Standard Operating Procedures

Edwards Thermal Evaporator

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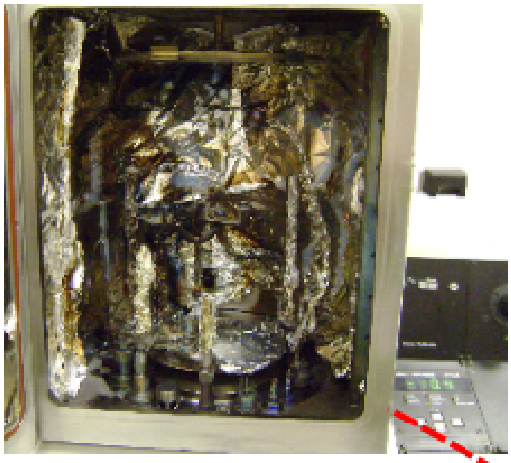
Important

- Gloves should be worn while handling substrate and deposition material to reduce contamination.
- Do not press “Stop” or “Start” buttons. They should be covered by a glass slide and labeled with a warning.
- Please return chamber to a vacuum when done with machine. This ensures no atmospheric contamination.
- You can only use CeNSE laboratories and equipment if you have been approved by Brian or Chuck, reserved the tool on the calendar, and filled out a form. No Exceptions!
- If the equipment is acting unusual STOP! Please discuss with Brian or Chuck before proceeding and leave a note on the machine.
- Any accidental damage must be reported immediately.
- All CeNSE laboratories are protected by video surveillance.

Machine exterior and chamber Device controls

Figure1c: Control panel

Figure 1a: Chamber interior



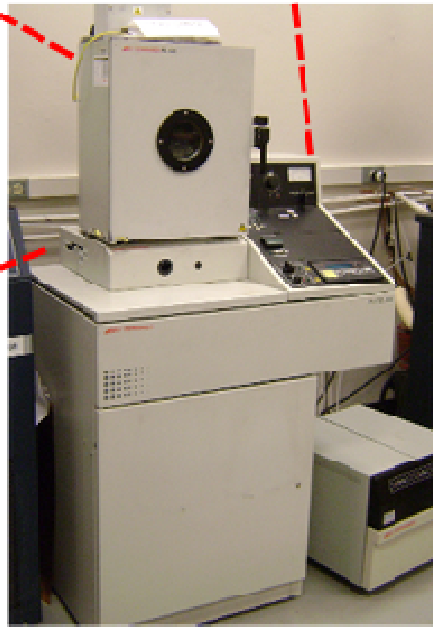
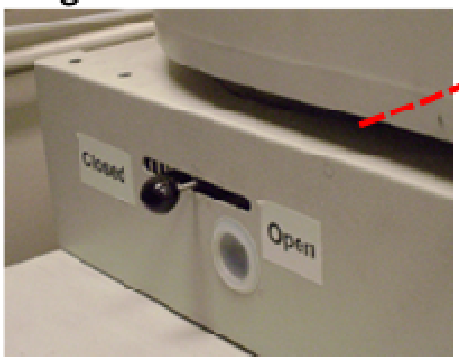


Fig1a: Shutter Control



Machine exterior and chamber Device controls

Figure 2d: Amperage control

Figure 2c: Thickness gauge

Figure 2b: Rotary workholder controller

Figure 2a: Chamber pressure controller

Operating Procedure

1. Preparation
    1.1. Before beginning, be sure to wear gloves to reduce contamination.
2. Pressurize chamber
    2.1. Press vent on chamber pressure controller (Fig 2a) – system will slowly pressurize to atmospheric pressure. This will take approximately 3 to 5 minutes.
    2.2. Once atmospheric pressure has been reached (~760 torr) the chamber door will release.
    2.3. A hissing sound will be observed coming from the machine. This is nitrogen gas purging the system. After several seconds, press “seal” on chamber pressure controller (Fig 2a) to stop purge.
3. Load Chamber
    3.1. This evaporator is capable of accepting two deposition materials at once. The evaporator has an upper and lower electrode.
    3.2. Clip sample onto stage at top of chamber.
    3.3. Select a tungsten filament or boat with appropriate deposition material. Using a hex wrench, tighten filament onto desired electrode.
4. Closing Chamber
    4.1. Ensure that all samples, deposition materials are loaded and secured.
    4.2. Close and lock chamber door
    4.3. Hit “Cycle” on chamber pressure controller (Fig 2a) be begin vacuum cycle.
    4.4. Proceed to next step once a chamber pressure range of 10^{-5} torr has been reached.
5. Set thickness gauge
    5.1. Using the thickness gauge (Fig 2c), press the “Data” button until the “Layer” LED is lit. This thickness gauge is capable of measuring two different films.
    5.2. Using the “Data” button, select the “Density” LED. Use the “Up” and “Down” buttons to enter the density of your first deposition material from appendix A, provided at the end of this document.
    5.3. Using the “Data” button, select either the nm or µm LED. Use the “Up” or “Down” buttons to select your desired thickness.
    5.4. Proceed to the next step.
6. Evaporating the deposition material.
    6.1. With the shutter in the “closed” position (Fig 1a), and with the chamber pressure in the 10-5 torr range, choose the deposition source material on the amperage control (Fig 2d).
    6.2. With the shutter still closed, slowly turn up the amperage on the power supply while monitoring chamber vacuum. Continue until a change in vacuum pressure

occurs or tungsten boat begins to glow. Once this occurs, leave the machine for 5 minutes.

6.3. After 5 minutes, increase amperage on power supply until thermal evaporation of source material occurs.

6.3.1. Ensure vacuum does not go beyond the 10^{-3} torr range

6.3.2. Adjust amperage to achieve desired deposition rate. Once achieved, open shutter and press the “Run” button on the thickness monitor.

6.4. Monitor thickness gauge until desired thickness is achieved.

6.4.1. Thickness gauge will dim the LED displaying “shutter open”. This indicates that the desired thickness has been achieved.

6.4.2. Once target thickness is achieved, close shutter and slowly turn down power supply amperage. Turn power supply back to zero.

6.5. For second material, repeat steps 6.1 through 6.4

7. Opening chamber

7.1. Once deposition procedure is complete, wait 10 minutes for boat to cool. Failure to do so can oxidize boat and deposition material.

7.2. After 10 minutes, press “vent” on the chamber pressure controller (Fig 2a). The chamber will now begin to pressurize. It will take approximately 3 to 5 minutes to reach atmospheric pressure. The chamber pressure controller will display “Sealed” when this occurs.

7.3. Remove deposition material and sample.

7.4. Return chamber to vacuum by pressing “cycle” on the chamber pressure controller (Fig 2a).

Appendix A: Deposition Material Properties

Deposition material properties:[1]

Formula	Density	Z-Ratio	Acoustic Impedance	Material Name
Ag	10.5	0.529	16.69	Silver
AgBr	6.47	1.18	7.48	Silver Bromide
AgCl	5.56	1.32	6.69	Silver Chloride
Al	2.70	1.08	8.18	Aluminum
Al2O3	3.97	0.336	26.28	Aluminum Oxide
Al4C3	2.36	?		Aluminum Carbide
AlF3	3.07	?		Aluminum Fluoride
AlN	3.26	?		Aluminum Nitride
AlSb	4.36	0.743	11.88	Aluminum Antimonide
As	5.73	0.966	9.14	Arsenic
As2Se3	4.75	?		Arsenic Selenide
Au	19.3	0.381	23.18	Gold
B	2.37	0.389	22.70	Boron
B2O3	1.82	?		Boron Oxide
B4C	2.37	?		Boron Carbide
BN	1.86	?		Boron Nitride
Ba	3.5	2.1	4.20	Barium
BaF2	4.886	0.793	11.13	Barium Fluoride
BaN2O6	3.244	1.261	7.00	Barium Nitrate
BaO	5.72	?		Barium Oxide
BaTiO3	5.999	0.464	19.03	Barium Titanate (Tetr)
BaTiO3	6.035	0.412	21.43	Barium Titanate (Cubic)
Be	1.85	0.543	16.26	Beryllium
BeF2	1.99	?		Beryllium Fluoride
BeO	3.01	?		Beryllium Oxide
Bi	9.8	0.79	11.18	Bismuth
Bi2O3	8.9	?		Bismuth Oxide
Bi2S3	7.39	?		Bismuth Trisuiphide
Bi2Se3	6.82	?		Bismuth Selenide

[1] SQM-160 User's Guide, Version 4.06. Sigma Instruments, Inc. 2000-2008.

Formula	Density	Z-Ratio	Acoustic Impedance	Material Name
Bi2Te3	7.7	?		Bismuth Telluride
BiF3	5.32	?		Bismuth Fluoride
C	2.25	3.26	2.71	Carbon (Graphite)
C	3.52	0.22	40.14	Carbon (Diamond)
C8H8	1.1	?		Parlyene (Union Carbide)
Ca	1.55	2.62	3.37	Calcium
CaF2	3.18	0.775	11.39	Calcium Fluoride
CaO	3.35	?		Calcium Oxide
CaO-SiO2	2.9	?		Calcium Silicate (3)
CaSO4	2.962	0.955	9.25	Calcium Sulfate
CaTiO3	4.1	?		Calcium Titanate
CaWO4	6.06	?		Calcium Tungstate
Cd	8.64	0.682	12.95	Cadmium
CdF2	6.64	?		Cadmium Fluoride
CdO	8.15	?		Cadmium Oxide
CdS	4.83	1.02	8.66	Cadmium Sulfide
CdSe	5.81	?		Cadmium Selenide,
CdTe	6.2	0.98	9.01	Cadmium Telluride
Ce	6.78	?		Cerium
CeF3	6.16	?		Cerium (III) Fluoride
CeO2	7.13	?		Cerium (IV) Dioxide
Co	8.9	0.343	25.74	Cobalt
CoO	6.44	0.412	21.43	Cobalt Oxide
Cr	7.2	0.305	28.95	Chromium
Cr2O3	5.21	?		Chromium (III) Oxide
Cr3C2	6.68	?		Chromium Carbide
CrB	6.17	?		Chromium Boride
Cs	1.87	?		Cesium
Cs2SO4	4.243	1.212	7.29	Cesium Sulfate
CsBr	4.456	1.41	6.26	Cesium Bromide
CsCl	3.988	1.399	6.31	Cesium Chloride
CsI	4.516	1.542	5.73	Cesium Iodide
Cu	8.93	0.437	20.21	Copper
Cu2O	6	?		Copper Oxide
Cu2S	Cu2S	5.6	1.58	Copper (I) Sulfide (Alpha)
Cu2S	Cu2S	5.8	1.52	Copper (I) Sulfide (Beta)
CuS	CuS	4.6	1.92	Copper (II) Sulfide
Dy	Dy	8.55	1.03	Dysprosium
Dy2O3	Dy2O3	7.81	1.13	Dysprosium Oxide
Er	Er	9.05	0.98	Erbium

Formula	Density	Z-Ratio	Acoustic Impedance	Material Name
Er2O3	Er2O3	8.64	1.02	Erbium Oxide
Eu	Eu	5.26	1.68	Europium
EuF2	EuF2	6.5	1.36	Europium Fluoride
Fe	7.86	0.349	25.30	Iron
Fe2O3	5.24	?		Iron Oxide
FeO	5.7	?		Iron Oxide
FeS	4.84	?		Iron Sulphide
Ga	5.93	0.593	14.89	Gallium
Ga2O3	5.88	?		Gallium Oxide (B)
GaAs	5.31	1.59	5.55	Gallium Arsenide
GaN	6.1	?		Gallium Nitride
GaP	4.1	?		Gallium Phosphide
GaSb	5.6	?		Gallium Antimonide
Gd	7.89	0.67	13.18	Gadolinium
Gd2O3	7.41	?		Gadolinium Oxide
Ge	5.35	0.516	17.11	Germanium
Ge3N2	5.2	?		Germanium Nitride
GeO2	6.24	?		Germanium Oxide
GeTe	6.2	?		Germanium Telluride
Hf	13.09	0.36	24.53	Hafnium
HfB2	10.5	?		Hafnium Boride,
HfC	12.2	?		Hafnium Carbide
HfN	13.8	?		Hafnium Nitride
HfO2	9.68	?		Hafnium Oxide
HfSi2	7.2	?		Hafnium Silicide
Hg	13.46	0.74	11.93	Mercury
Ho	8.8	0.58	15.22	Holminum
Ho2O3	8.41	?		Holminum Oxide
In	7.3	0.841	10.50	Indium
In2O3	7.18	?		Indium Sesquioxide
In2Se3	5.7	?		Indium Selenide
In2Te3	5.8	?		Indium Telluride
InAs	5.7	?		Indium Arsenide
InP	4.8	?		Indium Phosphide
InSb	5.76	0.769	11.48	Indium Antimonide
Ir	22.4	0.129	68.45	Iridium
K	0.86	10.189	0.87	Potassium
KBr	2.75	1.893	4.66	Potassium Bromide
KCl	1.98	2.05	4.31	Potassium Chloride
KF	2.48	?		Potassium Fluoride

Formula	Density	Z-Ratio	Acoustic Impedance	Material Name
KI	3.128	2.077	4.25	Potassium Iodide
La	6.17	0.92	9.60	Lanthanum
La2O3	6.51	?		Lanthanum Oxide
LaB6	2.61	?		Lanthanum Boride
LaF3	5.94	?		Lanthanum Fluoride
Li	0.53	5.9	1.50	Lithium
LiBr	3.47	1.23	7.18	Lithium Bromide
LiF	2.638	0.778	11.35	Lithium Fluoride
LiNbO3	4.7	0.463	19.07	Lithium Niobate
Lu	9.84	?		Lutetium
Mg	1.74	1.61	5.48	Magnesium
MgAl2O4	3.6	?		Magnesium Aluminate
MgAl2O6	8	?		Spinel
MgF2	3.18	0.637	13.86	Magnesium Fluoride
MgO	3.58	0.411	21.48	Magnesium Oxide
Mn	7.2	0.377	23.42	Manganese
MnO	5.39	0.467	18.91	Manganese Oxide
MnS	3.99	0.94	9.39	Manganese (II) Sulfide
Mo	10.2	0.257	34.36	Molybdenum
Mo2C	9.18	?		Molybdenum Carbide
MoB2	7.12	?		Molybdenum Boride
MoO3	4.7	?		Molybdenum Trioxdide
MoS2	4.8	?		Molybdenum Disulfide
Na	0.97	4.8	1.84	Sodium
Na3AlF6	2.9	?		Cryolite
Na5AL3F14	2.9	?		Chiolite
NaBr	3.2	?		Sodium Bromide
NaCl	2.17	1.57	5.62	Sodium Chloride
NaClO3	2.164	1.565	5.64	Sodium Chlorate
NaF	2.558	0.949	9.30	Sodium Fluoride
NaNO3	2.27	1.194	7.40	Sodium Nitrate
Nb	8.578	0.492	17.95	Niobium (Columbium)
Nb2O3	7.5	?		Niobium Trioxide
Nb2O5	4.47	?		Niobium (V) Oxide
NbB2	6.97	?		Niobium Boride
NbC	7.82	?		Niobium Carbide
NbN	8.4	?		Niobium Nitride
Nd	7	?		Neodynium
Nd2O3	7.24	?		Neodynium Oxide
NdF3	6.506	?		Neodynium Fluoride

Formula	Density	Z-Ratio	Acoustic Impedance	Material Name
Ni	8.91	0.331	26.68	Nickel
NiCr	8.5	?		Nichrome
NiCrFe	8.5	?		Inconel
NiFe	8.7	?		Permalloy
NiFeMo	8.9	?		Supermalloy
NiO	7.45	?		Nickel Oxide
P3N5	2.51	?		Phosphorus Nitride
Pb	11.3	1.13	7.81	Lead
PbCl2	5.85	?		Lead Chloride
PbF2	8.24	0.661	13.36	Lead Fluoride
PbO	9.53	?		Lead Oxide
PbS	7.5	0.566	15.60	Lead Sulfide
PbSe	8.1	?		Lead Selenide
PbSnO3	8.1	?		Lead Stannate
PbTe	8.16	0.651	13.56	Lead Telluride
Pd	12.038	0.357	24.73	Palladium
PdO	8.31	?		Palladium Oxide
Po	9.4	?		Polonium
Pr	6.78	?		Praseodymium
Pr2O3	6.88	?		Praseodymium Oxide
Pt	21.4	0.245	36.04	Platinum
PtO2	10.2	?		Platinum Oxide
Ra	5	?		Radium
Rb	1.53	2.54	3.48	Rubidium
Rbl	3.55	?		Rubidium Iodide
Re	21.04	0.15	58.87	Rhenium
Rh	12.41	0.21	42.05	Rhodium
Ru	12.362	0.182	48.52	Ruthenium
S8	2.07	2.29	3.86	Sulphur
Sb	6.62	0.768	11.50	Antimony
Sb2O3	5.2	?		Antimony Trioxide
Sb2S3	4.64	?		Antimony Trisulfide
Sc	3	0.91	9.70	Scandium
Sc2O3	3.86	?		Scandium Oxide
Se	4.81	0.864	10.22	Selenium
Si	2.32	0.712	12.40	Silicon
Si3N4	3.44	*1000		Silicon Nitride
SiC	3.22	?		Silicon Carbide
SiO	2.13	0.87	10.15	Silicon (II) Oxide
SiO2	2.648	1	8.83	Silicon Dioxide

Formula	Density	Z-Ratio	Acoustic Impedance	Material Name
Sm	7.54	0.89	9.92	Samarium
Sm2O3	7.43	?		Samarium Oxide
Sn	7.3	0.724	12.20	Tin
SnO2	6.95	?		Tin Oxide
SnS	5.08	?		Tin Sulfide
SnSe	6.18	?		Tin Selenide
SnTe	6.44	?		Tin Telluride
Sr	2.6	?		Strontium
SrF2	4.277	0.727	12.15	Strontium Fluroide
SrO	4.99	0.517	17.08	Strontium Oxide
Ta	16.6	0.262	33.70	Tantalum
Ta2O5	8.2	0.3	29.43	Tantalum (V) Oxide
TaB2	11.15	?		Tantalum Boride
TaC	13.9	?		Tantalum Carbide
TaN	16.3	?		Tantalum Nitride
Tb	8.27	0.66	13.38	Terbium
Tc	11.5	?		Technetium
Te	6.25	0.9	9.81	Tellurium
TeO2	5.99	0.862	10.24	Tellurium Oxide
Th	11.694	0.484	18.24	Thorium
ThF4	6.32	?		Thorium (IV) Fluoride
ThO2	9.86	0.284	31.09	Thorium Dioxide
ThOF2	9.1	?		Thorium Oxyfluoride
Ti	4.5	0.628	14.06	Titanium
Ti2O3	4.6	?		Titanium Sesquioxide
TiB2	4.5	?		Titanium Boride
TiC	4.93	?		Titanium Carbide
TiN	5.43	?		Titanium Nitride
TiO	4.9	?		Titanium Oxide
TiO2	4.26	0.4	22.08	Titanium (IV) Oxide
Tl	11.85	1.55	5.70	Thallium
TlBr	7.56	?		Thallium Bromide
TlCl	7	?		Thallium Chloride
TlI	7.09	?		Thallium Iodide (B)
U	19.05	0.238	37.10	Uranium
U3O8	8.3	?		Tri Uranium Octoxide
U4O9	10.969	0.348	25.37	Uranium Oxide
UO2	10.97	0.286	30.87	Uranium Dioxide
V	5.96	0.53	16.66	Vanadium
V2O5	3.36	?		Vanadium Pentoxide

Formula	Density	Z-Ratio	Acoustic Impedance	Material Name
VB2	5.1	?		Vanadium Boride
VC	5.77	?		Vanadium Carbide
VN	6.13	?		Vanadium Nitride
VO2	4.34	?		Vanadium Dioxide
W	19.3	0.163	54.17	Tungsten
WB2	10.77	?		Tungsten Boride
WC	15.6	0.151	58.48	Tungsten Carbide
WO3	7.16	?		Tungsten Trioxide
WS2	7.5	?		Tungsten Disulphide
WSi2	9.4	?		Tungsten Suicide
Y	4.34	0.835	10.57	Yttrium
Y2O3	5.01	?		Yttrium Oxide
Yb	6.98	1.13	7.81	Ytterbium
Yb2O3	9.17	?		Ytterbium Oxide
Zn	7.04	0.514	17.18	Zinc
Zn3Sb2	6.3	?		Zinc Antimonide
ZnF2	4.95	?		Zinc Fluoride
ZnO	5.61	0.556	15.88	Zinc Oxide
ZnS	4.09	0.775	11.39	Zinc Sulfide
ZnSe	5.26	0.722	12.23	Zinc Selenide
ZnTe	6.34	0.77	11.47	Zinc Telluride
Zr	6.49	0.6	14.72	Zirconium
ZrB2	6.08	?		Zirconium Boride
ZrC	6.73	0.264	33.45	Zirconium Carbide
ZrN	7.09	?		Zirconium Nitride
ZrO2	5.6	?		Zirconium Oxide