

元素之物理性質

元素記號	名稱	原子序	結晶構造	密度 (g/cm <sup>3</sup> ) at 20 °C	融點 (°C)	沸點 (°C)	比熱 (cal/gat 20°C)	熱膨脹係數 10 <sup>-6</sup> at 0-100 °C	熱傳導度 (cal/cm sec°C) at 20 °C	電氣傳導度 (μΩ·cm) at 20°C	電負度 Pauling's
Ag	銀	47	面心立方	10.49	960.8	2150	0.056	19.1	1.001	1.63	1.9
Al	鋁	13	面心立方	2.698	660.1	2477	0.215	23.5	0.569	2.67	1.5
As	砷 (砒素) *毒	33	菱面體	5.73	814	613 sublimes	0.082	4.7		33.3	2.0
Au	金	79	面心立方	19.29	1063	2710	0.030	14.1	0.700	2.2	2.4
B	硼	5	稠密六方 (菱面體 β)	2.35	2180	2777	0.309				2.0
Ba	鋇	56	體心立方	3.58	714	1640	0.068	18		50	0.9
Be	鈹	4	稠密六方	1.84	1287	2865	0.472	12	0.43	3.3	1.5
Bi	鉍 (蒼鉛)	83	菱面體	9.8	271.3	1560	0.0289	13.4	0.019	117	1.9
C	碳	6	稠密六方	2.26(石墨)	3727	4830	0.167		0.057	200-4000	2.5
Ca	鈣	20	面心立方	1.54	843	1492	0.149	22	0.3	4.1	1.0
Cd	鎘	48	稠密六方	8.65	321	767	0.055	31	0.2	7.3	1.7
Ce	鈰	58	面心立方	6.67	797	3468	0.045	8	0.03	78	
Co	鈷	27	稠密六方	8.9	1492	2877	0.102	12.5	0.165	6.24	1.8
Cr	鉻	24	體心立方	7.19	1890	2660	0.106	6.5	0.165	12.9	1.6
Cs	銫	55	體心立方	1.9	28.39	666	0.056	97	0.044	21	0.7
Cu	銅	29	面心立方	8.93	1083	2582	0.092	17.0	0.94	1.694	1.9
Dy	鐳	66	稠密六方	8.53	1409	2600	0.041	8.6	0.024	92.6	
Er	鉺	68	稠密六方	9.06	1522	2501	0.04		0.023	87	1.2
Eu	鎔	63	體心立方	5.25	826	1597	0.039	32		91.0	
Fe	鐵	26	體心立方	7.87	1536	2887	0.106	12.1	0.175	9.71	1.8
Ga	銻	31	複雜立方	5.903	29.75	2403	0.095	18.3	0.06	26	1.6
Gd	釷	64	稠密六方	7.87	1315	3233	0.071	6.4	0.021	131	1.1
Ge	矽	32	鑽石型	5.32	958.8	2830	0.074	5.75	0.14	2-40 X 10 <sup>6</sup>	1.8
Hf	鈷	72	稠密六方	13.28	2230	4302	0.035	6.0	0.05	30.6	1.3
Hg	汞 (水銀) *毒	80	菱面體	13.5	-38.88	356.6	0.033	61	0.022	95.8	1.9
Ho	釹	67	稠密六方	8.80	1461	2720	0.039	9.5		81.4	1.2
I	碘 (沃素) *劇	53	斜方	4.93	113.7	184.5	0.052		1.006 X 10 <sup>-3</sup>	5.85 X 10 <sup>6</sup>	2.5
In	銦	49	四方	7.28	156.6	2012	0.058	24.8	0.196	9.0	1.7
Ir	銱	77	面心立方	22.4	2443	4527	0.031	6.8	0.35	5.1	2.2
K	鉀	19	體心立方	0.87	63.2	757.8	0.18	83	0.22	6.86	0.8
La	釷	57	稠密六方	6.18	920	3469	0.045		0.033	79.8	1.1
Li	鋰	3	體心立方	0.531	180.5	1327	0.84	56	0.17	9.35	1.0
Lu	鑷	71	稠密六方	9.85	1652	3315	0.037			58.2	1.2
Mg	鎂	12	稠密六方	1.74	659	1103	0.244	26	0.399	4.2	1.2
Mn	錳	25	複雜立方	7.42	1244	2097	0.115	23		160(D)	1.5
Mo	鉬	42	體心立方	10.2	2615	5512	0.059	5.1	0.34	5.7	1.8
Na	鈉	11	體心立方	0.97	97.8	883	0.293	71	0.32	4.6	0.9
Nb	鈮	41	體心立方	8.57	2468	4927	0.064	7.2	0.13	14.5	1.6
Nd	釹	60	稠密六方	7.00	1024	3127	0.045		0.031	64.3	1.2
Ni	鎳	28	面心立方	8.9	1453	2782	0.104	13.3	0.21	6.9	1.8
Os	銱	76	稠密六方	22.5	3045	5027	0.031	4.57		9.5	2.2
P	磷 (燐)	15	複雜立方	2.34	589.5 六面體	416 sublimes					2.1
Pb	鉛	82	面心立方	11.34	327.4	1749	0.031	29.0	0.083	20.6	1.8
Pd	鈀	46	面心立方	12.02	1552	2877	0.058	11	0.179	10.8	2.2
Pr	釷	59	稠密六方	6.77	935	3212	0.048		0.028	68.0	1.1
Pt	鉑 (白金)	78	面心立方	21.45	1769	3827	0.032	9.0	0.172	10.58	2.2
Rb	銣	37	體心立方	1.53	38.9	688	0.079	90	0.07	12.5	0.8
Re	銱	75	稠密六方	21.03	3180	5627	0.032	6.6	0.17	18.7	1.9
Rh	銱	45	面心立方	12.44	1960	3627	0.058	8.5	0.356	4.7	2.2
Ru	鈷	44	稠密六方	12.2	2250	4052	0.056	9.6		7.3	2.2
S	硫 (硫黃)	16	立方	2.07	119	444.6	0.175		0.0007		2.5
Sb	銻	51	菱面體	6.68	630.5	1634	0.049	8-11	0.043	40.1	1.9
Sc	鈾	21	稠密六方	3.016	1537	2832	0.13	12	0.015	50.9	1.3
Se	硒 *毒	34	六方	4.81	217	685	0.084	22.9	1 X 10 <sup>-5</sup>	8 X 10 <sup>6</sup>	2.4
Si	矽 (珪素)	14	鑽石型	2.328	1426	2480	0.174	9.6	0.2	2.3 X 10 <sup>10</sup>	1.8
Sm	釷	62	菱面體	7.54	1072	1752	0.042			105.0	1.2
Sn	錫	50	四方 7.3正法晶 (5.8立方晶)	7.3	231.9	2480	0.053	23.5	0.155	12.8	1.8
Sr	銣	38	面心立方	2.6	774	1366	0.176			22.76	1.0
Ta	鉭	73	體心立方	16.6	2990	5499	0.033	6.5	0.13	13.5	1.5
Tb	鉬	65	稠密六方	8.27	1356	3041	0.044	7.0		114.5	1.2
Te	碲	52	稠密六方	6.24	449.5	989.8	0.047	1.7(//C軸) 27.5(⊥C軸)	0.014	4 X 10 <sup>5</sup>	2.1
Ti	鈦	22	稠密六方	4.5	1680	3262	0.124	8.9	0.038	54	1.5
Tl	鉍	81	稠密六方	11.85	302.8	1666	0.032	30	0.094	16.6	1.8
Tm	釷	69	稠密六方	9.33	1545	1727	0.038	11.6		67.6	1.2
V	鈮	23	體心立方	6.1	1905	3309	0.12	8.3	0.07	26	1.6
W	鎢	74	體心立方	19.3	3380	5727	0.032	4.5	0.399	5.4	1.7
Y	鈾	39	稠密六方	4.57	1509	3337	0.071	10.8	0.035	59.6	1.3
Yb	鉕	70	面心立方	7.03	824	1427	0.035	25.0		25.1	1.1
Zn	鋅	30	稠密六方	7.13	419.5	906	0.093	31	0.27	5.92	1.6
Zr	鈷	40	稠密六方	6.50	1855	4377	0.069	5.0	0.05	44.6	1.4

常用合金之性質

Material/composition, wt%	Density (g/cm <sup>3</sup> )	Properties M.P.=Melting Point Ts=Tensile strength Tc=Thermal conductivity CTE=Coefficient of Thermal Expansion R=Resistivity μ=Permeability	Feature
Al-additive Ti,Cr,Nd,Ta or Zr	2.7-2.92	R=4-16 μΩ-cm	Higher oxide resistance and optical reflection
Al/Si 99/1%	2.7	M.P.=600°C R=2.6-3.5 μΩ-cm	Higher oxide resistance and strength
Au/Ge 88/12%	14.673	M.P.=356°C	Low M.P. in Au alloy
Au/Sn 80/20%	14.51	M.P.=280°C	Low M.P. in Au alloy
Eligilloy Co/Ni/Cr/Mo/Fe	8.0	Ts≥240 kg/mm <sup>2</sup> Young's modulus=21000 kg/mm <sup>2</sup> R=90 μΩ-cm	High strength,anti-fatigue,corrosion resistance,and non-magnetic
Cu-additive Ag	8.95	M.P.=1064-1084°C Ts=18kg/mm <sup>2</sup> CTE=9.4x10 <sup>-6</sup> /°C @30-300°C	Excellent soldering and brazing
Cu/Cr 99/1%	8.89	M.P.=1070°C Ts=24kg/mm <sup>2</sup> CTE=9.8x10 <sup>-6</sup> /°C @30-300°C	Fabricated hot working Temp=815-927°C
Maraging steel Fe/Ni/Co/Mo	7.93	Ts≥220 kg/mm <sup>2</sup> Young's modulus=19500 kg/mm <sup>2</sup>	High strength
SUS 316 Fe/Cr/Ni/Mo	8.03	Ts=60kg/mm <sup>2</sup> CTE=8.9x10 <sup>-6</sup> /°C R=74 μΩ-cm anneal:1010-1120°C	Good corrosion resistance in standard SUS
17-4 PH Fe/Cr/Ni/Cu	7.79	Ts=105-150 kg/mm <sup>2</sup> CTE=5.5x10 <sup>-6</sup> /°C R=85 μΩ-cm	Fabricated hot working Temp=1200°C
In/Ag 97/3%	7.38	M.P.=143°C	Good wetting and soldering ability
In/Ga 24.5/ 75.5%	6.35	M.P.=15.7°C	Low M.P.
In/Sn 52/48%	7.30	M.P.=118°C	Good wetting and soldering ability
Ir/Pt 10/90%	21.53	M.P.=1800°C	High Temp measurement reference
Ir/Pt 30/70%	21.70	M.P.=1880°C	High Temp measurement reference
Mg/Al 6-9.5%	1.8	M.P.=443-610°C Ts=28 kg/mm <sup>2</sup> R=11-15 μΩ-cm CTE=16x10 <sup>-6</sup> /°C @20-400°C	Good resistance to air
Mg/Zn/- 94/5/1%	1.83	M.P.=525-650°C Ts=21 kg/mm <sup>2</sup> R=6 μΩ-cm CTE=16x10 <sup>-6</sup> /°C @20-400°C	Good resistance to air
Nd Fe B,anisotropic	7.5	R=150 μΩ-cm Curie point=310°C,(BH)max=30(MG·Oe)	Permanent magnet
Ni/Ti 55/45%	6.5	M.P.=1250-1280°C R=50-100 μΩ-cm	Shape memory alloy
42 alloy Ni/Fe 42/58%	8.20	CTE=4.5-5.3x10 <sup>-6</sup> @30-325°C μ <sub>i</sub> ≥5500 μ <sub>m</sub> ≥40000 R=64 μΩ-cm	High Bs, high μ and good sealing to soft glass
426 alloy Ni/Cr/Fe 42/6/52%	8.20	CTE=7.0-7.8x10 <sup>-6</sup> @30-325°C R=94 μΩ-cm	High strength sealing
52 alloy Ni/Fe 52/48%	8.25	CTE=10x10 <sup>-6</sup> @30-400°C B <sub>1000</sub> =1.4T Hc≤24A/m	High Bs, high μ and good sealing to soft glass
Elinvar Ni/Cr/Fe 36/9/55%	8.15	CTE of Resonance Frequency=0±10x10 <sup>-6</sup> /°C	Constant Young's modulus
Invar 36 Ni/Fe 36/64%	8.15	CTE<1.8x10 <sup>-6</sup> @30-100°C R=80 μΩ-cm	Low CTE
Invar 42 Ni additive Co/Fe 42/58%	8.2	CTE<1.8x10 <sup>-6</sup> @30-100°C R=80 μΩ-cm	Low CTE
Super Invar Ni/Co/Fe 31/5/64%	8.0	CTE<1.2x10 <sup>-6</sup> @30-100°C R=80 μΩ-cm	Low CTE
Kovar Ni/Co/Fe 29/16/-%	8.24	CTE=4.5-5.2x10 <sup>-6</sup> @30-400°C R=48 μΩ-cm	Good sealing to hard glass
Ni/Cr 80/20%	8.5	Ts≥70kg/mm <sup>2</sup> R=108 μΩ-cm	High electric resistivity,heat and corrosion resistance non-magnetic
Permalloy(high μ80) Ni/Mo/Fe 80/5/15%	8.83	μ <sub>i</sub> ≥20000 μ <sub>m</sub> ≥100000 R=60 μΩ-cm	High μ,low losses and less deterioration after resin mold
C-276 Ni/Cr/Mo/W/Fe	8.89	M.P.=1355-1370°C Ts=80kg/mm <sup>2</sup>	Excellent anti-corrosion,Oxide resist to 1030°C
Inconel 718 Ni/Cr/ Mo/Co/-	8.20	M.P.=1260-1336°C Ts=125-150kg/mm <sup>2</sup>	Oxide resist to 980°C
Monel 404 Ni/Cu 55/45%	8.89	CTE=14-17x10 <sup>-6</sup> @30-230°C R=50 μΩ-cm Ts=45 kg/mm <sup>2</sup>	Resistant to air (light tarnish)
Waspalloy Ni/Cr/Co/Mo/Ti	8.20	Ts=130 kg/mm <sup>2</sup> R=120-130 μΩ-cm	Good high Temp strength and corrosion resistance
Re/Mo 50/50%	13.7	M.P.=2550°C Tc=0.171 cal/cm <sup>2</sup> sec <sup>2</sup> @1800°C	Good bending ductility at high Temp
Re/W 25/75%	17.0	M.P.=2815°C Tc=0.151 cal/cm <sup>2</sup> sec <sup>2</sup> @1800°C	Fabricated working Temp=870-1320°C
Ti-3Al-2.5V	4.49	Ts=60-90 kg/mm <sup>2</sup> anneal Temp=670-730°C	Good anti-corrosion and strength
Ti-6Al-4V	4.43	Ts=100-120 kg/mm <sup>2</sup> anneal Temp=700-840°C	Good anti-corrosion and strength
Ti-6Al-4V-ELI	4.43	Excellent cryogenic properties ≤160°C Ts=90 kg/mm <sup>2</sup>	Good anti-corrosion and strength
Ti-6Al-6V-2Sn	4.54	Ts=105-135 kg/mm <sup>2</sup> anneal Temp=700-760°C	Good anti-corrosion and strength

工程塑膠特性之參考規格

Type/description	Density(g/cm <sup>3</sup> )	Continuous service Temp in air(°C)	CTE(10 <sup>-6</sup> /°C)	Volume resistivity(Ω-cm)	Flexural strength,23°C (kg/mm <sup>2</sup> )	Coefficient of Friction (dry v.s steel) Dynamic	Water vapor recover%
PET(polyester, Thermoplastic),extruded	1.41	99	59	5.5 X 10 <sup>14</sup>	12.64	0.20	0.07
PC(polycarbonate),extruded	1.20	121	70	2.0 X 10 <sup>16</sup>	9.08	-	0.2
PEI(polyetherimide),extruded	1.28	171	56	6.7 X 10 <sup>17</sup>	13.97	0.42	0.25
PEEK(polyetherether-ketone),compressed	1.32	249	46	4.9 X 10 <sup>16</sup>	17.54	0.4	0.15
PAI(polyamide-imide)	1.41-1.60	249-260	13-36	3-80 X 10 <sup>15</sup>	15.40-25.29	0.2-0.35	0.17-0.35
PTFE(polytetrafluoro-ethylene),static	2.30	260	103	10 <sup>10</sup> -10 <sup>12</sup>	1.53	0.10	0.03-0.04
PI(polyimide),compressed	1.34	304	36	>10 <sup>13</sup>	16.11	0.24	0.62
PBI(polybenz-imidazole),compressed	1.30	399	24	>10 <sup>13</sup>	22.43	0.24	0.4

常用陶瓷基板之參考規格

Material	Density(g/cm <sup>3</sup> )	Max.working Temp(°C)	Compressive strength(kg/mm <sup>2</sup> )	Tc(w/m·k)	CTE(10 <sup>-6</sup> /°C)	Dielectri constant(ε)
AlN	3.28	1900	≥300	170	5.6(25-800°C)	8.8(1 GHz)
Al <sub>2</sub> O <sub>3</sub>	3.9	1600	35	29.4	7.9(25-800°C)	9.8(1MHz)
Sapphire,單晶	3.98	2000	300	42	5.3/c 4.5⊥c(25°C)	11.5/c 9.3⊥c
Al <sub>2</sub> O <sub>3</sub> -TiC	4.28	-	>500	16.7	7.85	-
BN	1.91	850 oxide 3000Inert air	1.83// 2.39⊥	19.4/(1500°C) 30.7⊥	0.57 -0.46(25-1500°C)	4.0
BeO	2.85	M.P.=2575	150	250		