional bonding methods, including precise bonding parameter controls, cost-effectiveness, and precision alignment features. Given the involvement of high voltages, heat, pressure, and force, it is crucial to follow all safety protocols during operation. Please follow this link for more information.

Tips for Success

- Wafer cleanliness
- Alignment

Safety

- The interior of the chamber can get very hot. Make sure the tool has cooled to less than 150 C before attempting to remove your samples.
- This tool has high voltage sources for the rad ring and anodic bonding. Do not attempt to remove covers or to operate these functions with the lid open or with any covers removed.
- Do not pinch yourself when opening or closing the powered lid.
- The tool uses compressed oxygen and nitrogen. Wear safety glasses.

Allowed Materials and Processes

- Anodic bonding, SU-8 to SU-8 bonding, SU-8 to glass bonding, thermocompression bonding, gold-tin eutectic bonding.

Restricted Materials and Processes

- Work with the lab manager to develop new processes.

Important Notes

- Do not ever home the stage with the "Home Stages" button on the "Wafer alignment" window. The stages will be damaged if the motors do not shut down properly.
- Do not unintentionally hit the EMO on the front of the tool.
- When in manual mode, use caution when changing parameters. Be careful not to increase the force beyond recommended values (e.g., 1kN for the graphite platens). Note that the force increases immediately when you click out of the edit box.
- Do not ever turn on the high voltage supply when the chamber is not under vacuum.
- Never open the chamber when the temperature is above 200 C.

Equipment Checks

1. Check the tool configuration with the MMF staff. If you need different platens or a different configuration, request the desired changes from the staff with as much notice as possible.
2. Equipment checks
    a. Check that the machine is on and that the AWB Control Program window is open.
    b. If the AWB Launcher window is open, click on "Control Program."
    c. If the software is not open, click on the "AWB Launcher" icon on the desktop.

Automatic Operating Procedures

1. Note that these instructions may vary slightly depending on the automatic recipe steps. In particular, the wafer loading steps change depending on whether the wafers are stacked prior to insertion or if alignment is used and the upper platen clamp is used.
2. From main "AWB Control Program" window, select "Auto" and "Anodic" or "Other" and "Ok."
3. Enter a Run ID so that you can get the data later if needed.
4. Select your recipe from the "Recipe" drop down list. Verify that the "Platen size," "Upper platen," and "Lower platen" settings are correct for your recipe. For anodic bonding, "Upper platen" should be "Graphite."
5. Verify or edit your process steps. The password for editing is "aml". Verify your wafer thicknesses on the "General Parameters" tab of the "Edit existing recipe" window.
6. Select "OK" on the "Process Details" window to proceed.
7. Press "Start" on the upper right of the screen.
8. When the chamber has vented fully (as indicated by a message that pops up saying, "Please load wafers"), click "OK" and unscrew the bolts, using care to avoid unscrewing the bolts too far. If they are unscrewed too far, they will come out completely and are very difficult to get back in. Pull up on the washers slightly and move the bolts to the side.
9. Use the "OPEN" switch on the powered lid drive and the white powered lid drive button to open the chamber until it hits the hard stop. Make sure the station on the right side of the main

chamber doesn't have anything on it that will be squished by the cables coming from the main chamber.

10. When the chamber is open, verify that the centering shims on the bottom chuck and the centering screws on the top chuck are correct for your wafer thickness. They should be 80-120 um less than your wafer thickness. If you are putting the wafer stack together outside of the chamber, it may be necessary to remove the centering screws on the top.
11. Follow the instructions on the "Load Wafers" window. Make sure the "CLAMP /RELEASE" toggle is on the release position.
    a. If your recipe requires alignment, place one wafer on the bottom chuck and one wafer on the top. Make sure the correct sides are facing up. This is particularly important when using optically transparent wafers. Hit the "CLAMP/RELEASE" toggle to clamp the top wafer.
    b. If your recipe does not require alignment, you can align the wafers manually and then place the stack on the bottom chuck. Toggle the clamp to make sure that the tool thinks the top wafer is clamped.
    c. Close the chamber lid using the POWERED LID DRIVE buttons.
    d. Bolt down the lid using the torque wrench using a cross pattern. The red bar should be at 12 N-m on the torque wrench. Do not change it. If it isn't at 12, inform staff.
    e. Click "Ok" on the software. At this stage, the chamber will typically pump for most recipes.
12. Align wafers (optional and recipe dependent)
    a. On the "Camera Control" window, click the "Visible" button to turn on the microscope light sources. Use the x, y, and z micrometers on the microscope to move the alignment marks on the top wafer into the video screen. Then move the focal plane to the lower wafer using the larger focus knob behind the two microscopes.
    b. Adjust the step sizes for the translation and the rotation. Start with something like 100 um for the step size, and then move to 10 and 5 or 1 as you get closer to aligned. For the theta, start with 0.1 deg.
    c. Use the space bar and the arrows to translate the bottom wafer with respect to the fixed top wafer. Use the left and right arrows to rotate the bottom wafer. NOTE: pressing the up and down arrow without simultaneously pressing the space bar will raise and lower the stage. Do not reduce the spacing between your wafers to less than about 500 um to avoid catching them.
    d. You may draw a rectangle to aid in the alignment. Draw them on the fixed top wafer, then focus on the bottom wafer as you raise it upward.
    e. Close the camera window and accept the alignment or cancel the run.
13. Monitor bond.
14. Unload wafer. Follow the prompts.

15. Pump down.
    a. Close the chamber by holding "Powered Lid Drive" button and "Close" button.
    b. Tighten screws on chamber door.
    c. On the main page select "manual" and then okay. It will ask for a password, use "aml".
    d. Once in the manual mode home page of the software, press the "Start" button.
    e. Press the CLOSED button under Isolation. It will turn green and say OPEN. Press the switch under Pump to change it from the OFF to the ON position. Wait for the pressure to reach <1E-4.
    f. Turn pump off, the press "Stop Process". The system should exit software screen and return to beginning home page.

Manual Operation

- **Important: every manual process must have an accompanying SOP, checked off by the lab manager, that includes operating and shutdown procedures, as well as troubleshooting and contingency planning.**

Sample Process: Anodic Bonding with No Alignment

1. Check tool configuration. The following instructions assume that both tungsten platens are installed.
2. Select Manual in the "Make a Selection" box and press OK. Enter "aml" for the password.
3. Fill out the parameters on the Set parameters screen. Enter a Run ID. Enter comments if you would like. IN the Wafers section, enter the total wafer thicknesses including the thickness of one graphite plate (e.g. Upper = 0.525 mm Si + 0.500 mm Borofloat + 1.4 mm graphite = 2.6 mm). Change the log time to **10 s.** Do not change the vacuum pump settings.
4. Click Ok and then press "START [F1]" in the upper right of the window.
5. Check that the "Separation of wafers" value in the lefthand box (i.e. present value) is greater than 3 mm.
6. Open the nitrogen valve to vent the system by clicking on the "Closed" button below Nitrogen in the Valves box. Wait for the pressure to get >1.1E+3 mBar and for the Exhaust valve to open. After the exhaust valve opens, the pressure will drop back down to ~8.5 E+2.
7. Turn off the nitrogen by clicking the "Open" button below Nitrogen.
8. Verify that nothing is going to be squished by the cables to the right of the chamber. Unbolt the lid, verify that the button next to "Powered lid" is green and reads "Unlocked."
9. Open the chamber by pressing the white POWERED LID DRIVE button and rocking the POWERED LID DRIVE switch to the OPEN position.
10. Remove the alignment screws from the top platen. Lower the wafer clamp mechanism so it is below the level of the top platen.

11. Verify that there is not a graphite disc on the bottom platen. If there is one in place, remove it and replace the centering shims. The larger section of the centering shims faces inward. Install them in the same direction that you removed them. Verify that the screws are completely level or below the shims and do not protrude at all.
12. Load your wafers on the bottom chuck, with the glass wafer on top. Make sure the wafers are centered within the shims and that the flat is aligned toward you.
13. Place a lobed graphite disc over the top of the stack. Place the graphite so the lobes are out of phase with the shims on the platen.
14. Close and bolt the lid. Use the torque wrench with a cross pattern to tighten the bolts.
15. Press the CLOSED button under Isolation. It will turn green and say OPEN. Press the switch under Pump to change it from the OFF to the ON position. Wait for the pressure to reach <1E-4.
16. Test the HV by setting the Target voltage (V) to 100.0 and the Current limit (mA) to 0.1 and then turning on the HV SUPPLY by pressing the switch next to DISABLE/ENABLE. Verify that the voltage is ~100V and that the current is <0.05 mA.
17. Turn OFF the HV SUPPLY.
18. Set the Platen force to 100 N and hit "Controlling Force" to active force control. Wait for the wafers to come in contact and for the platen force reading to reach ~100 N.
19. Test the HV by setting the Target voltage (V) to 100.0 and the Current limit (mA) to 0.1 and then turning on the HV SUPPLY by pressing the switch next to DISABLE/ENABLE. Verify that the voltage is ~100V and that the current is <0.05 mA.
20. Turn OFF the HV SUPPLY.
21. Press the **Start controlled heating** button. Enter the bonding temperature for both platens. Do not bond at temperatures greater than 400 C without speaking with the lab manager. Use 20 C/min for the ramp rates. Leave differential heating disabled. Press Start controlled heating. The set temperatures should be visible and the green lights next to the platen temperature readings should flash on and off while it heats. (Note: if a red alert pops ups saying "AWB2005: Warning – temperature controller communications error on temp controller…" clear the warning and continue.)
22. When the temperatures stabilize at the set temperature, increase the platen force to the specified value. Do not use more than 1kN of force. Then press the "**Controlling Force"** button under "Platen Force"
23. Turn the voltage on at 100 V and 0.1 mA and then enable the HV SUPPLY. Wait 30 s and then change the current limit to 4 mA and then raise the voltage to 800 V.
24. Turn the voltage off after 20 minutes or when the total charge equals 1500 mC and record the Total Charge (mC) and the residual Current (mA).
25. Press the red OFF button in the red TEXT in the HEATERS section. This sets both temperature set points back to 0.

26. Verify that the Wafer clamp is still in the RELEASE position.
27. Set the Separation to 4.00 mm and hit the Controlling Separation button.
28. Press the on/off switch in the Pump section. This will close the isolation valve and turn off the turbo pump.
29. Presse the CLOSED button under Nitrogen. The button will turn green and read OPEN.
30. Wait until both platen temperatures are <150 C.
31. Press the OPEN button under Nitrogen to turn off the nitrogen.
32. Unbolt and open the lid. Remove your wafers and the graphite.
33. Close and bolt the lid. Open the isolation valve and turn on the pump. Wait for the pressure to reach <1E0 mBar.
34. Press STOP PROCESS [ESC] and Finish.

Troubleshooting: Tool will not pump down in manual mode

- Make sure to run the nitrogen and vent before trying to pump down chamber
- Ensure the isolation valve is open
- before turning on pumping

- Tool will not vent.
  - Watch the pressure in the chamber. The tool registers as vented only when the pressure reached 1.1E+2 mbar. It cannot reach this pressure unless the chamber is bolted down. If the bolts are not tight, it will not reach this pressure.
- During alignment a message reads, "X, Y software limit active"
  - Get staff to help.
- Chamber lid will not open after process is finished and platens are cooled
  - Open exhaust to let chamber pressure settle, then close exhaust when settled
  - wait for a few minutes before attempting again
- A message says "The vacuum pump is due for a service. You will not be allowed to proceed past the configuration screen without confirming that the oil has been changed, or supplying the engineer password to override this warning."
  - Our tool has a diaphragm pump that doesn't require an oil change. Press OK and continue. You will later need to enter "aml" as the engineer password.

Sample Process: Anodic Bonding with Alignment

1. Check tool configuration. The following instructions assume that both tungsten platens are installed.
2. Select Manual and press OK. Enter "aml" for the password.
3. Enter a Run ID. Enter the total wafer thickness stack including the thickness of one graphite plate (e.g. 520um Si + 500 um Borofloat + 1.4 mm graphite = 2.6 mm).
4. Change the log time to 5 s. Do not change the vacuum pump settings.

5. Click Ok and then press Start in the upper right of the window.
6. Check that the wafer separation is >3 mm.
7. Open the nitrogen valve to vent the system by clicking on the "Closed" button below Nitrogen.
    a. Wait for the pressure to get >1.1E+3 mBar and for the Exhaust valve to open. After the exhaust valve opens, the pressure will drop back down to ~8.5 E+2.
    b. Turn off the nitrogen by clicking the "Open" button below Nitrogen.
8. Verify that nothing is going to be squished by the cables to the right of the chamber. Unbolt the lid, verify that the button next to Powered lid is green and reads "Unlocked."
9. Open the chamber by pressing the white POWERED LID DRIVE button and rocking the POWERED LID DRIVE switch to the OPEN position.
10. Verify that there is not a graphite disc on the bottom platen. If there is one in place, remove it and replace the centering shims. The larger section of the centering shims faces inward. Install them in the same direction that you removed them. To avoid damaging the machine, verify that the screws are completely level or below the shims and do not protrude at all.
11. Check the alignment screws from the top platen. Note that the height they protrude is significantly less than their nominal value because the graphite has been slowly worn away. For example, as of 12/16/2020, the 0.6 mm screws protrude ~0.4 mm from the platen.
12. Check the centering shims on the bottom platen. They should be >100 um less than the thickness of the wafer. For example, with 0.350 mm thick wafers, the shims should be 0.25 mm.
13. Load the glass wafer on the top platen and clamp it. If possible, verify that the clamp is ~100 um below the surface of the wafer, and adjust the height using the wide thumb screw on top of the clamp mechanism. This may be tricky to accomplish. If you cannot get a good clamp while the height is ~100 um below the wafer surface, get it as low as possible while still clamping securely. Make sure that the clamp retracts at least 2 mm from the edge of the wafer, and then clamp one final time.
14. Load your silicon wafer on the bottom chuck. Make sure the wafers are centered within the shims and that the flat is aligned toward you. Place a lobed graphite disc over the top of the stack. Place the graphite so the lobes are out of phase with the shims on the platen.
15. Close and bolt the lid. Use the torque wrench with a cross pattern to tighten the bolts.
16. Press the CLOSED button under Isolation. It will turn green and say OPEN. Press the switch under Pump to change it from the OFF to the ON position. Wait for the pressure to reach <1E-4.
17. Test the HV by setting the Target voltage (V) to 100.0 and the Current limit (mA) to 0.1 and then turning on the HV SUPPLY by pressing the switch next to DISABLE/ENABLE. Verify that the voltage is ~100V and that the current is <0.05 mA.
18. Set the Platen force to 100 N and hit Controlling Force to active force control. Wait for the wafers to come in contact and for the platen force reading to reach ~100 N.

19. Press the **Start controlled heating** button. Enter the bonding temperature for both platens. Do not bond at temperatures greater than 400 C without speaking with the lab manager. Use 20 C/min for the ramp rates. Leave differential heating disabled. Press Start controlled heating. The set temperatures should be visible and the green lights next to the platen temperature readings should flash on and off while it heats. (Note: if a red alert pops ups saying "AWB2005: Warning – temperature controller communications error on temp controller…" clear the warning and continue.)
20. When the temperatures stabilize at the set temperature, increase the platen force to the specified value. Do not use more than 1kN of force.
21. Turn the voltage on at 100 V and 0.1 mA. Wait 30 s and then change the current limit to 4 mA and then raise the voltage to 800 V.
22. Turn the voltage off after 20 minutes and record the Total Charge (mC) and the residual Current (mA).
23. Press the red OFF button in the HEATERS section.
24. Verify that the Wafer clamp is still in the RELEASE position.
25. Set the Separation for 4.00 mm and hit the Controlling Separation button.
26. Press the on/off switch in the Pump section. This will close the isolation valve and turn off the turbo pump.
27. Presse the CLOSED button under Nitrogen. The button will turn green and read OPEN.
28. Wait until both platen temperatures are <150 C.
29. Press the OPEN button under Nitrogen to turn off the nitrogen.
30. Unbolt and open the lid. Remove your wafers and the graphite.
31. Close and bolt the lid. Open the isolation valve and turn on the pump. Wait for the pressure to reach <1E0 mBar.
32. Press STOP PROCESS and Finish.

Troubleshooting

- Tool will not pump down in manual mode
    - Make sure to run the nitrogen and vent before trying to pump down chamber
    - Ensure the isolation valve is open before turning on pumping
- Tool will not vent.
    - Watch the pressure in the chamber. The tool registers as vented only when the pressure reached 1.1E+2 mbar. It cannot reach this pressure unless the chamber is bolted down. If the bolts are not tight, it will not reach this pressure.
- During alignment a message reads, "X, Y software limit active"
    - Get staff to help.

Version History

- 2020.1 Original document written by Andrew Lingley. Incomplete.
- 2021.1 Various clarifications and additions to automatic and manual processes.
- 2023.1 Updated by Jesse Denk. Added Process Overview and Tips for Success.
- 2025.1 Updated for accessibility by Owen Bunn