TABELA DE TEMPERATURAS E DE MATERIAIS DE SUPORTE

TABLE 4 Temperatures and Support Materials Used in the Evaporation of the Elements

Element and predominant vapor species	Temp, °C		Support materials		Remarks
	mp	$p^* = 10^{-2}$ Torr	Wire, foil	Crucible	
Aluminum (Al)	659	1220	W	C, BN, TiB_2-BN	Wets all materials readily and tends to creep out of containers. Alloys with W and reacts with carbon. Nitride crucibles preferred
Antimony (Sb_4, Sb_2)	630	530	Mo, Ta, Ni	Oxides, BN, metals, C	Polyatomic vapor, $\alpha_v = 0.2$. Requires temperatures above mp. Toxic
Arsenic (As_4, As_2)	820	~300	.....	Oxides, C	Polyatomic vapor, $\alpha_v = 5.10^{-5}$–5.10^{-2}. Sublimates but requires temperatures above 300°C. Toxic
Barium (Ba)...	710	610	W, Mo, Ta, Ni, Fe	Metals	Wets refractory metals without alloying. Reacts with most oxides at elevated temperatures
Beryllium (Be)	1283	1230	W, Mo, Ta	C, refractory oxides	Wets refractory metals. Toxic, particularly BeO dust
Bismuth (Bi, Bi_2)	271	670	W, Mo, Ta, Ni	Oxides, C, metals	Vapors are toxic
Boron (B).....	2100 ±100	2000	.....	C	Deposits from carbon supports are probably not pure boron
Cadmium (Cd)	321	265	W, Mo, Ta, Fe, Ni	Oxides, metals	Film condensation requires high supersaturation. Sublimates. Wall deposits of Cd spoil vacuum system
Calcium (Ca)..	850	600	W	Al_2O_3	
Carbon (C_3, C, C_2)	~3700	~2600	.....	.....	Carbon-arc or electron-bombardment evaporation. $\alpha_v < 1$
Chromium (Cr)	~1900	1400	W, Ta	.....	High evaporation rates without melting. Sublimation from radiation-heated Cr rods preferred. Cr electrodeposits are likely to release hydrogen
Cobalt (Co)...	1495	1520	W	Al_2O_3, BeO	Alloys with W, charge should not weigh more than 30 % of filament to limit destruction. Small sublimation rates possible
Copper (Cu)...	1084	1260	W, Mo, Ta	Mo, C, Al_2O_3	Practically no interaction with refractory materials. Mo preferred for crucibles because it can be machined and conducts heat well
Gallium (Ga)..	30	1130	.....	BeO, Al_2O_3	Alloys with refractory metals. The oxides are attacked above 1000°C
Germanium (Ge)	940	1400	W, Mo, Ta	W, C, Al_2O_3	Wets refractory metals but low solubility in W. Purest films by electron-gun evaporation
Gold (Au).....	1063	1400	W, Mo	Mo, C	Reacts with Ta, wets W and Mo. Mo crucibles last for several evaporations
Indium (In)...	156	950	W, Mo	Mo, C	Mo boats preferred
Iron (Fe).....	1536	1480	W	BeO, Al_2O_3, ZrO_2	Alloys with all refractory metals. Charge should not weigh more than 30 % of W filament to limit destruction. Small sublimation rates possible
Lead (Pb).....	328	715	W, Mo, Ni, Fe	Metals	Does not wet refractory metals. Toxic
Magnesium (Mg)	650	440	W, Mo, Ta, Ni	Fe, C	Sublimates
Manganese (Mn)	1244	940	W, Mo, Ta	Al_2O_3	Wets refractory metals

TABLE 4 Temperatures and Support Materials Used in the Evaporation of the Elements (Continued)

Element and predominant vapor species	Temp, °C		Support materials		Remarks
	mp	$p^* = 10^{-2}$ Torr	Wire, foil	Crucible	
Molybdenum (Mo)	2620	2530	.....	.....	Small rates by sublimation from Mo foils. Electron-gun evaporation preferred
Nickel (Ni)....	1450	1530	W, W foil lined with Al_2O_3	Refractory oxides	Alloys with refractory metals; hence charge must be limited. Small rates by sublimation from Ni foil or wire. Electron-gun evaporation preferred
Palladium (Pd)	1550	1460	W, W foil lined with Al_2O_3	Al_2O_3	Alloys with refractory metals. Small sublimation rates possible
Platinum (Pt)	1770	2100	W	ThO_2, ZrO_2	Alloys with refractory metals. Multistrand W wire offers short evaporation times. Electron-gun evaporation preferred
Rhodium (Rh)	1966	2040	W	ThO_2, ZrO_2	Small rates by sublimation from Rh foils. Electron-gun evaporation preferred
Selenium (Se_2, Se_n: n = 1–8)[93]	217	240	Mo, Ta, stainless steel 304	Mo, Ta, C, Al_2O_3	Wets all support materials. Wall deposits spoil vacuum system. Toxic. $\alpha_v = 1$
Silicon (Si)....	1410	1350	.....	BeO, ZrO_2, ThO_2, C	Refractory oxide crucibles are attacked by molten Si and films are contaminated by SiO. Small rates by sublimation from Si filaments. Electron-gun evaporation gives purest films
Silver (Ag)....	961	1030	Mo, Ta	Mo, C	Does not wet W. Mo crucibles are very durable sources
Strontium (Sr).	770	540	W, Mo, Ta	Mo, Ta, C	Wets all refractory metals without alloying
Tantalum (Ta)	3000	3060	.....	.....	Evaporation by resistance heating of touching Ta wires, or by drawing an arc between Ta rods. Electron-gun evaporation preferred
Tellurium (Te_2)	450	375	W, Mo, Ta	Mo, Ta, C, Al_2O_3	Wets all refractory metals without alloying. Contaminates vacuum system. Toxic. $\alpha_v = 0.4$
Tin (Sn).....	232	1250	W, Ta	C, Al_2O_3	Wets and attacks Mo
Titanium (Ti)	1700	1750	W, Ta	C, ThO_2	Reacts with refractory metals. Small sublimation rates from resistance-heated rods or wires. Electron-gun evaporation preferred
Tungsten (W)	3380	3230	.....	.....	Evaporation by resistance heating of touching W wires, or by drawing an arc between W rods. Electron-gun evaporation preferred
Vanadium (V).	1920	1850	Mo, W	Mo	Wets Mo without alloying. Alloys slightly with W. Small sublimation rates possible
Zinc (Zn).....	420	345	W, Ta, Ni	Fe, Al_2O_3, C, Mo	High sublimation rates. Wets refractory metals without alloying. Wall deposits spoil vacuum system
Zirconium (Zr)	1850	2400	W	.....	Wets and slightly alloys with W. Electron-gun evaporation preferred