BURR-BROWN®
APPLICATION BULLETIN
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THERMAL AND ELECTRICAL PROPERTIES OF SELECTED PACKAGING MATERIALS

	MATERIAL	THERMAL CONDUCTIVITY (W/in-°C) NOM	THERMAL CONDUCTIVITY (W/in-°C) LOW	THERMAL CONDUCTIVITY (W/in-°C) HIGH	THERMAL EXPANSION (10^{-6}/°C) NOM	THERMAL EXPANSION (10^{-6}/°C) LOW	THERMAL EXPANSION (10^{-6}/°C) HIGH	TCR (10^{-6}/°C)	RESISTIVITY AT 20°C ($\mu\Omega$-cm)
ELEMENTS	ALUMINUM	6.02	5.63	6.38	23.9	19.4	25	4290	2.66
	ANTIMONY	0.620	0.481	0.648(β)		8.46	10.8		41.7
	ARSENIC	1.28	1.08(α)	1.37(β)	4.7				33.3
	BARIUM	0.468			18				50.0
	BERYLLIUM	5.10	4.04	5.54(β)	12			25000	5.9
	BISMUTH	0.201(k)	0.134(a)	0.233(b)	13				106.8
	BORON	0.696	0.478(α)	0.808(β)	8.3				1.8×10^{12}(m)
	CADMIUM	2.46(k)	2.11(g)	2.62(d)	29.9			4200	6.83
	CALCIUM	5.10	3.20	5.23	22			4160	3.43
	CARBON	3.70(c)	0.0404(j)	58.9(z)		0.54	4.32		1375(l)
	CESIUM	0.912			97				20.0
	CHROMIUM(k)	2.38			6.1			3000	13.0
	COBALT(k)	2.54			12			6040	6.24
	COPPER	10.2			17			6800	1.673
	GALLIUM	1.04(e)	0.404(g)	2.24(f)	18				56.8
	GERMANIUM	1.53	1.18(α)	1.69(β)	5.9				10^2 - 10^{7}(t)
	GOLD (10.2 oz. troy/in^3)	8.08			14.2			4000	2.19
	HAFNIUM	0.584	0.569(α)	0.592(β)	5.9			3800	32.4
	INDIUM(k)	2.08	1.94(α)	2.12(β)	32				8.37
	IRIDIUM	3.73			6.8			3925	5.3
	IRON	2.04	1.85(h)	2.20(β)	11.7			6510	9.71
	LEAD	0.897	0.874(α)	0.904(β)	29.3			3360	20.65
	MAGNESIUM(k)	3.96			25			16500	4.46
	MANGANESE	0.198			22				185
	MOLYBDENUM	3.50			5.4				5.17
	NICKEL	2.31	2.10(α)	2.39(β)	13			6900	6.84
	NIOBIUM	1.36			7.1				12.5
	OSMIUM(k)	1.55			4.7			4200	9.5
	PALLADIUM	1.82			11.9			3770	10.8
	PHOSPHORUS		.0064(j)	.307(k)	126				10^{17}
	PLATINUM	1.82			8.8			3927	9.83
	RHENIUMk	1.22			6.7			3950	19.3
	RHODIUM	3.81			8.3			4200	4.51
	RUBIDIUM	1.48			90				12.5
	RUTHENIUM	2.97			9.6				7.6(l)
	SELENIUM	0.033(d)	0.013(j)	0.115(g)	38				12(AC)
	SILICON	3.78	2.1	4.27(β)	3.5111(AB)	2.9	7.4		10^2 to 10^{8}(t)
	SILVER	10.9			19.6			4100	1.59
	STRONTIUM	0.899	0.826(α)	0.924(β)					23.0
	SULFUR(k)	0.0069	0.0039(α)	0.0073(β)	65				2×10^{23}(m)

NOTES: Values at 20°C unless otherwise specified. (α) At 100°C. (β) At 0°C. (a) || to triangle axis. (b) ⊥ to triangle axis. (c) Average value; graphite varies from 2.0 to 5.6 depending on type and orientation. Pyrolytic graphite is 0.16 and 50 ⊥ and || to layer planes. (d) Crystalline, ⊥ to c-axis; polycrystalline = 0.006W/in-°C. (e) || to a-axis. (f) || to b-axis. (g) || to c-axis. (h) Armco iron. (i) White phosphorous. (j) Amorphous. (k) Polycrystalline. (l) Resistivity at 0°C. (m) Intrinsic value, actual value sensitive to purity. (t) With 10^{21}/cm^3 to 10^{14}/cm^3 impurity concentration. (z) Type IIa diamond. (AB) Measured by J. Naylor. (AC) Crystalline, amorphous ≈ 10^6μΩ-cm.

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THERMAL AND ELECTRICAL PROPERTIES OF SELECTED PACKAGING MATERIALS (CONT)

	MATERIAL	THERMAL CONDUCTIVITY (W/in-°C)			THERMAL EXPANSION (10^{-6}/°C)			TCR [10^{-6}/°C]	RESISTIVITY AT 20°C [μΩ-cm]
		NOM	LOW	HIGH	NOM	LOW	HIGH		
ELEMENTS	TANTALUM	1.46			6.5			3830	12.4
	TELLURIUM	0.150			17				2×10^5
	TIN	1.70(k)	1.31(g)	1.89(d)	23	20	25	4700	11.5
	TITANIUM(k)	0.556	0.526(α)	0.569(β)	8.5				47.8
	TUNGSTEN	4.39	4.14	4.50	4.3	4.2	4.5	5240	5.6
	VANADIUM	0.780			7.7				24.8-26.0
	ZINC(k)	2.95				17	40	4190	5.8
	ZIRCONIUM	0.576	0.554	0.589	5.6			4400	41.0
ORGANIC	EPOXIES		0.0042	0.035		11.0	60		10^{21}(m)
	GLASS-EPOXY (PC-G10)	0.08			(n)	10(n)	15(n)		10^{21}(m)
	KAPTON	0.0039				34	40		10^{24}(m)
	NYLON		0.0054	0.0085		82.8	128		10^{20}(m)
	PARYLENE	0.0032				35	69		10^{22}(m)
	RTV	0.0053	0.004	0.008	930				3×10^{15}(m)
	TEFLON		0.0056	0.0296	83	50	162		10^{24}(m)
	MYLAR		0.0045	0.0073		60	95		10^{21}(m)
MISCELLANEOUS	AIR	0.00066							
	Al_2O_3	0.53(v)	0.42(w)	0.85(x)	6.7(v)	6.5	7.3		5×10^{21}(m)
	BRASS(p)	2.95				18	21	2000	6.4
	BeO	6.0	5.5	7.1	8.0	6.5	8.7		10^{22}(m)
	EUTECTIC (Au-Si) MP 370°C	5.5			13.7				2.53
	EUTECTIC (Au-Sn) MP 280°C	6.4			16				2.6
	EUTECTIC (Au-Ge) MP 356°C	6.7			12.6				2.6
	FERRITE	0.085		0.159		8	12		127×10^6
	GLASS(y)		0.010	0.037		0.55	12.4		10^{24}(m)
	KOVAR	0.425			5.5				49.0
	KOVAR-42	0.28			4.9				78
	MANGANIN	0.564	0.523	0.635	18.7			±15	44
	MICA	0.011	0.009	0.017		32.4	48.6		10^{21}(m)
	QUARTZ (SiO_2)	0.035	0.19(β)(d)	0.37(β)(g)	0.55				10^{24}(m)
	SAPPHIRE	0.821	0.691	1.0	6.67(q)	5.0(r)	8.33(s)		10^{25}(m)
	SOLDER (60/40)	1.0			23				13.5
	STEEL (1008)	1.2			12			6510	11
	STEEL, STAINLESS	0.35303	0.30310	0.94501	18304			170(AA)	112(AA)

NOTES: Values at 20°C unless otherwise specified. (α) At 100°C. (β) At 0°C. (d) ⊥ to c-axis. (e) || to a-axis. (f) || to b-axis. (g) || to c-axis. (k) Polycrystalline. (m) Intrinsic value; actual value sensitive to purity. (n) 40-300 for vertical axis. (p) Yellow brass. (q) || to c-axis at 50°C. (r) ⊥ to c-axis at 50°C. (s) || to c-axis at 500°C. (v) 96%. (w) 90%. (x) 99.5%. (y) See quartz. (AA) Nichrome 60% Ni, 25% Fe, 15% Cr.

THERMAL CONDUCTIVITY (K) CONVERSIONS

ORIGINAL UNIT	CONVERSION UNIT: cal / s-cm-°C	watt / cm-°C	watt / in-°C	BTU / hr-ft-°F	kg-cal / hr-m-°C	watt / m-°C
1 cal/s-cm-°C	1.0	4.186	10.63	241.9	360.0	418.6
1 watt/cm-°C	0.2389	1.0	2.540	57.8	86.00	100
1 watt/in-°C	0.09405	0.3937	1.0	22.75	33.86	39.37
1 BTU/hr-ft-°F	4.134(10^{-3})	0.01730	0.0440	1.0	1.488	1.730
1 kg-cal/hr-m-°C	2.778(10^{-3})	0.01163	0.0295	0.672	1.0	1.163
1 watt/m-°C	0.002389	0.01	0.0254	0.578	0.8600	1.0

EXAMPLE
232 (BTU/hr-ft-°F) x 0.0440
= 10.2 (watt/°C-in)

FORMULAE

$$°C/W = \frac{\text{Length (in)}}{\text{Area (in}^2\text{)} \bullet K \text{ (W/in-°C)}}$$