TELEMARK

THIN FILM EVAPORATION GUIDE

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	Symbol	Melting Point °C	Bulk Density g/cm^3	Acustic Impedance Ratio, z	Temperature (°C) Vap. Press 10^{-6} Torr	Temperature (°C) Vap. Press 10^{-4} Torr	Electron Beam Suitability	Crucible Liner	Index of Refraction @ microns	Remarks
Aluminum	Al	660	2.70	1.05	821	1010	Xlnt.	TiB_2-BN ZrB_2 BN	1.0@.85 33@12	Alloys and wets tungsten; stranded superior.
Aluminum Antimonide	AlSb	1080	4.3						3.62	
Aluminum Arsenide	AlAs	1600	3.7			≈1300				
Aluminum Bromide	$AlBr_3$	97	2.64			≈50		Graphite		
Aluminum Carbide	Al_4C_3	2100	2.36			≈800	Fair		2.75@.70	Sublimes
Aluminum 2% Copper	Al2%Cu	640	2.82							Wire feed and flash, difficult from dual sources.
Aluminum Fluoride	AlF_3	2191	2.88		490	700	Poor	Graphite	1.38@.55	Sublimes.
Aluminum Nitride	AlN	2200	3.26			≈1750	Fair			Decomposes. Reactive evap Al in 10^3 N_2 with glow discharge.
Aluminum Oxide (a)(alumina)	Al_2O_3	2045	3.96	.36		1550	Xlnt.		1.59@.60 1.56@1.6	Sapphire xlnt. in EB, forms smooth hard films.
Aluminum Phosphide	AlP	2000	2.42							
Aluminum 2% Silicon	Al2%Si	640	2.69			1010		TiB_2-BN		Wire feed and flash, difficult from dual source.
Antimony	Sb	631	6.62	.59	345	428	Fair	BN, C Al_2O_3	3.4@1.0 5.1@11	Toxic. Film structure is rate dependent Use Mo E.B. liner.
Antimony Telluride	Sb_2Te_3	629	6.50			600		Carbon		Toxic. Decomposes over 750°C.
Antimony Oxide	Sb_2O_3	656	5.82			≈300	Good	BN Al_2O_3	2.10@.50	Toxic, sublimes. Decomposes on W. Use low rate. Z. Physik 165,202 (1961).
Antimony Selenide	Sb_2Se_3	629	6.50	1.87				Carbon		Toxic. Stoichiometry variable.
Antimony Sulfide	Sb_2S_3	550	4.12			≈200	Good	Al_2O_3	3.01@.55	Toxic. No decomposition.
Arsenic	As	814	5.73		150	210	Poor	Al_2O_3 BeO Vit. Carbon		Toxic. Sublimes rapidly at low temperature.
Arsenic Selenide	As_2Se_3	360	4.75					Al_2O_3 Quartz	3.03@.82 2.9@92	Toxic. JVST 10, 748 (1973).
Arsenic Sulfide	AS_2S_3	300	3.43			≈400	Fair	Mo	2.69@.56 2.84@88	Toxic. JVST 10, 748 (1973).
Arsenic Telluride	AS_2Te_3	362	≈5.0							Toxic. JVST 10, 748 (1975).
Barium	Ba	725	3.51		627	735	Fair		.85@.50	Toxic. Wets w/o alloying, reacts with ceramics.
Barium Chloride	$BaCl_2$	961	3.86			≈650	Good		1.74@.58	Use gentle preheat to outgas.
Barium Fluoride	BaF_2	1280	4.89	.90		≈480	Good		1.51@.27 1.40@10.3	Sublimes. Density rate dependent.
Barium Oxide	BaO	1923	5.72			≈1300	Poor	Al_2O_3	1.98@.59	Decomposes slightly.

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Barium Sulfide	BaS	1200	4.25			1100			2.16@.59	Sublimes.
Barium Titanate	$BaTiO_3$	1620	5.85	.32	Decomposes ...				2.4@.8	Decomposes, yields free Ba; sputter or coevaporate.
Beryllium	Be	1283	1.85	.55	710	1000	Xlnt.	BeO C Vit. Carbon	2.5@.5	Metal powder and oxides very toxic. Wets W/Mo/Ta.
Beryllium Chloride	$BeCl_2$	440	1.90			≈150				Very toxic.
Beryllium Fluoride	BeF_2	800	1.99			≈480	Good		1.33@.59	Very toxic, sublimes.
Beryllium Oxide	BeO	2575	3.01			1900	Good		1.82@.19 1.72@.55	Powders very toxic. No decomposition from EB guns.
Bismuth	Bi	271	9.80	.81	410	520	Xlnt.	Al_2O_3 Vit. Carbon	.82@.35 4.5@1.0	Vapors are toxic. High resistivity.
Bismuth Fluoride	BiF_3	727	5.32			≈300		Graphite	1.74@1.0 1.64@10	Toxic, sublimes. App. Opt. 18,105 (1979).
Bismuth Oxide	Bi_2O_3	811	8.9			≈1390	Poor		2.48@.58	Vapors are toxic. JVST 12, 63 (1975).
Bismuth Selenide	Bi_2Se_3	710	7.66			≈650	Good	Graphite Quartz		Toxic. Sputter or coevaporate.
Bismuth Telluride	Bi_2Te_3	585	6.82			≈600		Graphite Quartz		Toxic. Sputter or coevaporate.
Bismuth Titanate	$Bi_2Ti_2O_7$				Decomposes ...					Toxic. Decomposes. Sputter or coevaporate in 10^2 O_2.
Bismuth Sulfide	Bi_2S_3	685	7.39						≈1.5	Toxic.
Boron	B	2100	2.34	.45	1548	1797	Fair	C Vit. Carbon		Material explodes with rapid cooling. Forms carbide with container.
Boron Carbide	B_4C	2350	2.52		2580	2650	Xlnt.			Similar to chromium.
Boron Nitride	BN	2300	2.25			≈1600	Poor			Sputtering pref. Decomposes. JVST A5(4),2696 (1987).
Boron Oxide	B_2O_3	460	2.46			≈1400	Good		1.46	
Boron Sulfide	B_2S_3	310	1.55			800		Graphite		
Cadmium	Cd	321	8.65	.6	120	180	Fair	Al_2O_3 Quartz	1.13@.6	Poisons vacuum systems, low sticking coefficient. Use Mo E.B. liner.
Cadmium Antimonide	CdSb	456	6.92							
Cadmium Arsenide	Cd_3As_2	721	6.21					Quartz		Toxic.
Cadmium Bromide	$CdBr_2$	567	5.19			≈300				Sublimes.
Cadmium Chloride	$CdCl_2$	960	4.05			≈400				Sublimes.
Cadmium Fluoride	CdF_2	1100	6.64			≈600			1.56@.58	

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Cadmium Iodide	CdI_2	387	5.67			≈250				
Cadmium Oxide	CdO	1430	8.15			≈530			2.49@.67	Disproportionates.
Cadmium Selenide	CdSe	1351	5.79			580	Good	Al_2O_3 Quartz	2.4@.58	Toxic, sublimes.
Cadmium Silicide	$CdSiO_2$					≈600			1.69	
Cadmium Sulfide	CdS	1750	4.82	1.02		550	Good	Al_2O_3 Quartz	2.43@.67 2.31@1.4 2.27@7.0	Sublimes. Sticking coeff. affected by sub temp. Comp. variable JVST 12,188 (1975)
Cadmium Telluride	CdTe	1041	6.20	.98		450			2.68@4.0 2.51@32	Toxic. Stoichiometry depends on substrate temp. JVST 8,412 (1971).
Calcium	Ca	845	1.55	2.36	357	459	Poor	Al_2O_3 Quartz	.29@.58	Flammable, sublimes. Corrodes in air. Optic 18,59 (1961).
Calcium Fluoride	CaF_2	1360	3.18	.85		≈1100	Xlnt.	Quartz	1.47@.24 1.32@9.4	Rate control important. Use gentle preheat to Outgas.
Calcium Oxide	CaO	2580	3.35-3.38			≈1700		ZrO_2	1.84@.59	Forms volatile oxides with W and Mo.
Calcium Silicate	CaO SiO_2	1540	2.90				Good	Quartz	1.61	
Calcium Sulfide	CaS	subl.	2.5			1100			2.14@.59	Decomposes.
Calcium Titanate	$CaTiO_3$	1975	4.10		1600	1690	Poor		2.34@.59	Disproportionates except in sputtering.
Calcium Tungstate	$CaWO_4$	1620	6.06				Good		1.92@.59	
Carbon (Diamond)	C	3727	3.52	.22					2.94@.19 2.42@.66	Deposit by CVD.
Carbon (Graphite)	C	subl.	2.26	4.33	1867	2137	Fair		1.47	Sublimes. EB preferred, Arc evaporat. Poor film adhesion.
Cerium	Ce	795	6.67	.86	1150	1380	Good	Al_2O_3 BeO Vit. Carbon	1.91@.59	Films oxidize easily.
Cerium (III) Fluoride	CeF_3	1460	6.16			≈900	Good		1.63@.55 1.55@12	Use gentle preheat to outgas.
Cerium (IV) Oxide	CeO_2	2600	7.13		1890	2310	Good		2.18@.55	Sublimes. Use 250°C sub. temperature. Reacts with W. J Opt Soc Am 48,324 (1958).
Cerium Oxide	Ce_2O_3	1691	6.89	≈.41			Fair		2.18@.58	Alloys with source. J.Opt.Soc.Am 48,324 (1958).
Cesium	Cs	29	1.89		22	30		Quartz		Flammable.
Cesium Bromide	CsBr	636	4.44	1.72		≈400			1.79@.36 1.56@39	
Cesium Chloride	CsCl	646	3.99			≈500			1.64	Hygroscopic.
Cesium Fluoride	CsF	682	4.11			≈500				
Cesium Hydroxide	CsOH	272	3.67			550				

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Cesium Iodide	CsI	621	4.51	2.95		≈500		Pt Quartz	1.99@.23 1.62@53	
Chiolote	$Na_5Al_3F_{14}$		2.9			≈800			1.33	
Chromium	Cr	1875	7.19	.31	977	1157	Good	Vit. Carbon	.83@.13 3.19@.63	Sublimes. Films very adherent. High rates possible.
Chromium Boride	CrB	2760	6.17							
Chromium Bromide	$CrBr_2$	842	4.36			550				
Chromium Carbide	Cr_3C_2	1890	6.68			≈2000	Fair			
Chromium Chloride	$CrCl_2$	824	2.88			550				Sublimes easily.
Chromium Oxide	Cr_2O_3	2435	5.21			≈2000	Good		2.5@.59	Disproportionates to lower oxides, reoxidizes @ 600°C in air.
Chromium Silicide	Cr_3Si_2	1710	6.51							
Chromium-Silicon Monoxide	Cr-SiO	influenced by composition					Good			Flash.
Cobalt	Co	1495	8.92	.34	990	1200	Xlnt.	Al_2O_3 BeO	1.10@.23 5.65@2.2	Alloys with refractory metals.
Cobalt Bromide	$CoBr_2$	678	4.91			400				Sublimes.
Cobalt Chloride	$CoCl_2$	724	3.37			472			1.51@.63	Sublimes.
Cobalt Oxide	CoO	1935	6.45							Sputtering preferred.
Copper	Cu	1083	8.94	.43	857	1017	Xlnt.	Al_2O_3 Mo, Ta	.87@.45 15.5@12	Films do not adhere well. Use intermediate Cr layer, O_2 free Cu req'd.
Copper Chloride	CuCl	431	4.19			≈580			1.93	
Copper Oxide	Cu_2O	1235	6.0			≈600	Good	Al_2O_3	2.70@.59	Sublimes. Evaporate in 10^2 to 10^4 of O_2; J.Electrochem. Soc. 110,119 (1967).
Copper (I) Sulfide	Cu_2S	1100	5.6	.68						
Copper (II) Sulfide	CuS	1113	6.75	.82		≈500			1.45	Sublimes.
Cryolite	Na_3AlF_6	1000	2.9		1260	1480	Xlnt.	Vit. Carbon	2.34@.63	Large chunks reduce spitting. Little decomposition. App.Opt.15, 1969 (1976).
Dysprosium	Dy	1407	8.54	.60	750	900	Good			Flammable.
Dysprosium Fluoride	DyF_3	1360				≈800	Good			Sublimes.
Dysprosium Oxide	Dy_2O_3	2340	7.81			≈1400				Loses oxygen.
Erbium	Er	1461	9.09	.74	775	980	Good			Sublimes.

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Erbium Fluoride	ErF_3	1350	7.81			≈750				JVST A3(6),2320.
Erbium Oxide	Er_2O_3	2400	8.64			≈1600				Loses oxygen.
Europium	Eu	826	5.26	1.62	360	480	Fair	Al_2O_3		Flammable, sublimes. Low tantalum solubility.
Europium Fluoride	EuF_2	1390	6.5			≈950				
Europium Oxide	Eu_2O_3	2056	7.42			≈1600	Good	ThO_2		Loses oxygen; films clear and hard.
Europium Sulfide	EuS		5.75				Good			
Gadolinium	Gd	1312	7.89	.67	900	1175	Xlnt.	Al_2O_3		High Ta solubility. Flammable.
Gadolinium Oxide	Gd_2O_3	2310	7.41				Fair		1.8@.55	Loses oxygen.
Gallium	Ga	30	5.91	.59	742	907	Good	Al_2O_3 BeO Quartz		Alloys with refractory metals. Use EB gun.
Gallium Antimonide	GaSb	710	5.6				Fair		3.80@2.2	Flash evaporate.
Gallium Arsenide	GaAs	1238	5.31	1.59			Good	Carbon	3.34@.78 2.12@23	Flash evaporate.
Gallium Nitride	GaN	800	6.1			≈200		Al_2O_3		Sublimes. Evaporate Ga in $10^3 N_2$.
Gallium Oxide(β)	Ga_2O_3	1900	5.88							Loses oxygen.
Gallium Phosphide	GaP	1348	4.1		770	920		Quartz	3@2.15	Decomposes. Vapor mostly P.
Germanium	Ge	937	5.32	.51	957	1167	Xlnt.	Quartz Al_2O_3	4.20@2.1 4.00@20	
Germanium Nitride	Ge_3N_2	450	5.25			≈650				Sublimes. Sputtering preferred.
Germanium Oxide	GeO_2	1086	6.24			≈625	Good	Quartz Al_2O_3	≈1.61@.59	Similar to SiO, film predominately GeO.
Germanium Telluride	GeTe	725	6.20			381		Quartz Al_2O_3		
Glass, Schott 8329	-		2.20				Xlnt.		1.47	Evaporable alkali glass. Melt in air before evaporating.
Gold	Au	1962	19.32	.39	947	1132	Xlnt.	Al_2O_3 BN Vit. Carbon	1.50@.13 32@12	Films soft, not very adherent.JVST 12,704 (1975).
Hafnium	Hf	2222	13.09	.34	2250	3090	Good			
Hafnium Boride	HfB_2	3250	10.5							
Hafnium Carbide	HfC	3890	12.20			≈2600				Sublimes.
Hafnium Nitride	HfN	3305	13.8							

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Hafnium Oxide	HfO_2	2811	9.69			≈2500	Fair		2.08@.48	Film HfO. App. Opt. Apr. 1977.
Hafnium Silicide	$HfSi_2$	1680	8.02							
Holnium	Ho	1461	8.80	.58	770	950	Good			Sublimes.
Holnium Fluoride	HoF_3	1143	7.64			≈800		Quartz		
Holnium Oxide	Ho_2O_3	2360	8.36							Loses oxygen. App. Opt. 16,439
Inconel	Ni/Cr/Fe	1425	8.5	.33			Good			Use fine wire prewrapped on W. Low rate required for smooth films.
Indium	In	157	7.31	.84	597	742	XInt.	Graphite Al_2O_3		Wets W and Cu; use Mo liner in guns.
Indium Antimonide	InSb	535	5.76	.77		≈400			1.00@.55 4.0@7.9 3.8@22	Toxic. Decomposes; sputter preferred; or coevaporate from 2 sources; flash.
Indium Arsenide	InAs	943	5.7		870	970			≈3.3@10	Toxic. Sputtering preferred; or coevaporate from 2 sources; flash.
Indium Oxide	In_2O_3	1565	7.18			≈1200	Good	Al_2O_3		Sublimes. Film In_2O; transparent conductor. JVST 12,99 (1975).
Indium Phosphide	InP	1071	4.9		630	730		Graphite	≈3.3@8.8	Deposits P rich. Flash evaporate.
Indium Selenide	In_2Se_3	890	5.67							Sputter, coevaporate or flash.
Indium (III) Sulfide	In_2S_3	1050	4.45			850		Graphite		Sublimes. Film In_2S.
Indium (I) Sulfide	In_2S	653	5.87			650		Graphite		
Indium Telluride	In_2Te_3	667	5.8							Sputter, coevaporate, or flash.
Iridium	Ir	2454	22.45	.13	2080	2380	Fair	ThO_2		
Iron	Fe	1536	7.87	.35	998	1180	Good	Al_2O_3 BeO	2.0@.58	Attacks W. Films hard, smooth. Use gentle preheat to outgas.
Iron Bromide	$FeBr_2$	684	4.64			561		Fe		
Iron Chloride	$FeCl_2$	674	3.16			300		Fe	1.57@.59	Sublimes.
Iron Iodide	FeI_2	592	5.31			400		Fe		
Iron (II) Oxide	FeO	1420	5.7				Poor		2.32@.59	Decomposes; sputtering preferred.
Iron (III) Oxide	Fe_2O_3	1538	5.18				Good		3.0	Disproportionates to Fe_3O_4 at 1530°C.
Iron Sulfide	FeS	1195	4.74					Al_2O_3		Decomposes.
Kanthal	FeCrAl	1500	7.1			≈1150			1.74@.58	JVST 7, 739 (1980).

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Lanthanium	La	920	6.1	.93	1212	1368	XInt.	Al_2O_3		Films will burn in air if scraped.
Lanthanium Boride	LaB_6	2210	2.61				Good			Toxic.
Lanthanium Fluoride	LaF_3	1491	5.99			900	Good		1.40@.30 1.20@8.8	Sublimes. No decomposition. Heat substrate over 300°C.
Lanthanium Oxide	La_2O_3	2315	6.51			1400	Good		1.95@.55 1.89@2.0	Loses oxygen.
Lead	Pb	327	11.34	1.10	427	497	XInt.	Al_2O_3 Quartz	2.6@.58	Toxic. Use Mo liner in E.B. gun.
Lead Bromide	$PbBr_2$	373	6.68			≈300				Toxic.
Lead Chloride	$PbCl_2$	501	5.85			≈325		Al_2O_3	2.3@.55 2.0@10	Toxic. Little decomposition.
Lead Fluoride	PbF_2	855	8.24			≈400		BeO	1.92@.30 1.60@11	Toxic, sublimes. Z.Physic 159,117 (1959).
Lead Iodide	PbI_2	502	6.16			≈320		Quartz	≈2.7	Toxic. J. Opt. Soc. 65,914.
Lead Oxide	PbO	888	9.53			≈550		Quartz Al_2O_3	2.51@.59	Toxic. No decomposition. J.Opt.Soc.Am. 52,161 (1962).
Lead Stannate	$PbSnO_3$	1115	8.1		780	905	Poor	Al_2O_3		Toxic. Disproportionates.
Lead Selenide	PbSe	1065	8.10			≈500		Graphite Al_2O_3	≈3.5@1.0	Toxic, sublimes.
Lead Sulfide	PbS	1114	7.5	.56		550		Quartz Al_2O_3	≈3.9@.5	Toxic, sublimes. Little decomposition.
Lead Telluride	PbTe	917	8.16		910	1050		Graphite Al_2O_3	≈5.6@5 ≈3.4@30	Vapors toxic. Deposits Te rich. Sputter or coevaporate.
Lead Titanate	$PbTiO_3$		7.52							Toxic.
Lithium	Li	180	0.53	5.95	307	407	Good	Al_2O_3 BeO		Metal reacts rapidly in air.
Lithium Bromide	LiBr	550	3.46			≈500			1.78@.59	
Lithium Chloride	LiCl	614	2.07			400			1.66@.59	Use gently preheat for outgas.
Lithium Fluoride	LiF	841	2.59	.78	1020	1180	Good	Al_2O_3	1.44@.19 1.36@3.5	Rate control important. Use preheat for outgas. App. Opt.11,2245 (1972).
Lithium Iodide	LiI	450	3.49			400			1.96@.59	
Lithium Oxide	Li_2O	1427	2.01			850			1.64@.59	
Lutetium	Lu	1652	9.84	.48		1300	XInt.	Al_2O_3		Ta impurity a problem.
Lutetium Oxide	Lu_2O_3	2487	9.41			1400				Decomposes.
Magnesium	Mg	650	1.74	1.61	247	327	Good	Al_2O_3 Vit. Carbon	.52@.40	Flammable, sublimes. Extremely high rates possible.

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Magnesium Aluminate	$MgAl_2O_4$	2135	3.6				Good			Natural spinel.
Magnesium Bromide	$MgBr_2$	700	3.72			≈450				Decomposes.
Magnesium Chloride	$MgCl_2$	714	2.32			400			1.6	Decomposes.
Magnesium Fluoride	MgF_2	1248	3.0	≈.68		1000	XInt.	Al_2O_3	1.52@.20 1.36@2.0	Rate control & sub. heat required for optical films. App. Opt.11, 2245 (1972).
Magnesium Iodide	MgI_2	700	4.24			200				
Magnesium Oxide	MgO	2800	3.58	.38		1300	Good	Carbon Al_2O_3	1.77@.36 1.63@5.1	W produces volatile oxides. App. Opt.11, 2243 (1972).
Manganese	Mn	1241	7.39	.43	572	648	Good	Al_2O_3 BeO	2.59@.59	Flammable, sublimes.
Manganese Bromide	$MnBr_2$	695	4.38			500				
Manganese Chloride	$MnCl_2$	650	2.98			450				
Manganese Oxide	Mn_3O_4	1705	4.86						1.73	
Manganese Sulfide	MnS	1615	3.58	.94		1300			2.7	Decomposes.
Mercury	Hg	-39	13.55	.74	-42	-6				Toxic.
Mercury Sulfide	HgS	583	8.10			250		Al_2O_3		Toxic, decomposes.
Molybdenum	Mo	2610	10.22	.27	1822	2117	XInt.		3.65@.59	Films smooth, hard. Careful degas req'd.
Molybdenum Boride	Mo_2B_3	2200	7.48				Poor			
Molybdenum Carbide	Mo_2C	2687	9.18				Fair			Evaporation of $Mo(CO)_6$ yields Mo_6C.
Molybdenum Silicide	$MoSi_2$	2050	6.31						1.9	Slight O_2 loss.
Molybdenum Sulfide	MoS_2	1185	4.80			≈50				Decomposes.
Molybdenum Oxide	MoO_3	795	4.69			≈900		Al_2O_3 BN		
Neodynium	Nd	1024	7.00	.84	871	1062	XInt.	Al_2O_3	.89@.39 .30@.88	Flammable. Low Ta solubility.
Neodynium Fluoride	NdF_3	1410	6.51			≈900	Good	Al_2O_3	1.61@.55 1.58@2.0	Very little decomposition.
Neodynium Oxide	Nd_2O_3	1900	7.24			≈1400	Good	ThO_2	2.0@.55 1.95@2.0	Loses O_2, films clear, EB preferred. Hygroscopic. n varies with substrate temp.
Nichrome IV	Ni/Cr	1395	8.50		987	1217	XInt.	Al_2O_3 Vit. Carbon BeO	3.74@8.8 10.2@12.5	Alloys with refractory metals.
Nickel	Ni	1453	8.91	.33	1072	1262	Fair	Al_2O_3 BeO Vit. Carbon	3.74@8.8 10.2@12.5	Alloys with refractory metals. Forms smooth adherent films.

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Nickel Bromide	$NiBr_2$	963	4.64			362				Sublimes.
Nickel Chloride	$NiCl_2$	1001	3.55			444				Sublimes.
Nickel Oxide	NiO	1990	6.69			≈1480		Al_2O_3	2.18@.48	Dissociates upon heating.
Niobium (Columbium)	Nb	2468	8.57	.47	1977	2287	Xlnt.		1.80@.58	Attacks W source.
Niobium Boride	NbB_2	3050	6.97							
Niobium Carbide	NbC	3500	7.82				Fair			
Niobium Nitride	NbN	2573	8.4							Reactive, evaporate Nb in 10^3 N_2.
Niobium Oxide	NbO		7.30			1100				
Niobium Oxide (V)	Nb_2O_5	1520	4.47						2.3	
Niobium Telluride	$NbTe_5$		7.6							Composition variable.
Niobium-Tin	Nb_3Sn		-				Xlnt.			Coevaporate from 2 sources.
Osmium	Os	3045	22.6	.13	2430	2760	Fair			Toxic.
Palladium	Pd	1552	12.02	.38	992	1192	Xlnt.	Al_2O_3 BeO	1.5@.30 2.3@.54	Alloys with refractory metals; rapid evaporation suggested. Spits in EB.
Palladium Oxide	PdO	870	8.70			575		Al_2O_3		Decomposes.
Parylene-N	C_6H_8	300	1.1			-400				Vapor depositable plastic. (Union Carbide).
Permalloy	Ni/Fe	1395	8.7		1047	1307	Good	Al_2O_3 Vit. Carbon		Film low in Ni content. Use 84% Ni source. JVST 7(6),573 (1970).
Phosphorus	P	44.2	1.82		361	402		Al_2O_3		Metal reacts violently in air.
Platinum	Pt	1769	21.45	.24	1492	1747	Xlnt.	C ThO_2	3.42@1.0	Alloys, E.B. req'd. Films soft. Poor adhesion.
Platinum Oxide	PtO_2	450	10.2							
Plutonium	Pu	635	19							Toxic, radioactive.
Polonium	Po	254	9.4		170	244		Quartz		Radioactive.
Potassium	K	64	0.86		60	125		Quartz	.74@.25	Metal reacts violently in air. Use gentle preheat to outgas.
Potassium Bromide	KBr	731	2.79			≈450		Quartz	1.56@.48 1.47@24	Use gentle preheat to outgas.
Potassium Chloride	KCl	776	2.51	2.05		510	Good		1.72@.20 1.25@24	Melt in air to outgas.

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Potassium Fluoride	KF	846	2.48			≈500	Poor	Quartz	1.35@1.4	Melt in air to outgas.
Potassium Hydroxide	KOH	360	2.04			≈400				Melt in air to outgas. Hygroscopic.
Potassium Iodide	KI	686	3.13	2.0		≈500			1.92@.27 1.56@28	Melt in air to outgas.
Praseodymium	Pr	936	6.77		950	1150	Good			Flammable.
Praseodymium Chloride	$PrCl_3$	786	4.02			≈500			1.86	
Praseodymium Oxide	Pr_2O_3	2125	6.88			1400	Good	ThO_2	1.92@.27 1.83@2.0	Loses oxygen.
Radium	Ra	700	5.0		320	416				
Rhenium	Re	3180	21.04	.14	2207	2571	Poor		3.18@.59	Fine wire will selfevaporate.
Rhenium Oxide	Re_2O_7	297	6.10			≈100				
Rhodium	Rh	1966	12.41	.24	1472	1707	Good	ThO_2 Vit. Carbon	1.62@.55	EB gun preferred.
Rubidium	Rb	38	1.53	2.54	37	111		Quartz	1.03@.25	
Rubidium Chloride	RbCl	715	2.80			≈550		Quartz	1.49	
Rubidium Iodide	RbI	641	3.59			≈400		Quartz	1.68@.58	
Ruthenium	Ru	2500	12.45	.20	1990	2260	Poor			Spits violently in EB. Requires long degas.
Samarium	Sm	1072	7.54	.91	460	573	Good	Al_2O_3		
Samarium Oxide	Sm_2O_3	2350	8.35				Good	ThO_2	1.97	Loses O_2. Films smooth, clear.
Samarium Sulfide	Sm_2S_3	1900	5.72				Good			A.IP Conf.Proc. on Mag.& Mag. Mat.B, 5,860 (1971).
Scandium	Sc	1539	2.99	.91	837	1002	Xlnt.	Al_2O_3 BeO		Alloys with Ta.Flammable.
Scandium Fluoride	ScF_3	1550	2.50			≈1400	Good			
Scandium Oxide	Sc_2O_3	2300	3.86			≈400	Fair		1.88@.55	Loses O_2.
Selenium	Se	217	4.79	.87	125	170	Xlnt.	Al_2O_3 Vit. Carbon	1.88@.24 2.43@2.36	Very toxic. Poisons vacuum systems. JVST 9, 387 (1972) JVST 12, 573 & 807 (1975)
Silicon	Si	1410	2.33	.88	1147	1337	Fair	BeO Ta Vit. Carbon	3.49@1.4 3.42@32	Alloys with W; Some SiO produced above $4x10^6$ Torr. App.Opt. 15,2348 (1976).
Silicon Boride	SiB_4	1870	2.47				Poor			
Silicon Carbide	SiC	2700	3.22			1000			2.62@.69 6.86@13	Sputtering preferred.

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Silicon Dioxide	SiO_2	1610-1710	2.20 - 2.70	1.00 influenced by composition		≈1025	Xlnt.	Al_2O_3	1.47@.30 1.45@2.8	Quartz xlnt. in EB.
Silicon (II) Monoxide	SiO	1702	2.1	.50		850	Poor	Ta	2.10@.10 1.67@6 2.75@11	Sublimes. Baffle box source best.
Silicon Nitride	Si_3N_4	1900	3.44			≈800			2.0@.12 2.05@4	Sublimes.
Silicon Selenide	SiSe					550		Quartz		Toxic.
Silicon Sulfide	SiS	subl.	1.85			450		Quartz		
Silicon Telluride	$SiTe_2$		4.39			550		Quartz		Toxic.
Silver	Ag	961	10.49	.50	958	1105	Xlnt.	Al_2O_3 Mo	1.2@.30 14.5@12	Evaporates well from any source.
Silver Bromide	AgBr	431	6.49	1.18		≈380		Quartz	2.28@.58	
Silver Chloride	AgCl	455	5.56	1.41		≈520		Quartz	2.13@.43 1.91@19	
Silver Iodide	AgI	558	6.01			≈500			2.02@.59	
Sodium	Na	97	0.97	4.8	124	192		Quartz	.03@.59	Metal reacts violently in air.
Sodium Bromide	NaBr	755	3.20			≈400		Quartz	2.12@.21 1.64@.59	Use gentle preheat to outgas.
Sodium Chloride	NaCl	801	2.16	1.57		530	Good	Quartz	1.79@.20 1.20@27	Little decomposition. Use gentle preheat to outgas. Hygroscopic.
Sodium Cyanide	NaCN	563				550			1.45@.59	Toxic. Use gentle preheat to outgas.
Sodium Fluoride	NaF	988	2.56			≈700	Good	BeO	1.39@.19 1.25@23	Use gentle preheat to outgas.
Sodium Hydroxide	NaOH	318	2.13			≈470			1.36	Melt in air to outgas. Deliquescent.
Sodium Iodide	NaI	651	3.67			≈700			1.80@.49 1.76@.66	
Spinel	MgO_3 $5Al_2O_3$		8.0				Good		1.72@.66	
Strontium	Sr	769	2.6		309	403	Poor	Vit. Carbon	.61@.58	Toxic. Wets but does not alloy with refractory metal May react violently in air.
Strontium Fluoride	SrF_2	1450	4.24			≈1000		Al_2O_3	1.44@1.4	
Strontium Oxide	SrO	2461	4.9			1500		Al_2O_3	1.88@.58	Sublimes. Reacts with Mo and W.
Strontium Sulfide	SrS	>2000	3.70						2.11@.59	Decomposes.
Sulfur	S	115	2.07	2.29	19	57	Poor	Quartz		Toxic. Poisons vacuum system.
Supermalloy	Ni/Fe/Mo	1410	8.9				Good			Sputtering preferred; or coevap. from 2 sources: Permalloy and Mo.

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Tantalum	Ta	2996	16.6	.26	2240	2590	XInt.		2.05@.58	Forms good films.
Tantalum Boride	TaB_2	3000	11.15							
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 Oxide	Ta_2O_5	1800	8.74	.30	1780	1920	Good	Vit. Carbon	2.28@.40 2.0@1.5	Slight decomposition; evap. in 10^3 Torr of O_2. App. Opt. 19, 1737 (1980).
Tantalum Sulfide	TaS_2	1300								
Technetium	Tc	2200	11.5		1800	2090				
Teflon	PTFE	330	2.9							Baffled source. Film structure doubtful.
Tellurium	Te	452	6.25	.53	207	277	Poor	Al_2O_3 Quartz	4.9@6.0	Toxic. Wets w/o alloying.
Terbium	Tb	1357	8.27	.64	950	1150	XInt.	Al_2O_3		
Terbium Fluoride	TbF_3	1176				≈800				
Terbium Oxide	Tb_2O_3	2387	7.87			1300				Partially decomposes.
Terbium Oxide	Tb_4O_7									Films TbO.
Thallium	Tl	301	11.89	1.58	360	480	Poor	Al_2O_3 Quartz		Wets freely, very toxic.
Thallium Bromide	TlBr	480	7.56	1.77		≈200		Quartz	2.65@.44 2.32@24	Toxic, sublimes.
Thalium Chloride	TlCl	430	7.00	1.21		≈150		Quartz	2.20@.75 2.6@12	Toxic, sublimes.
Thallium Iodide (B)	TlI	440	7.09			≈200		Quartz	2.78@.75	Toxic, sublimes.
Thallium Oxide	Tl_2O_3	717	9.65			350				Toxic. Goes to Tl_2 at 850°C.
Thorium	Th	1875	11.7	.54	1660	1925	XInt.			Toxic, radioactive.
Thorium Bromide	$ThBr_4$		5.67						2.47@5	Radioactive, sublimes.
Thorium Carbide	ThC_2	2773	8.96			≈2300		Carbon		Radioactive.
Thorium Fluoride	ThF_4	900	6.32	.74		≈750	Fair	Vit. Carbon	1.52@.40 1.25@12	Radioactive. Heat substrate to above 150°C. JVST 12,919 (1975).
Thorium Oxide	ThO_2	3050	9.86			≈2100	Good		1.8@.55 1.75@2.0	Radioactive.
Thorium Oxyfluoride	$ThOF_2$	900	9.1						1.52	Radioactive. Films often ThF_4.

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Thorium Sulfide	ThS_2	1925	6.80							Radioactive. Sputtering preferred; or coevaporate from 2 sources.
Thulium	Tm	1545	9.32	.52	554	680	Good	Al_2O_3		Sublimes.
Thulium Oxide	Tm_2O_3		8.90			1500				Decomposes.
Tin	Sn	232	7.29	.74	807	997	Xlnt.	Al_2O_3	1.48@.59	Wets Mo; use Ta liner in EB guns.
Tin Oxide	SnO_2	1131	6.99			≈1000	Xlnt.	Quartz Al_2O_3	2.08@.58	Films from W oxygen deficient, oxidize in air.
Tin Selenide	SnSe	861	6.18			≈400	Good	Quartz		JVST 12, 110 (1975).
Tin Sulfide	SnS	882	5.22			≈450		Quartz		
Tin Telluride	SnTe	780	6.44			≈450		Quartz		
Titanium	Ti	1668	4.50	.63	1235	1453	Xlnt.	TiC	2.04@.45	Alloys with refractory metals; evolves gas on first heating.
Titanium Boride	TiB_2	2900	4.50				Poor			
Titanium Carbide	TiC	3140	4.93			≈2300				JVST 12, 851 (1975).
Titanium Oxide (IV) (rutile)	TiO_2	1840	4.26	.40		≈1300	Fair		2.55@.38 2.30@1.0	Evaporate in 10^4 of O_2 onto 350°C substrates. App.Opt.15,2986 (1976).
Titanium(II) Oxide	TiO	1700	4.95			≈1500	Good	Vit. Carbon	≈2.2	Use gentle preheat to outgas. Films TiO_2 if evaporated like TiO_2.
Titanium Nitride	TiN	2930	5.43				Good			Sputter preferred. Decomposes with thermal evaporation.
Titanium Silicide	$TiSi_2$	1540	4.39							
Tungsten	W	3387	19.3	.16	2407	2757	Good		2.76@.58	Forms volatile oxides. Films hard and adherent.
Tungsten Boride	WB_2	2900	12.75				Poor			
Tungsten Carbide	W_2C	267	15.6	.18	1720	2120	Xlnt.			
Tungsten Oxide	WO_3	1473	7.16			980	Good		2.0@.5 2.0@2.0	Sublimes Preheat to outgas. W reduces oxide slightly. App. OPT 28, 1497.
Tungsten Selenide	WSe_2	2150	9.0							
Tungsten Silicide	WSi_2	2165	9.4							
Tungsten Sulfide	WS_2	1250	7.51							
Tungsten Telluride	WTe_3		9.49					Quartz		
Uranium	U	1132	19.07	.24	1327	1582	Good			Films oxidize.

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Uranium Carbide	UC_2	2260	11.28			2100		Carbon		Decomposes.
Uranium Fluoride	UF_4	≈1000				300				
Uranium (IV) Oxide	UO_2	2500	10.9							Ta causes decomposition.
Uranium Oxide	U_3O_3	dec	8.30							Decomposes at 1300°C to UO_2.
Uranium Phosphide	UP_2		8.57			1200				Decomposes.
Uranium Sulfide	U_2S_3					1400				Slight decomposition.
Vanadium	V	1890	6.11	.53	1332	1547	XInt.		3.03@.58	Wets Mo. EB evaporated films preferred.
Vanadium Boride	VB_2	2400	5.10							
Vanadium Carbide	VC	2810	5.77			≈1800				
Vanadium Nitride	VN	2320	6.13							
Vanadium (IV) Oxide	VO_2	1967	4.34			≈575			2.51@.63 2.76@3.4	Sublimes. Deposit V metal @ $7x10^3$ O_2 JVST A2(2),301 (1984) & A7(3),1310 (1989).
Vanadium (V) Oxide	V_2O_5	690	3.36			≈500		Quartz		
Vanadium Silicide	VSi_2	1700	4.42							
Ytterbium	Yb	824	6.98	1.27	590	690	Good			Sublimes.
Ytterbium Fluoride	YbF_3	1161	8.19			≈780			1.48@2.2 1.32@14	
Ytterbium Oxide	Yb_2O_3	2227	9.17			≈1500				Sublimes. Loses oxygen.
Yttrium	Y	1509	4.47	.82	973	1157	XInt.	Al_2O_3		High Ta solubility.
Yttrium Aluminum Oxide	$Y_3Al_5O_{12}$	1990					Good			Films not ferroelectric.
Yttrium Fluoride	YF_3	1152	4.01						1.46@2.5 1.42@10	
Yttrium Oxide	Y_2O_3	2410	5.01			≈2000	Good	C	1.79@1	Sublimes. Loses oxygen, films smooth and clear.
Zinc	Zn	419	7.14	.50	177	250	XInt.	Al_2O_3 Quartz	2.62@.69	Evaporates well under wide range of conditions. Use Mo E.B. liner.
Zinc Antimonide	Zn_3Sb_2	570	6.33							
Zinc Bromide	$ZnBr_2$	391	4.99			≈300		Carbon	1.58@.58	Decomposes.
Zinc Fluoride	ZnF_2	872	4.95			≈800		Quartz		

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Zinc Nitride	Zn_3N_2		6.22							Decomposes.
Zinc Oxide	ZnO	1975	5.60	.55		≈1800	Fair		2.02@.59	Anneal in air at 450°C to reoxidize. JVST 12,879 (1975).
Zinc Selenide	ZnSe	1526	5.42	.72		660		Quartz	2.61@.40 2.43@18	Toxic. Use gentle preheat to outgas. Sublimes well. Z.Angew.Phys.19,392 (1965).
Zinc Sulfide	ZnS	1700	4.10	.77		≈800	Good		2.35@.55 2.60@4.0 2.13@13	Sublimes Gentle preheat rqd Sticking coeff varies with sub temp. JVST 6,433 (1969)
Zinc Telluride	ZnTe	1240	6.34			≈600			3.56@.59 2.80@8.0	Toxic, sublimes. Use gentle preheat to outgas.
Zircon	$ZrSiO_4$	2550	4.56						1.96@.59	
Zirconium	Zr	1851	6.39	.58	1702	1987	XInt.			Flammable. Alloys with W. Films oxidize readily.
Zirconium Bromide	ZrB_2	3000	6.09				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	2715	5.49			≈2200	Good		2.05@.50 2.0@2	Films oxygen deficient, clear and hard.
Zirconium Silicide	$ZrSi_2$	1790	4.88							

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