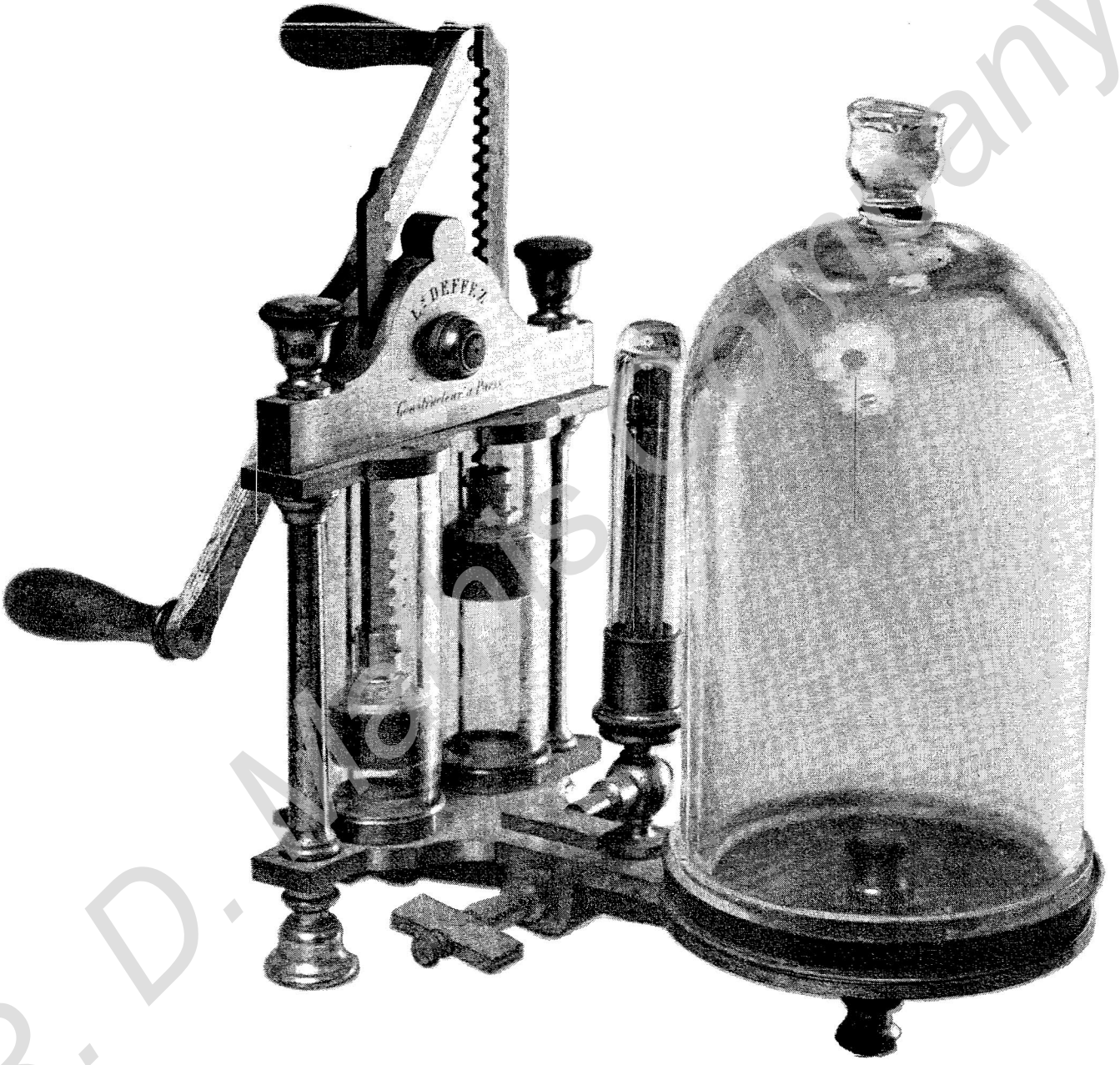
THIN FILM EVAPORATION SOURCE REFERENCE



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THIN FILM EVAPORATION SOURCE REFERENCE

NAME	SYMBOL	MELTING POINT °C	DENSITY g/cm³	TEMPERATURE (°C) @ VAP. PRESS			EVAPORATION TECHNIQUES				REMARKS n = Index of refraction
				10^{-8} TORR	10^{-6} TORR	10^{-4} TORR	ELECTRON BEAM	CRUCIBLE	COIL	BOAT	
Aluminum	Al	660	2.70	677	821	1010	XInt.	TiB_2-BN ZrB_2, BN	W	TiB_2, W	Alloys and wets; tungsten-stranded superior
Aluminum Antimonide	AlSb	1080	4.3	—	—	—	—	—	—	—	—
Aluminum Arsenide	AlAs	1600	3.7	—	—	~1300	—	—	—	—	—
Aluminum Bromide	$AlBr_3$	97	3.01	—	—	~50	—	Graphite	—	Mo	—
Aluminum Carbide	Al_4C_3	1400	2.36	—	—	~800	Fair	—	—	—	n = 2.7
Aluminum 2% Copper	Al2%Cu	640	2.82	—	—	—	—	—	—	—	Wire feed and flash. Difficult from dual sources.
Aluminum Fluoride	AlF_3	1257 Subl.	3.07	410 Sublimes	490	700	Poor	Graphite	—	Mo, W	n = 1.38 @ .55μ
Aluminum Nitride	AlN	Subl.	3.26	—	—	~1750	Fair	—	—	—	Decomposes. Reactive evaporate in 10^{-3} N_2 with glow discharge.
Aluminum Oxide (a) (alumina)	Al_2O_3	2045	3.97	—	—	1550	XInt.	—	—	W	Sapphire xInt in EB, forms smooth hard films. n = 1.66
Aluminum 2% Silicon	Al2%Si	640	2.69	—	—	1010	—	TiB_2-BN	—	—	Wire feed and flash. Difficult from dual sources.
Antimony	Sb	630	6.68	279 Sublimes	345	425	Poor	BN, C Al_2O_3	Mo Ta	Mo, Ta Al_2O_3 Coated	Toxic. Evaporates well. Film structure is rate-dependent.
Antimony Telluride	Sb_2Te_3	619	6.50	—	—	600	—	Carbon	—	—	Decomposes over 750°C
Antimony Trioxide	Sb_2O_3	656	5.2 or 5.76	— Sublimes	—	~300	Good	BN, Al_2O_3	—	Pt	Toxic. Decomposes on W. n = 2.05
Antimony Triselenide	Sb_2Se_3	611	—	—	—	—	—	Carbon	—	Ta	Stoichiometry variable.
Antimony Trisulphide	Sb_2S_3	550	4.64	—	—	~200	Good	Al_2O_3	—	Mo Ta	n = 3.01 @ .55μ. No decomposition.
Arsenic	As	814	5.73	107 Sublimes	150	210	Poor	Al_2O_3 BeO Vit. Carbon	—	C	Toxic. Sublimes rapidly at low temperature.
Arsenic Selenide	As_2Se_3	360	4.75	—	—	—	—	Al_2O_3 Quartz	—	—	n = 2.41 @ 3.8μ JVST 10, 748 (1973)
Arsenic Trisulphide	As_2S_3	300	3.43	—	—	~400	Fair	Al_2O_3 Quartz	—	Mo	n = 2.8 JVST 10, 748 (1973)
Arsenic Tritelluride	As_2Te_3	362	—	—	—	—	—	—	—	Flash	JVST 10, 748 (1975)
Barium	Ba	710	3.78	545	627	735	Fair	Metals	W	W Ta Mo	Wets w/o alloying — reacts with ceramics.
Barium Chloride	$BaCl_2$	962	3.86	—	—	~650	—	—	—	Ta Mo	Use gentle preheat to outgas.
Barium Fluoride	BaF_2	1280	4.83	— Sublimes	—	~700	Good	—	—	Mo	n = 1.29 @ 5μ Density Rate Dependent
Barium Oxide	BaO	1923	5.72 or 5.32	—	—	~1300	Poor	Al_2O_3	—	Pt	Decomposes slightly. n = 1.98

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				10^{-6} TORR	10^{-5} TORR	10^{-4} TORR	ELECTRON BEAM	CRUCIBLE	COIL	BOAT	
Barium Sulphide	BaS	2200	4.25	—	—	1100	—	—	—	Mo	n = 2.16
Barium Titanate	$BaTiO_3$	Dec.	6.0	Decomposes			—	—	—	—	Decomposes, yields free Ba from single source; sputtering preferred; or co-evaporate from 2 sources
Beryllium	Be	1278	1.85	710	878	1000	XInt.	BeO C Vit. Carbon	W	W Ta	Wets W/Mo/Ta. Metal powder and oxides are toxic. Evaporates easily.
Beryllium Chloride	$BeCl_2$	440	1.90	—	—	~150	—	—	—	—	—
Beryllium Fluoride	BeF_2	800	1.99	—	—	~200	Good	—	—	—	Toxic.
				Sublimes							
Beryllium Oxide	BeO	2530	3.01	—	—	1900	Good	—	—	—	Powders toxic. No decomposition from EB guns. n = 1.72
Bismuth	Bi	271	9.80	330	410	520	XInt.	Al_2O_3 Vit. Carbon	W	W, Mo Al_2O_3 Ta	Vapors are toxic. High resistivity. No shorting of baskets.
Bismuth Fluoride	BiF_3	727	8.75	—	—	~300	—	Graphite	—	—	n = 1.74 @ 1μ, 1.64 @ 10μ App. Opt. 18, 105 (1979)
				Sublimes							
Bismuth Oxide	Bi_2O_3	820	8.9	—	—	~1400	Poor	—	—	Pt	Vapors are toxic. n = 2.55. JVST 12, 63 (1975)
Bismuth Selenide	Bi_2Se_3	710	7.66	—	—	~650	Good	Graphite Quartz	—	—	Sputtering preferred; or co-evaporate from 2 sources.
Bismuth Telluride	Bi_2Te_3	585	7.85	—	—	~600	—	Graphite Quartz	—	W Mo	Sputtering preferred; or co-evaporate from 2 sources.
Bismuth Titanate	$Bi_2Ti_2O_7$	—	—	Decomposes			—	—	—	—	Decomposes. Sputtering preferred; or co-evaporate from 2 sources in $10\text{-}2O_2$
Bismuth Trisulphide	Bi_2S_3	685	7.39	—	—	—	—	—	—	—	n ≅ 1.5
Boron	B	2100	2.36	1278	1548	1797	XInt.	C Vit. Carbon	—	C	Material explodes with rapid cooling. Forms carbide with container.
				Sublimes							
Boron Carbide	B_4C	2350	2.50	2500	2580	2650	XInt.	—	—	—	Similar to chromium.
Boron Nitride	BN	2300	2.20	—	—	~1600	Poor	—	—	—	Sputtering preferred; Decomposes.
				Sublimes							
Boron Oxide	B_2O_3	460	1.82	—	—	~1400	Good	—	—	Pt, Mo	n = 1.46
Boron Trisulphide	B_2S_3	310	1.55	—	—	800	—	Graphite	—	—	—
Cadmium	Cd	321	8.64	64	120	180	Poor	Al_2O_3 Quartz	—	W, Cb Mo Ta	Poisons vacuum systems, low sticking coefficient.
Cadmium Antimonide	CdSb	456	6.92	—	—	—	—	—	—	—	—
Cadmium Arsenide	Cd_3As_2	721	6.21	—	—	—	—	Quartz	—	—	—
Cadmium Bromide	$CdBr_2$	567	5.19	—	—	~300	—	—	—	—	—
Cadmium Chloride	$CdCl_2$	570	4.05	—	—	~400	—	—	—	—	—
Cadmium Fluoride	CdF_2	1070	6.64	—	—	~500	—	—	—	—	n = 1.56
Cadmium Iodide	CdI_2	400	5.30	—	—	~250	—	—	—	—	—
Cadmium Oxide	CdO	900	6.95	—	—	~530	—	—	—	—	Disproportionates. n = 2.49
Cadmium Selenide	CdSe	1264	5.81	—	—	540	Good	Al_2O_3 Quartz	—	Mo Ta	Evaporates easily. n = 2.4 @ .6μ
				Sublimes							
Cadmium Siliside	$CdSiO_2$	—	—	—	—	~600	—	—	—	—	n = 1.69
Cadmium Sulphide	CdS	1750	4.82	—	—	550	Fair	Al_2O_3 Quartz	—	W Mo Ta	Sticking coefficient strongly affected by substrate temperature. Stoichiometry variable. n = 2.4. JVST 12, 188 (1975)
				Sublimes							
Cadmium Telluride	CdTe	1098	6.20	—	—	450	—	—	W	W Mo Ta	Stoichiometry depends on substrate temperature. n = 2.6
Calcium	Ca	842	1.55	272	357	459	Poor	Al_2O_3 Quartz	W	W	Corrodes in air.
				Sublimes							
Calcium Fluoride	CaF_2	1360	3.18	—	—	~1100	XInt.	Quartz	W Mo Ta	W Mo Ta	Rate control important. Use gentle preheat to outgas. n = 1.2 - 1.4
Calcium Oxide	CaO	2580	3.35	—	—	~1700	—	ZrO_2	—	W Mo	Forms volatile oxides with W and Mo. n = 1.84
Calcium Silicate	$CaO\text{-}SiO_2$	1540	2.90	—	—	—	Good	Quartz	—	—	n = 1.61
Calcium Sulphide	CaS	Subl.	2.18	—	—	1100	—	—	—	Mo	Decomposes. n = 2.14
Calcium Titanate	$CaTiO_3$	1975	4.10	1490	1600	1690	Poor	—	—	—	Disproportionates except in sputtering.
Calcium Tungstate	$CaWO_4$	1620	6.06	—	—	—	Good	—	—	W	n = 1.92

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Carbon	C	Subl.	1.8 - 2.3	1657 Sublimes	1867	2137	XInt.	—	—	—	EB preferred. Arc evaporation. Poor film adhesion. Vitreous carbon n = 1.47
Cerium	Ce	795	8.23	970	1150	1380	Good	Al_2O_3 BeO Vit. Carbon	W	W Ta	Films oxidize easily.
Ceric Oxide	CeO_2	2600	7.3	1890 Sublimes	2000	2310	Good	—	—	W	Use 250—300 °C substrate temperature. n = 2.2—2.4. Reacts with W.
Cerium Fluoride	CeF_3	1418	6.16	—	—	~900	Good	—	—	W Mo Ta	Use gentle preheat to outgas. n = 1.63 @ .55μ
Cerium Oxide	Ce_2O_3	1692	6.87	—	—	—	Fair	—	—	W	Alloys with source; use .015-.020 W boat. n = 1.95
Cesium	Cs	28	1.87	−16	+22	+30	—	Quartz	—	S.S.	—
Cesium Bromide	CsBr	636	4.44	—	—	~400	—	—	—	W	n = 1.70
Cesium Chloride	CsCl	646	3.97	—	—	~500	—	—	—	W	n = 1.64 Hygroscopic
Cesium Fluoride	CsF	684	3.59	—	—	~500	—	—	—	W	—
Cesium Hydroxide	CsOH	272	3.67	—	—	550	—	—	—	Pt	—
Cesium Iodide	CsI	621	4.51	—	—	~500	—	Pt Quartz	—	W, Pt	n = 1.79
Chiolote	$Na_5Al_3F_{14}$	—	2.9	—	—	~800	—	—	—	Mo W	n = 1.33
Chromium	Cr	1890	7.20	837 Sublimes	977	1157	Good	Vit. Carbon	W	Cr-plated rod or strip	Films very adherent. High rates possible.
Chromium Boride	CrB	2760	6.17	—	—	—	—	—	—	—	—
Chromium Bromide	$CrBr_2$	842	4.36	—	—	550	—	—	—	Inconel	—
Chromium Carbide	Cr_3C_2	1890	6.68	—	—	~2000	Fair	—	—	W	—
Chromium Chloride	$CrCl_2$	824	2.75	—	—	550	—	—	—	Fe Inconel	Sublimes easily.
Chromium Oxide	Cr_2O_3	2435	5.21	—	—	~2000	Good	—	—	W Mo	Disproportionates to lower oxides, reoxidizes @ 600 °C in air. n = 2.4
Chromium Silicide	Cr_3Si	1710	6.51	—	—	—	—	—	—	—	—
Chromium Silicon Monoxide	Cr-SiO	Influenced by composition					Good	—	—	W	Flash.
Cobalt	Co	1495	8.90	850	990	1200	XInt.	Al_2O_3 BeO	—	W Cb	Alloys with refractory metals.
Cobalt Bromide	$CoBr_2$	678	4.91	— Sublimes	—	400	—	—	—	Inconel	—
Cobalt Chloride	$CoCl_2$	740	3.36	— Sublimes	—	472	—	—	—	Inconel	—
Cobalt Oxide	CoO	1935	5.68	—	—	—	—	—	—	—	Sputtering preferred.
Copper	Cu	1083	8.92	727	857	1017	XInt.	Al_2O_3 Mo, Ta	W	Mo	Films do not adhere well. Use intermediate layer, e.g., chromium. Evaporates from any source material.
Copper Chloride	CuCl	422	3.53	—	—	~600	—	—	—	—	n = 1.93
Copper Oxide	Cu_2O	1235	6.0	— Sublimes	—	~600	Good	Al_2O_3	—	Ta	Evaporate in 10^{-2} - 10^{-4} of O_2; n = 2.70. J. Electrochem. Soc. 110, 119 (1967)
Copper Sulfide	CuS	1113	6.75	Sublimes		~500	—	—	—	—	n = 1.45
Cryolite	Na_3AlF_6	1000	2.9	1020	1260	1480	XInt.	Vit. Carbon	—	W Mo Ta	Large chunks reduce spitting. Little decomposition. n = 2.34 at 6330A App. Opt. 15, 1969 (1976)
Dysprosium	Dy	1409	8.54	625	750	900	Good	—	—	Ta	—
Dysprosium Fluoride	DyF_3	1360	—	— Sublimes	—	~800	Good	—	—	Ta	—
Dysprosium Oxide	Dy_2O_3	2340	7.81	—	—	~1400	—	—	—	Ir	Loses oxygen.
Erbium	Er	1497	9.06	650 Sublimes	775	930	Good	—	—	W Ta	—
Erbium Fluoride	ErF_3	1350	7.81	—	—	~750	—	—	—	Mo	JVST A3 (6) 2320
Erbium Oxide	Er_2O_3	2400	8.64	—	—	~1600	—	—	—	Ir	Loses oxygen.
Europium	Eu	822	5.26	280 Sublimes	360	480	Fair	Al_2O_3	—	W Ta	Low tantalum solubility.
Europium Fluoride	EuF_2	1380	6.5	—	—	~950	—	—	—	Mo	—

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Europium Oxide	Eu_2O_3	2056	7.42	—	—	~1600	Good	ThO_2	—	Ir Ta W	Loses oxygen; films clear and hard.
Europium Sulphide	EuS	—	5.75	—	—	—	Good	—	—	—	—
Gadolinium	Gd	1312	7.89	760	900	1175	XInt.	Al_2O_3	—	Ta	High Ta solubility.
Gadolinium Oxide	Gd_2O_3	2310	7.41	—	—	—	Fair	—	—	Ir	Loses oxygen. n = 1.8 @ .55μ
Gallium	Ga	30	5.90	619	742	907	Good	Al_2O_3 BeO Quartz	—	—	Alloys with refractory metals. Use EB gun.
Gallium Antimonide	GaSb	710	5.6	—	—	—	Fair	—	—	W Ta	Flash evaporate.
Gallium Arsenide	GaAs	1238	5.3	—	—	—	Good	Carbon	—	W Ta	Flash evaporate. n = 5.64 @ 10.6μ
Gallium Nitride	GaN	Subl.	6.1	—	—	~200	—	Al_2O_3	—	—	Evaporate Ga in 10^{-3} N_2.
Gallium Oxide (β)	Ga_2O_3	1900	5.88	—	—	—	—	—	—	Pr W	Loses oxygen.
Gallium Phosphide	GaP	1540	4.1	—	770	920	—	Quartz	—	W Ta	Decomposes vapor mostly P.
Germanium	Ge	937	5.35	812	957	1167	XInt.	Quartz Al_2O_3	—	W C Ta	Excellent films from EB sources. Use .040 W. n = 4.01
Germanium Nitride	Ge_3N_2	450	5.2	—	—	~650	—	—	—	—	Sputtering preferred.
				Sublimes							
Germanium Oxide	GeO_2	1086	6.24	—	—	~625	Good	Quartz Al_2O_3	—	Ta Mo	Similar to SiO, film predominantly GeO.
Germanium Telluride	GeTe	725	6.20	—	—	381	—	Quartz Al_2O_3	—	W Mo	—
Glass, Schott 8329	—	—	2.20	—	—	—	XInt.	—	—	—	Evaporable alkali glass. Melt in air before evaporating. n = 1.47
Gold	Au	1062	19.32	807	947	1132	XInt.	Al_2O_3 BN Vit. Carbon	W	W, Mo Coated Al_2O_3	Films soft, not very adherent.
Hafnium	Hf	2230	13.09	2160	2250	3090	Good	—	—	—	—
Hafnium Boride	HfB_2	3250	10.5	—	—	—	—	—	—	—	—
Hafnium Carbide	HfC	4160	12.2	—	—	~2600	—	—	—	—	—
				Sublimes							
Hafnium Nitride	HfN	2852	13.8	—	—	—	—	—	—	—	—
Hafnium Oxide	HfO_2	2812	9.68	—	—	~2500	Fair	—	—	W	Film HfO n = 2.0 @ .5μ App. Opt. Apr. 1977
Hafnium Silicide	$HfSi_2$	1750	7.2	—	—	—	—	—	—	—	—
Holmium	Ho	1470	8.80	650	770	950	Good	—	W	W Ta	—
				Sublimes							
Holmium Fluoride	HoF_3	1143	7.64	—	—	~800	—	Quartz	—	—	—
Holmium Oxide	Ho_2O_3	2370	8.41	—	—	—	—	—	—	Ir	Loses oxygen.
Inconel	Ni/Cr/Fe	1425	8.5	—	—	—	Good	—	W	W	Use fine wire pre-wrapped on W. Low rate req'd. for smooth films.
Indium	In	157	7.30	487	597	742	XInt.; Mo Liner req'd.	Graphite Al_2O_3	W	W Mo	Wets W and Cu; use Mo liner in guns.
Indium Antimonide	InSb	535	5.8	500	—	~400	—	—	—	W	Toxic, Decomposes; sputtering preferred; or co-evaporate from 2 sources; flash. n = 4.3 @ 1μ
Indium Arsenide	InAs	943	5.7	780	870	970	—	—	—	W	Toxic, Sputtering preferred; or co-evaporate from 2 sources; flash. n = 4.5 @ 1μ
Indium Oxide	In_2O_3	1565	7.18	—	—	~1200	Good	Al_2O_3	—	W Pt	Film In_2O; transparent conductor. JVST 12, 99 (1975)
				Sublimes							
Indium Phosphide	InP	1058	4.8	—	630	730	—	Graphite	—	W Ta	Deposits P rich. Flash evaporate.
Indium Selenide	In_2Se_3	890	5.7	—	—	—	—	—	—	—	Sputtering preferred; or co-evaporate from 2 sources; flash.
Indium Sesquisulphide	In_2S_3	1050	4.90	—	—	850	—	Graphite	—	—	Film In_2S
				Sublimes							
Indium Sulphide	In_2S	653	5.87	—	—	650	—	Graphite	—	—	—
Indium Telluride	In_2Te_3	667	5.8	—	—	—	—	—	—	—	Sputtering preferred; or co-evaporate from 2 sources; flash.
Iridium	Ir	2459	22.65	1850	2080	2380	Fair	ThO_2	—	—	—
Iron	Fe	1535	7.86	858	998	1180	XInt.	Al_2O_3 BeO	W	W	Attacks W. Films hard, smooth. Use gentle preheat to outgas.

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Iron Bromide	$FeBr_2$	689	4.64	—	—	561	—	Fe	—	—	—
Iron Chloride	$FeCl_2$	670	2.98	—	—	300 Sublimes	—	Fe	—	—	—
Iron Iodide	FeI_2	592	5.31	—	—	400	—	Fe	—	—	—
Iron Oxide	FeO	1425	5.7	—	—	—	Poor	—	—	—	Decomposes; sputtering preferred.
Iron Oxide	Fe_2O_3	1565	5.24	—	—	—	Good	—	—	W	Disproportionates to Fe_3O_4 at 1530 °C, n ≅ 3.0
Iron Sulphide	FeS	1195	4.84	—	—	—	—	Al_2O_3	—	—	Decomposes.
Kanthal	FeCrAl	1500	7.1	—	—	~1150	—	—	W	W	JVST 7, 739 (1980)
Lanthanum	La	920	6.17	990	1212	1388	XInt.	Al_2O_3	—	W Ta	Films will burn in air if scraped.
Lanthanum Boride	LaB_6	2210	2.61	—	—	—	Good	—	—	—	—
Lanthanum Bromide	$LaBr_3$	783	5.06	—	—	—	—	—	—	—	n = 1.94 Hygroscopic
Lanthanum Fluoride	LaF_3	1490	6.0	—	—	900 Sublimes	Good	—	—	Ta Mo	No decomposition. n = 1.59 @ .55μ
Lanthanum Oxide	La_2O_3	2250	5.84	—	—	1400	Good	—	—	W Ta	Loses oxygen. n ≅ 1.9 @ .5μ
Lead	Pb	328	11.34	342	427	497	XInt.	Al_2O_3 Quartz	W	W Mo	Toxic. Carefully controlled rates req'd. for superconductors.
Lead Bromide	$PbBr_2$	373	6.66	—	—	~300	—	—	—	—	—
Lead Chloride	$PbCl_2$	501	5.85	—	—	~325	—	Al_2O_3	—	Pt	Little decomposition. n = 2.2
Lead Fluoride	PbF_2	822	8.24	—	—	~400 Sublimes	—	BeO	—	W Pt, Mo	Toxic. n = 1.75 @ .3μ
Lead Iodide	PbI_2	502	6.16	—	—	~500	—	Quartz	—	Pt	n ≅ 2.7 J. Opt. Soci. 65, 914
Lead Oxide	PbO	890	9.53	—	—	~550	—	Quartz Al_2O_3	—	Pt	No decomposition. n = 2.55
Lead Stannate	$PbSnO_3$	1115	8.1	670	780	905	Poor	Al_2O_3	—	Pt	Disproportionates.
Lead Selenide	PbSe	1065	8.10	—	—	~500 Sublimes	—	Graphite Al_2O_3	—	W Mo	—
Lead Sulphide	PbS	1114	7.5	—	—	550 Sublimes	—	Quartz Al_2O_3	—	W	Little decomposition. n = 3.91
Lead Telluride	PbTe	917	8.16	780	910	1050	—	Al_2O_3 Graphite	—	Mo Pt Ta	Vapors toxic. Deposits Te rich. Sputtering preferred, or co-evaporate from sources. n = 5.6 @ 5μ
Lead Titanate	$PbTiO_3$	—	7.52	—	—	—	—	—	—	Ta	—
Lithium	Li	179	0.53	227	307	407	Good	Al_2O_3 BeO	—	Ta S.S.	Metal reacts violently in air.
Lithium Bromide	LiBr	547	3.46	—	—	~500	—	—	—	Ni	n = 1.78
Lithium Chloride	LiCl	613	2.07	—	—	400	—	—	—	Ni	Use gentle preheat for outgas. n = 1.66
Lithium Fluoride	LiF	870	2.60	875	1020	1180	Good	Al_2O_3	—	Ni, Ta Mo W	Rate control important for optical films. Use gentle preheat for outgas. n = 1.36. J. Appl. Opt. 11, 2245 (1972)
Lithium Iodide	LiI	446	4.06	—	—	400	—	—	—	Mo W	—
Lithium Oxide	Li_2O	1427	2.01	—	—	850	—	—	—	Pt Ir	n = 1.64
Lutetium	Lu	1652	9.84	—	—	1300	XInt.	Al_2O_3	—	Ta	—
Lutetium Oxide	Lu_2O_3	2489	9.41	—	—	1400	—	—	—	Ir	Decomposes.
Magnesium	Mg	651	1.74	185	247	327 Sublimes	Good	Al_2O_3 Vit. Carbon	W	W Mo Ta, Cb	Extremely high rates possible.
Magnesium Aluminate	$MgAl_2O_4$	2135	3.6	—	—	—	Good	—	—	—	Natural spinel.
Magnesium Bromide	$MgBr_2$	700	3.72	—	—	~450	—	—	—	Ni	Decomposes.
Magnesium Chloride	$MgCl_2$	708	2.32	—	—	400	—	—	—	Ni	Decomposes. n = 1.6
Magnesium Fluoride	MgF_2	1266	2.9-3.2	—	—	1000	XInt.	Al_2O_3	—	Mo Ta	Rate control and substrate heat important for optical films. n = 1.38 J. Appl. Opt. 11, 2245 (1972)
Magnesium Iodide	MgI_2	700	4.24	—	—	200	—	—	—	Ir	—

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				10^{-8} TORR	10^{-6} TORR	10^{-4} TORR	ELECTRON BEAM	CRUCIBLE	COIL	BOAT	
Magnesium Oxide	MgO	2800	3.58	—	—	1300	Good	Carbon Al_2O_3	—	—	W produces volatile oxides. n ≅ 1.7 J. Appl. Opt. 11, 2243 (1972)
Manganese	Mn	1244	7.20	507 Sublimes	572	647	Good	Al_2O_3 BeO	W	W Ta Mo	—
Manganese Bromide	$MnBr_2$	695	4.38	—	—	500	—	—	—	Inconel	—
Manganese Chloride	$MnCl_2$	650	2.98	—	—	450	—	—	—	Inconel	—
Manganese Oxide	Mn_3O_4	1705	4.86	—	—	—	—	—	—	W	—
Manganese Sulphide	MnS	1615	3.99	—	—	1300	—	—	—	Mo	Decomposes. n = 2.7
Mercury	Hg	−39	13.55	−68	−42	−6	—	—	—	—	—
Mercury Sulphide	HgS	Subl.	8.10	— Sublimes	—	250	—	Al_2O_3	—	—	Decomposes.
Molybdenum	Mo	2610	10.22	1592	1822	2117	XInt.	—	—	—	Films smooth, hard. Careful degas req'd.
Molybdenum Boride	MoB_2	2100	7.12	—	—	—	Poor	—	—	—	—
Molybdenum Carbide	Mo_2C	2687	9.18	—	—	—	Fair	—	—	—	Evaporation of $Mo(CO)_6$ yields Mo_2C.
Molybdenum Disulphide	MoS_2	1185	4.80	—	—	~50	—	—	—	—	—
Molybdenum Silicide	$MoSi_2$	2050	6.3	—	—	—	—	—	—	W	Decomposes.
Molybdenum Trioxide	MoO_3	795	4.70	—	—	~900	—	Al_2O_3 BN	—	Mo Pt	Slight O_2 loss. n ≅ 1.9
Neodymium	Nd	1024	7.00	731	871	1062	XInt.	Al_2O_3	—	Ta	Low Ta solubility.
Neodymium Fluoride	NdF_3	1410	6.5	—	—	~900	Good	Al_2O_3	—	Mo W	Very little decomposition. n = 1.61 @ .55μ
Neodymium Oxide	Nd_2O_3	2272	7.24	—	—	~1400	Good	ThO_2	—	Ta W	Loses oxygen, films clear, EB preferred. Hygroscopic n = 1.79 n varies with substrate temp.
Nichrome IV	Ni/Cr	1395	8.50	847	987	1217	XInt.	Al_2O_3 Vit. Carbon BeO	W	Al_2O_3 Coated	Alloys with refractory metals.
Nickel	Ni	1453	8.90	927	1072	1262	XInt.	Al_2O_3 BeO Vit. Carbon	W	W	Alloys with refractory metals. Forms smooth adherent films.
Nickel Bromide	$NiBr_2$	963	4.64	— Sublimes	—	362	—	—	—	Inconel	—
Nickel Chloride	$NiCl_2$	1001	3.55	— Sublimes	—	444	—	—	—	Inconel	—
Nickel Oxide	NiO	1990	7.45	—	—	~1470	—	Al_2O_3	—	—	Dissociates upon heating. n = 2.18
Niobium (Columbium)	Nb	2468	8.55	1728	1977	2287	XInt.	—	—	W	Attacks W source.
Niobium Boride	NbB_2	3050	6.97	—	—	—	—	—	—	—	—
Niobium Carbide	NbC	3800	7.82	—	—	—	Fair	—	—	—	—
Niobium Nitride	NbN	2573	8.4	—	—	—	—	—	—	—	Reactive, evaporate Nb in 10^{-3} N_2.
Niobium Oxide	NbO	—	6.27	—	—	1100	—	—	—	Pt	—
Niobium Pentoxide	Nb_2O_5	1530	4.47	—	—	—	—	—	—	W	n = 2.3
Niobium Telluride	$NbTe_x$	—	7.6	—	—	—	—	—	—	—	Composition variable.
Niobium-Tin	Nb_3Sn	—	—	—	—	—	XInt.	—	—	—	Co-evaporate from 2 sources.
Niobium Trioxide	Nb_2O_3	1780	7.5	—	—	—	—	—	—	W	—
Osmium	Os	1700	22.5	2170	2430	2760	Fair	—	—	—	—
Palladium	Pd	1550	12.40	842	992	1192	XInt.	Al_2O_3 BeO	W	W	Alloys with refractory metals; rapid evaporation suggested. Spits in EB.
Palladium Oxide	PdO	870	8.31	—	—	575	—	Al_2O_3	—	—	Decomposes.
Parylene (Union Carbide)	C_8H_8	300—400	1.1	—	—	—	—	—	—	—	Vapor depositable plastic.
Permalloy	Ni/Fe	1395	8.7	947	1047	1307	Good	Al_2O_3 Vit. Carbon	—	W	Film low in Ni content. Use 84% Ni source. JVST Vol. 7, No. 6, p. 573
Phosphorus	P	41.4	1.82	327	361	402	—	Al_2O_3	—	—	Metal reacts violently in air.

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				10^{-8} TORR	10^{-6} TORR	10^{-4} TORR	ELECTRON BEAM	CRUCIBLE	COIL	BOAT	
Platinum	Pt	1769	21.45	1292	1492	1747	XInt.	C ThO_2	W	W	Alloys with metals. Films soft, poor adhesion.
Plutonium	Pu	635	19	—	—	—	—	—	—	W	Toxic, radioactive.
Polonium	Po	254	9.4	117	170	244	—	Quartz	—	—	Radioactive
Potassium	K	64	0.86	23	60	125	—	Quartz	—	Mo	Metal reacts violently in air. Use gentle preheat to outgas.
Potassium Bromide	KBr	730	2.75	—	—	~450	—	Quartz	—	Ta Mo	Use gentle preheat to outgas. n = 1.56
Potassium Chloride	KCl	776	1.98	—	—	510	Good	—	—	Ta Ni	Use gentle preheat to outgas. n = 1.49
Potassium Fluoride	KF	880	2.48	—	—	~500	Poor	Quartz	—	—	Use gentle preheat to outgas. n = 1.35
Potassium Hydroxide	KOH	360	2.04	—	—	~400	—	—	—	Pt	Use gentle preheat to outgas.
Potassium Iodide	KI	723	3.13	—	—	~500	—	—	—	Ta	Use gentle preheat to outgas. n = 1.68
Praseodymium	Pr	931	6.78	800	950	1150	Good	—	—	Ta	—
Praseodymium Oxide	Pr_2O_3	2125	6.88	—	—	1400	Good	ThO_2	—	Ir	Loses oxygen. n = 2.0
Radium	Ra	700	5.0	246	320	416	—	—	—	—	—
Rhenium	Re	3180	20.53	1928	2207	2571	Poor	—	—	—	Fine wire will self-evaporate.
Rhenium Oxide	Re_2O_7	297	8.2	—	—	~100	—	—	—	—	—
Rhodium	Rh	1966	12.41	1277	1472	1707	Good	ThO_2 Vit. Carbon	W	W	EB gun preferred.
Rubidium	Rb	38.5	1.47	−3	37	111	—	Quartz	—	—	—
Rubidium Chloride	RbCl	715	2.76	—	—	~550	—	Quartz	—	—	n = 1.49
Rubidium Iodide	RbI	642	3.55	—	—	~400	—	Quartz	—	—	—
Ruthenium	Ru	2700	12.45	1780	1990	2260	Poor	—	—	W	Spits violently in EB. Requires degas.
Samarium	Sm	1072	7.54	373	460	573	Good	Al_2O_3	—	Ta	—
Samarium Oxide	Sm_2O_3	2350	7.43	—	—	—	Good	ThO_2	—	Ir	Loses O_2. Films smooth, clear.
Samarium Sulphide	Sm_2S_3	1900	5.72	—	—	—	Good	—	—	—	AIP Conf. Proc. on Mag. & Mag. Mat. B, 5, 860 (1971)
Scandium	Sc	1539	2.99	714	837	1002	XInt.	Al_2O_3 BeO	—	W	Alloys with Ta
Scandium Oxide	Sc_2O_3	2300	3.86	—	—	~400	Fair	—	—	—	Loses oxygen. n = 1.88 @ .5μ
Selenium	Se	217	4.79	89	125	170	Good	Al_2O_3 Vit. Carbon	W Mo	W Mo	Toxic. Poisons vacuum systems. JVST 9, 387 (1972); 12, 573 & 807 (1975)
Silicon	Si	1410	2.42	992	1147	1337	Fair	BeO Ta Vit. Carbon	—	W Ta	Alloys with W; use heavy W boat. SiO produced above 4 x 10^{-6} Torr. EB best. n = 3.42 App. Opt. 15, 2348 (1976)
Silicon Boride	SiB_6	—	2.47	—	—	—	Poor	—	—	—	—
Silicon Carbide	SiC	2700	3.22	—	—	1000	—	—	—	—	Sputtering preferred.
Silicon Dioxide	SiO_2	1610—1710	2.2-2.7	—	—	~1025 Influenced by composition	XInt.	Al_2O_3	—	—	Quartz xInt in EB. n = 1.47
Silicon Monoxide	SiO	1702	2.1	—	—	850 Sublimes	Fair	Ta	W	Ta	Baffle box source best for resistance evaporation. Low rate suggested. n = 1.6
Silicon Nitride	Si_3N_4	Subl.	3.44	—	—	~800	—	—	—	—	n ≅ 2.1
Silicon Selenide	SiSe	—	—	—	—	550	—	Quartz	—	—	—
Silicon Sulphide	SiS	Subl.	1.85	—	—	450	—	Quartz	—	—	—
Silicon Telluride	$SiTe_2$	—	4.39	—	—	550	—	Quartz	—	—	—
Silver	Ag	961	10.49	847	958	1105	XInt.	Al_2O_3 Mo	W	Ta Mo	Evaporates well from any source.
Silver Bromide	AgBr	432	6.47	—	—	~380	—	Quartz	—	Ta	n = 2.25
Silver Chloride	AgCl	455	5.56	—	—	~520	—	Quartz	—	Mo Pt	n = 2.07

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				10^{-8} TORR	10^{-6} TORR	10^{-4} TORR	ELECTRON BEAM	CRUCIBLE	COIL	BOAT	
Silver Iodide	AgI	558	5.67	—	—	~500	—	—	—	Ta	n = 2.21
Sodium	Na	97	0.97	74	124	192	—	Quartz	—	Ta S.S.	Use gentle preheat to outgas. Metal reacts violently in air.
Sodium Bromide	NaBr	755	3.20	—	—	~400	—	Quartz	—	—	Use gentle preheat to outgas. n = 1.64
Sodium Chloride	NaCl	801	2.16	—	—	530	Good	Quartz	—	Ta W Mo	Cu ovens, little decomposition. Use gentle preheat to outgas. n = 1.54
Sodium Cyanide	NaCN	563	—	—	—	~550	—	—	—	Ag	Use gentle preheat to outgas. n = 1.45
Sodium Fluoride	NaF	988	2.79	—	—	~700	Good	BeO	—	Mo Ta W	Use gentle preheat to outgas. No decomposition. n = 1.30 @ .55μ
Sodium Hydroxide	NaOH	318	2.13	—	—	~470	—	—	—	Pt	Use gentle preheat to outgas. n = 1.36
Spinel	MgO_3 $5Al_2O_3$	—	8.0	—	—	—	Good	—	—	—	n = 1.72
Strontium	Sr	769	2.6	239	309	403	Poor	Vit. Carbon	W	W Ta Mo	Wets but does not alloy with refractory metals. May react violently in air.
Strontium Fluoride	SrF_2	1190	4.24	—	—	~1000	—	Al_2O_3	—	—	n = 1.44
Strontium Oxide	SrO	2460	4.7	— Sublimes	—	1500	—	Al_2O_3	—	Mo	Reacts with Mo and W; n = 1.87
Strontium Sulphide	SrS	Above 2000	3.70	—	—	—	—	—	—	Mo	Decomposes. n = 2.11
Sulphur	S_8	115	2.0	13	19	57	Poor	Quartz	—	W	Poisons vacuum system.
Supermalloy	Ni/Fe/Mo	1410	8.9	—	—	—	Good	—	—	—	Sputtering preferred; or co-evaporate from 2 sources, Permalloy and Mo.
Tantalum	Ta	2996	16.6	1960	2240	2590	XInt.	—	—	—	Forms good films.
Tantalum Boride	TaB_2	3000	12.38	—	—	—	—	—	—	—	—
Tantalum Carbide	TaC	3880	14.65	—	—	~2500	—	—	—	—	JVST 12, 811 (1975)
Tantalum Nitride	TaN	3360	16.30	—	—	—	—	—	—	—	Reactive; evaporate Ta in 10^{-3} N_2.
Tantalum Pentoxide	Ta_2O_5	1800	8.74	1550	1780	1920	Good	Vit. Carbon	W	Ta	Slight decomposition; evaporate in 10^{-3} Torr of O_2. n ≅ 2.0 @ 1.5μ App. Opt. 19, 1737 (1980)
Tantalum Sulphide	TaS_2	1300	—	—	—	—	—	—	—	—	—
Technetium	Tc	2200	11.5	1570	1800	2090	—	—	—	—	—
Teflon	PTFE	330	2.9	—	—	—	—	—	—	W	Baffled source. Film structure doubtful.
Tellurium	Te	452	6.25	157	207	277	Poor	Al_2O_3 Quartz	W	W Ta	Wets w/o alloying. Toxic.
Terbium	Tb	1357	8.27	800	950	1150	XInt.	Al_2O_3	—	Ta	—
Terbium Fluoride	TbF_3	1176	—	—	—	~800	—	—	—	—	—
Terbium Oxide	Tb_2O_3	2387	7.87	—	—	1300	—	—	—	Ir	Partially decomposes.
Terbium Oxide	Tb_4O_7	—	—	—	—	—	—	—	—	Ta	Films TbO.
Thallium	Tl	302	11.85	280	360	470	Poor	Al_2O_3 Quartz	—	W Ta	Wets freely, very toxic.
Thallium Bromide	TlBr	480	7.56	— Sublimes	—	~250	—	Quartz	—	Ta	Toxic n = 2.3
Thallium Chloride	TlCl	430	7.00	— Sublimes	—	~150	—	Quartz	—	Ta	Toxic n = 2.25
Thallium Iodide (B)	TlI	440	7.09	— Sublimes	—	~250	—	Quartz	—	—	Toxic n = 2.78
Thallium Oxide	Tl_2O_3	717	9.65	—	—	350	—	—	—	—	Toxic, Goes to Tl_2O @ 850°C.
Thorium	Th	1875	11.7	1430	1660	1925	XInt.	—	W	W Ta Mo	Toxic, radioactive.
Thorium Bromide	$ThBr_4$	—	5.67	— Sublimes	—	—	—	—	—	Mo	Toxic n = 2.47 @ 5μ
Thorium Carbide	ThC_2	2773	8.96	—	—	~2300	—	Carbon	—	—	Radioactive.
Thorium Dioxide	ThO_2	3050	10.03	—	—	~2100	Good	—	—	W	Radioactive. n = 1.86 at 2.2 microns
Thorium Fluoride	ThF_4	1110	6.3	—	—	~750	Fair	Vit. Carbon	—	Mo	Radioactive. n = 1.52 Heat substrate to above 150°C. JVST 12, 919, (1975)

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				10^{-8} TORR	10^{-6} TORR	10^{-4} TORR	ELECTRON BEAM	CRUCIBLE	COIL	BOAT	
Thorium Oxyfluoride	$ThOF_2$	900	9.1	—	—	—	—	—	—	Mo Ta	Radioactive. n = 1.52
Thorium Sulphide	ThS_2	—	6.80	—	—	—	—	—	—	—	Sputtering preferred; or co-evaporate from 2 sources.
Thulium	Tm	1545	9.32	461 Sublimes	554	680	Good	Al_2O_3	—	Ta	—
Thulium Oxide	Tm_2O_3	—	8.90	—	—	1500	—	—	—	Ir	Decomposes.
Tin	Sn	232	7.75	682	807	997	XInt.	Al_2O_3	W	Mo	Wets Mo; use Ta liner in EB guns.
Tin Oxide	SnO_2	1127	6.95	— Sublimes	—	~1000	XInt.	Quartz Al_2O_3	W	W	Films from W oxygen deficient, oxidize in air. n = 2.0
Tin Selenide	SnSe	861	6.18	—	—	~400	Good	Quartz	—	—	JVST 12, 110 (1975)
Tin Sulphide	SnS	882	5.08	—	—	~450	—	Quartz	—	—	—
Tin Telluride	SnTe	780	6.44	—	—	~450	—	Quartz	—	—	—
Titanium	Ti	1675	4.50	1067	1235	1453	XInt.	TiC	—	W	Alloys with refractory metals; evolves gas on first heating.
Titanium Boride	TiB_2	2980	4.50	—	—	—	Poor	—	—	—	—
Titanium Carbide	TiC	3140	4.93	—	—	~2300	—	—	—	—	JVST 12, 851, (1975)
Titanium Dioxide (rutile)	TiO_2	1640	4.29	—	—	~1300	Fair	—	—	W Mo	Evaporate in 10^{-4} of O_2 onto 350° substrates. n = 2.4 App. Opt. 15, 2986 (1976)
Titanium Monoxide	TiO	1750	4.93	—	—	~1500	Good	Vit. Carbon	—	W Mo	Use gentle preheat to outgas. Films TiO_2 if evaporated like TiO_2; n ≅ 2.2
Titanium Nitride	TiN	2930	5.43	—	—	—	Good	—	—	Mo	Sputtering preferred. Decomposes with thermal evaporation.
Titanium Sesquioxide	Ti_2O_3	2130	4.6	—	—	—	Good	—	—	W	Decomposes.
Tungsten	W	3410	19.3	2117	2407	2757	Good	—	—	—	Forms volatile oxides. Films hard & adherent.
Tungsten Boride	WB_2	2900	12.75	—	—	—	Poor	—	—	—	—
Tungsten Carbide	W_2C	2860	17.15	1480	1720	2120	XInt.	—	—	C	—
Tungsten Telluride	WTe_3	—	9.49	—	—	—	—	Quartz	—	—	—
Tungsten Trioxide	WO_3	1473	7.16	— Sublimes	—	980	Good	—	—	W Pt	Use gentle preheat to outgas. W reduces oxide slightly. n = 1.68
Uranium	U	1132	19.07	1132	1327	1582	Good	—	W	Mo W	Films oxidize.
Uranium Carbide	UC_2	2260	11.28	—	—	2100	—	Carbon	—	—	Decomposes.
Uranium Dioxide	UO_2	2176	10.9	—	—	—	—	—	—	W	Ta causes decomposition.
Uranium Fluoride	UF_4	~1000	—	—	—	300	—	—	—	Ni	—
Uranium Oxide	U_3O_8	dec	8.30	—	—	—	—	—	—	W	Decomposes at 1300 °C to UO_2.
Uranium Phosphide	UP_2	—	8.57	—	—	1200	—	—	—	Ta	Decomposes.
Uranium Sulphide	U_2S_3	—	—	—	—	1400	—	—	—	W	Slight decomposition.
Vanadium	V	1890	5.96	1162	1332	1547	XInt.	—	—	W Mo	Wets Mo. EB evaporated films preferred.
Vanadium Boride	VB_2	2400	5.10	—	—	—	—	—	—	—	—
Vanadium Carbide	VC	2810	5.77	—	—	~1800	—	—	—	—	—
Vanadium Dioxide	VO_2	1967	4.34	— Sublimes	—	~575	—	—	—	—	Deposit metal in 1 x 10^{-3} O_2 JVST A2(2) 301 (1984)
Vanadium Nitride	VN	2320	6.13	—	—	—	—	—	—	—	—
Vanadium Pentoxide	V_2O_5	690	3.36	—	—	~500	—	Quartz	—	—	—
Vanadium Silicide	VSi_2	1700	4.42	—	—	—	—	—	—	—	—
Ytterbium	Yb	824	6.98	520 Sublimes	590	690	Good	—	—	Ta	—
Ytterbium Fluoride	YbF_3	1157	8.17	—	—	~800	—	—	—	Mo	n = 1.57 @ 3.8μ

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				10^{-8} TORR	10^{-6} TORR	10^{-4} TORR	ELECTRON BEAM	CRUCIBLE	COIL	BOAT	
Ytterbium Oxide	Yb_2O_3	2346	9.17	— Sublimes	—	~1500	—	—	—	Ir	Loses oxygen.
Yttrium	Y	1509	4.48	830	973	1157	XInt.	Al_2O_3	W	W Ta	High Ta solubility.
Yttrium Aluminum Oxide	$Y_3Al_5O_{12}$	1990	—	—	—	—	Good	—	W	—	Films not ferroelectric.
Yttrium Fluoride	YF_3	1387	4.01	—	—	—	—	—	—	—	—
Yttrium Oxide	Y_2O_3	2680	4.84	— Sublimes	—	~2000	Good	C	—	W	Loses oxygen, films smooth and clear. n = 1.79 @ 1μ
Zinc	Zn	419	7.14	127	177	250	XInt.	Al_2O_3 Quartz	W	Mo W Ta	Evaporates well under wide range of conditions.
Zinc Antimonide	Zn_3Sb_2	546	6.3	—	—	—	—	—	—	—	—
Zinc Bromide	$ZnBr_2$	394	4.22	—	—	~300	—	Carbon	—	W	Decomposes.
Zinc Fluoride	ZnF_2	872	4.84	—	—	~800	—	Quartz	—	Pt Ta	—
Zinc Nitride	Zn_3N_2	—	6.22	—	—	—	—	—	—	Mo	Decomposes.
Zinc Oxide	ZnO	1975	5.61	—	—	~1800	Fair	—	—	—	Anneal in air at 450°C to reoxidize; n = 2.0 JVST 12, 879 (1975)
Zinc Selenide	ZnSe	1526	5.42	—	—	660	—	Quartz	W Mo	Ta W Mo	Use gentle preheat to outgas. Evaporates well. n = 2.6
Zinc Sulphide	ZnS	1830	4.09	— Sublimes	—	~800	Good	—	—	Ta Mo	Use gentle preheat to outgas. Films partially decompose. Sticking coefficient varies with substrate temperature. n ≅ 2.3 @ .5μ
Zinc Telluride	ZnTe	1238	6.34	—	—	~600	—	—	—	Mo Ta	Use gentle preheat to outgas. n = 2.85 @ .5μ
Zircon	$ZrSiO_4$	2550	4.56	—	—	—	—	—	—	—	—
Zirconium	Zr	1852	6.40	1477	1702	1987	XInt.	—	—	W	Alloys with W. Films oxidize readily.
Zirconium Boride	ZrB_2	3040	6.08	—	—	—	Good	—	—	—	—
Zirconium Carbide	ZrC	3540	6.73	—	—	~2500	—	—	—	—	—
Zirconium Nitride	ZrN	2980	7.09	—	—	—	—	—	—	—	Reactively evaporate in 10^{-3} N_2 atmosphere.
Zirconium Oxide	ZrO_2	2700	5.49	—	—	~2200	Good	—	—	W	Films oxygen deficient, clear and hard. n = 2.05 @ .75μ
Zirconium Silicide	$ZrSi_2$	1700	4.88	—	—	—	—	—	—	—	—

IN THE PREPARATION OF THIS GUIDE, EVERY EFFORT HAS BEEN MADE TO ENSURE ACCURACY. HOWEVER, ERRORS ARE PROBABLE. EDWARD GRAPER, LEBOW CO. AND R.D. MATHIS CO. DO NOT ASSUME RESPONSIBILITY FOR CORRECTNESS OF THE INFORMATION AND FOR THE RESULTS OF ANY APPLICATION.

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APRIL, 2004