# Thermal Evaporator User Manual

## Important Note

1. **Don't turn off the power of the machine unless it is not in heavy use**
2. **Do not use the machine without trained and qualified by staff.**
3. **Materials allowed for each system are restricted which are listed in the attached table. Never deposit materials that are not allowed.**
4. **Staff contacts:**

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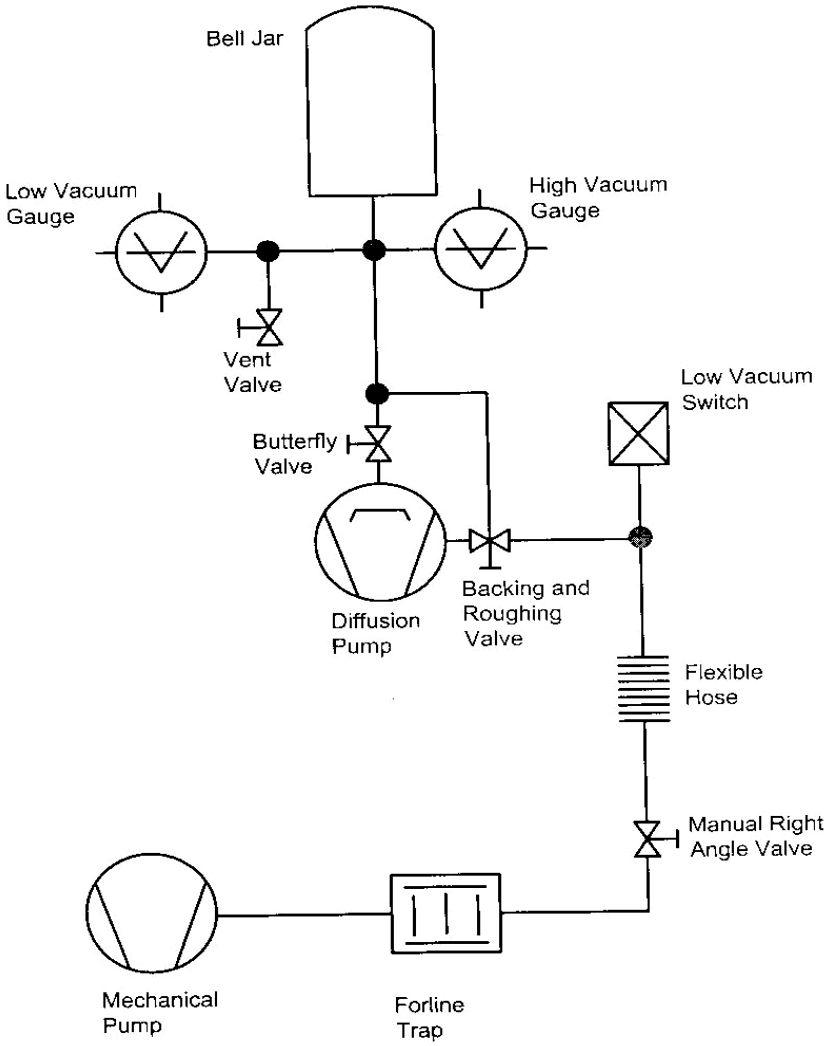


# Typical Operating Procedure

### *I. Starting from cold pump*

1. Ensure the butterfly valve between the diffusion pump and the baseplate is closed (SHUT)_lever fully anticlockwise(see the arrow on the tool)
2. Ensure the vacuum valve between the foreline trap and the diffusion pump is open (left always open unless a next regeneration is needed every ~ 6 months)
3. Set the roughing/backing valve to backing position
4. Ensure the cooling water from the chiller flowing into diffusion pump cooling line.
5. Switch on the mechanical pump
6. Set roughing/backing valve to backing position, turn on the diffusion pump. Wait for 45 min to allow the diffusion pump to reach operating temperature and outgas its oil.
7. Now, you are ready to go to Bell Jar Pump-Down

### *II. Venting*

1. Check the low-pressure $N_2$ supply (at the entrance of the supporting area) is on and set at ~15 psi (~1atm)
2. Check the high-vacuum gauge (IG: Ion Gauge), make sure it is off
3. Close the High Vacuum Gate Valve_Butterfly Valve (wait for it to close completely), make sure the Backing & Roughing Valve is on Backing position for the diffusion pump.
4. Open the vent valve; wait for the chamber pressure fully reaches atmosphere pressure.
5. 'Raise' the Bell Jar. Once the chamber is opened, close the vent valve.

### *III. Loading sample and metal source*

1. Open the shutter
2. Mount your sample on the sample holder using clamps or vacuum tape, and install the holder plate on the supporting frame facing downwards to the evaporation source.

   **Note:**

   a) The position (height) of the sample holder is fixed and marked by two screws. The tooling factor for each material is calibrated based on the position of the screws.
   b) NEVER change the screw position.
   c) NEVER change the position or angle of the crystal monitor, otherwise the measurement of film thickness is not accurate.
3. Secure tungsten source boats into the selected electrodes (electrode positions are numbered backwards); tighten the electrodes.
4. Put the evaporant in the boat (make sure the material is allowed for the system).
5. Make sure the sample/substrate as well as the crystal monitor is in line with the source.
6. Close the shutter

***IV. Bell Jar Pump-Down***

Assume the mechanical pump is on; the roughing/backing valve is set to backing and the butterfly valve is SHUT; the diffusion pump has been on for 45 minutes.

1. Ensure the chamber vent valve is closed;
2. Wipe off the gasket to make sure there is no particle sticking on the O-ring.
3. Gently lower the bell jar and lightly press it against baseplate;
4. Move the roughing/backing valve to roughing (The vacuum protection switch installed in the roughing/backing line will automatically switch off the diffusion pump until the pressure returns to an acceptable level.)
5. Wait for the pressure to reach 100mTorr ($10^{-1}$ Torr). Observe the low vacuum gauge (thermocouple), the needle go down from atmospheric pressure to below 100mTorr. Then, the diffusion pump will be switched on automatically.
6. When the vacuum reaches 50 mTorr, move the roughing/backing valve to backing.
7. Slowly open the butterfly valve
8. Turn on the IG, the pressure fall from $10^{-4}$ to $10^{-6}$ Torr (If necessary, wait for about one minute and turn on the "degas' button of the IG for another minute. Turn off 'degas' then after).
9. Wait for pressure to reach $< 5\times10^{-7}$ Torr if possible.
10. You are now ready to start deposition.

***V. Set up the evaporation program on the controller***

1. IMPORTANT NOTE:
   a) Only several materials are allowed for each machine, as listed in Table 1. Never deposit materials that are not allowed.
   b) For each controller, the maximum film number that can be edited is 9. Among them, the first 7 films (No. 1 - 7) are reserved for the most commonly used materials and should not be edited. Individual users can use the last two film numbers (8 – 9) for other allowed materials.
   c) For each machine, the material parameters, such as bulk density, Z-value and tooling factor, are listed in Table 1. The tooling factor will be calibrated and provided periodically.
2. Move the power switch to the selected power source (It's fixed in this system unless multi-source operation is necessary), and make sure the shutter is closed.
3. Refer to the Manual Chapter 2 for Rate/Thickness Monitor
   a. Press Program and dial Control Knob to select the desired film #(1~9)
   b. Set the film thickness as required. For more meterial parameters, refer to the appendix.
   c. Press "Program" again to confirm the setting.

**VI.** ***Evaporation and Deposition***

When the vacuum level approaches $2\times10^{-6}$ Torr and the sample substrate is heated to the desired temperature, it's ready to start deposition.

1. Turn off the IG;
2. Turn on the source (evaporation) power supplier TEPS2000.

3. Raise the power slowly. At a certain point depending on the material, the chamber pressure may increase due to 'degassing' of the source. Wait for the pressure to be stabilized. Repeat the procedure until evaporation begins to occur.
4. When the evaporation rate is stable at the desired rate, open the shutter then press 'Zero'.
5. When the desired thickness is reached, close the shutter
6. Decrease the power to zero.
7. Turn off the evaporation power supplies.
8. Turn off the substrate heater

***VII. Unload sample, clean-up and finish***

1. Wait for 2 minutes for sources to cool down.
2. Turn off the Ion Gauge IG.
3. Close the high vacuum valve (butterfly valve to the diffusion pump).
4. Open the vent valve.
5. After the chamber pressure fully reaches atmosphere, raise the Bell Jar. Once the chamber is open, close the vent valve.
6. Remove the sample and the source boat (bar). Remove any vacuum tape from the substrate holder.
7. To start another deposition, repeat the process from Step III
8. If you want to shut down the system, Lower the Bell Jar, vacuum the chamber to the $10^{-1}$ Torr level. Move roughing/backing valve to Backing position, turn off the diffusion pump and leave backing pump on for ~ 30min. Then turn off the mechanical pump and cooling water.
9. Otherwise, keep the chamber in high vacuum with diffusion pump/backing pump on.

***Useful knowledge on thermal evaporation***

## Evaporation System Requirements

• Vacuum:
– Need $10^{-6}$ torr for medium quality films.
– Can be accomplished in UHV down to $10^{-9}$ torr.
• Cooling water:
– Hearth
– Thickness monitor
• Mechanical shutter:
– Evaporation rate is set by temperature of source, but this cannot be turned on and off rapidly. A mechanical shutter allows evaporant flux to be rapidly modulated.
• Electrical power:
– Either high current or high voltage, typically 1-10 kW

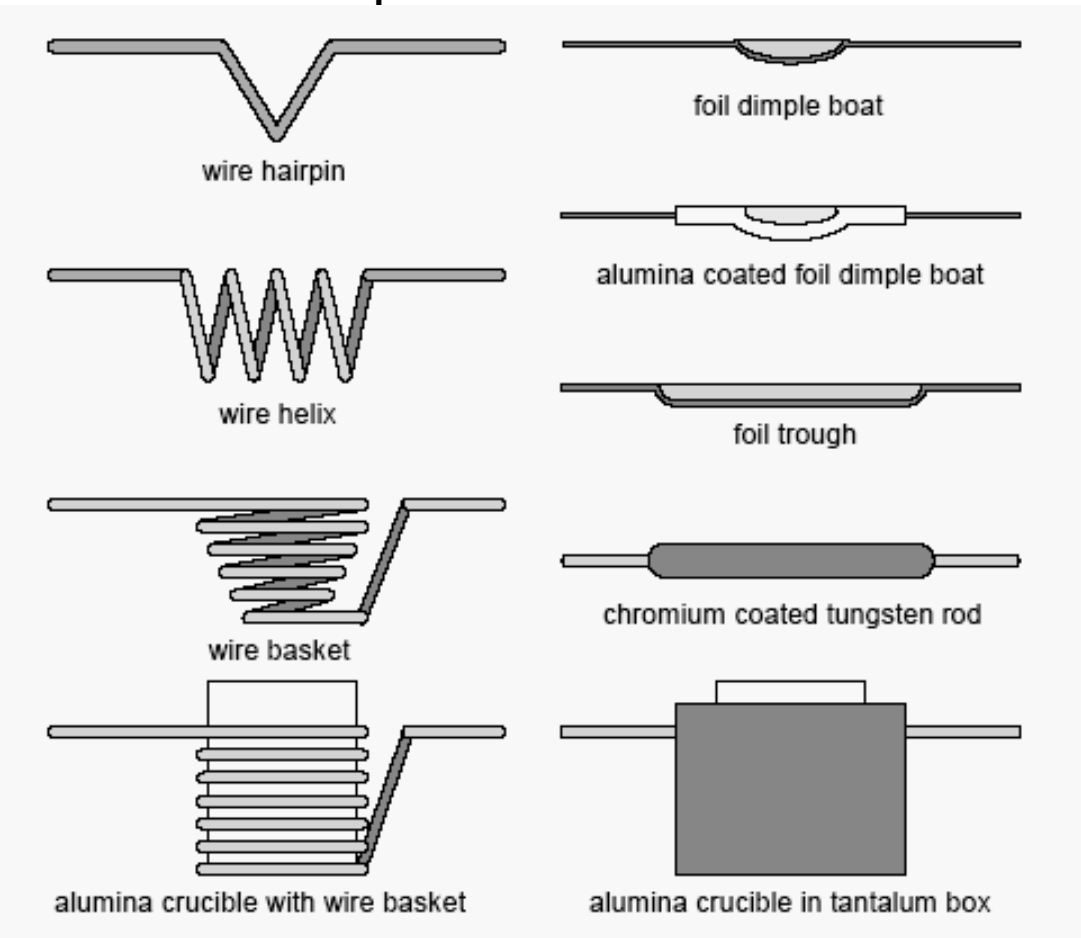
## Evaporation Support Materials

• Refractory metals:
– Tungsten (W); MP = 3380°C, P* = $10^{-2}$ torr at 3230°C
– Tantalum (Ta); MP = 3000°C, P* = $10^{-2}$ torr at 3060°C
– Molybdenum (Mo); MP = 2620°C, P* = $10^{-2}$ torr at 2530°C
• Refractory ceramics:
– Graphitic Carbon (C); MP = 3700°C, P* = $10^{-2}$ torr at 2600°C
– Alumina ($Al_2O_3$); MP = 2030°C, P* = $10^{-2}$ torr at 1900°C
– Boron nitride (BN); MP = 2500°C, P* = $10^{-2}$ torr at 1600°C
• Engineering considerations:
– Thermal conductivity
– Thermal expansion
– Electrical conductivity
– Wettability and reactivity

## Resistance Heated Evaporation

• Simple, robust, and in widespread use.
• Can only achieve temperatures of about 1800°C.
• Use W, Ta, or Mo filaments to heat evaporation source.
• Typical filament currents are 200-300 Amperes.
• Exposes substrates to visible and IR radiation.
• Typical deposition rates are 1-20 Angstroms/second.
• Common evaporant materials:
– Au, Ag, Al, Sn, Cr, Sb, Ge, In, Mg, Ga
– CdS, PbS, CdSe, NaCl, KCl, AgCl, $MgF_2$, $CaF_2$, $PbCl_2$

## Resistance Heated Evaporation Source Fixtures



# Appendix

**Table 1, Deposition Parameters of Materials (TE-3)**

**(NOTE: TE-3 only allows NON-MAGNETIC METALS and CONTACT material, such as Al, Ti, Cr, Cu, Pd, Ag, Pt, Au)**

| Film Number | Metal | Density (g/cm3) | Z-Ratio | Tooling factor (date: __/__/__) | Tooling factor (date: __/__/__) | Tooling factor (date: __/__/__) | Tooling factor (date: __/__/__) | Tooling factor (date: __/__/__) |
|---|---|---|---|---|---|---|---|---|
| 1 | Cr | 7.2 | 0.305 | 105% | | | | |
| 2 | Ti | 4.5 | 0.628 | 105% | | | | |
| 3 | Au | 19.3 | 0.381 | 105% | | | | |
| 4 | Pd | 12 | 0.357 | 105% | | | | |
| 5 | Ag | 10.5 | 0.529 | 105% | | | | |
| 6 | Al | 2.73 | 1.08 | 105% | | | | |
| 7 | Pt | 21.4 | 0.245 | | | | | |
| 8 | Cu | 8.93 | 0.437 | | | | | |
| 9 | other | | | | | | | |

**Table 1, Tooling Factors of Materials (TE-4, for both controller)**

**((NOTE: TE-4 only allows LOW-VAPOR METALS, such as Al, Ti, Cr, Fe, Co, Ni, Cu, Pd, Ag, Pt, Au)**

| Film Number | Metal | Density (g/cm3) | Z-Ratio | Tooling factor (date: __/__/__) | Tooling factor (date: __/__/__) | Tooling factor (date: __/__/__) | Tooling factor (date: __/__/__) | Tooling factor (date: __/__/__) |
|---|---|---|---|---|---|---|---|---|
| 1 | Cr | 7.2 | 0.305 | R,110/L, 100 | | | | |
| 2 | Ti | 4.5 | 0.628 | R,100/L, 100 | | | | |
| 3 | Au | 19.3 | 0.381 | R,110/L, 100 | | | | |
| 4 | Pd | 12 | 0.357 | | | | | |
| 5 | Ag | 10.5 | 0.529 | R,100/L, 100 | | | | |
| 6 | Al | 2.73 | 1.08 | R,100/L, 100 | | | | |
| 7 | Pt | 21.4 | 0.245 | | | | | |
| 8 or 9 | Fe | 7.86 | 0.349 | R,100/L, 100 | | | | |
| 8 or 9 | Co | 8.71 | 0.343 | R,100/L, 100 | | | | |
| 8 or 9 | Ni | 8.91 | 0.331 | R,100/L, 100 | | | | |
| 8 or 9 | Cu | 8.93 | 0.437 | R,100/L, 100 | | | | |
| 8 or 9 | | | | | | | | |
| 8 or 9 | | | | | | | | |

**Table 1, Tooling Factors of Materials (TE-5)**

**((NOTE: TE-5 only allows GENERAL METALS and CONTACT material, such as Al, Ti, Cr, Ni, Ge, Pd, Ag, Pt, Au)**

| Film Number | Metal | Density (g/cm3) | Z-Ratio | Tooling factor (date: __/__/__) | Tooling factor (date: __/__/__) | Tooling factor (date: __/__/__) | Tooling factor (date: __/__/__) | Tooling factor (date: __/__/__) |
|---|---|---|---|---|---|---|---|---|
| 1 | Cr | 7.2 | 0.305 | 90 | | | | |
| 2 | Ti | 4.5 | 0.628 | 90 | | | | |
| 3 | Au | 19.3 | 0.381 | 90 | | | | |
| 4 | Pd | 12 | 0.357 | | | | | |
| 5 | Ag | 10.5 | 0.529 | 90 | | | | |
| 6 | Al | 2.73 | 1.08 | 90 | | | | |
| 7 | Pt | 21.4 | 0.245 | | | | | |
| 8 | Ni | 8.91 | 0.331 | 90 | | | | |
| 9 | Ge/other | 5.35 | 0.516 | 90 | | | | |
| 9 | Other | | | | | | | |