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Data Article

Properties of particle phases for metal-matrix-composite design

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ABSTRACT

Successful metallurgical design of metal-matrix-composites relies on the knowledge of the intrinsic property profiles of the metal matrix and especially the compounds employed for particles, whiskers or fibres. In this work we compiled the key properties melting point, bulk modulus, shear modulus, Young's modulus, density, hardness, Poisson's ratio and structure/space group from the widespread literature data for the most relevant compound types, i.e. borides, carbo-borides, carbides, oxides, nitrides and intermetallic phases.

Specifications Table

Subject area	*Physical metallurgy, Material Science, Engineering*
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Value of the data

- The comprehensive data collection allows straightforward comparisons of individual properties, types and groups of compounds.
- Readily obtainable ratios of properties allow judging particles concerning their suitability for specific design goals (such as the material stiffness/density ratio).
- Specific effects of particles on the properties of the bulk composite can be estimated, for example regarding the co-deformation of particles and matrix influenced by their crystallographic coherency, or the amount of particles required for a specific gain in stiffness.

1. Data

Metal-matrix-composites allow overcoming the specific limitations of metallic and ceramic materials by blending their typically mutually exclusive property profiles. Knowledge based design of the composites requires, depending on the desired property profile and application, the choice of suitable metallic matrices and particles characterized by their intrinsic properties. In the following table the intrinsic properties (melting point, bulk modulus (B), shear modulus (G), Young's modulus (E), density, hardness, Poisson's ratio and structure/space group) of different types of phases (borides, carbo-borides, carbides, oxides, nitrides and intermetallics) are compiled from literature sources. The reference for each value or range of values is listed next to it on the right. Unless specified otherwise, values were assumed to have been determined experimentally as specifications are in most cases not given in the listed references. Densities determined by X-ray diffraction (XRD) are enclosed in curved brackets {}. Theoretically determined values are marked with a star *. Furthermore, the main selection criteria brittleness (expressed by the B/G ratio; B/G values below 1.75 are considered to represent 'more brittle' compounds [1]) and specific modulus (i.e. the E/density ratio) have been derived. If more than one value is given for E and density of a compound, i.e. several values from one reference or diverging values from different references, the E/density ratio is given as a range. In case of several values listed for B and G, the determined B/G ratio was chosen conservatively using the lowest B and highest G value, respectively (Table 1).

Table 1

Legend: *theoretical value; {} XRD;

Phase	Melting point / °C	Ref.	**B** Bulk modulus / GPa	**G** Shear modulus / GPa	Ref.	**B / G**	***E*** Young's modulus / GPa	Ref.	Density / g cm^{-3}	Ref.	**Specific modulus / GPa cm^3 g^{-1}**	Hardness / GPa	Ref.	Poisson's ratio	Ref.	Space group / structure	Ref.
Borides																	
AlB_2	975	[2]	190*	95*	[3]	**2.00**	244.4*	[3]	{3.19}	[4]	**76.6 - 90.5**	23.6	[4]	0.29*	[3]	P6/mmm	[3]
									2.9	[5]						P6/mmm	[2]
									2.955	[6]							
									2.7	[7]							
BeB_2	> 1970	[2]	215*		[8]				2.32 - 2.48	[2]		31.2	[9]			P6/mmm	[2]
	~ 1700	[6]															
BeB_6	~ 2100	[2]							2.35 / {2.33}	[2]		25.3	[9]			P43212	[2]
	2300	[6]															
CrB	1515 / 1550 +-50	[4]							6.05	[4]		20.9	[4]			Cmcm	[2]
	~ 2060	[2]							6.04 / {6.11}	[2]		19.2 - 22.9	[10]				
	2050	[6]							6.05 / {6.11}			11.8 - 12.7	[6,9]				
CrB_2	2280	[2]	239.2*	139.9*	[3]	**1.71**	415.4*	[3]	[5.6]	[4]	**34.0 - 79.6**	17.7	[4]	0.26*	[3]	P6/mmm	[2]
	1960 / 1900 / 1850+-50	[4]					211	[4]	5.22 / {5.60}	[6]		20.3 - 22.5	[10]			hex (c-32 type)	[4]
	2200+-50	[6]					210.9	[9]	6.2	[7]		20.6	[6]				
	2100	[7]					235.6	[7]			**~ 38.0** [7]						
CrB_4	1400 - 1600	[9]	265*	261*	[11]	**1.02**	312*	[12]				48.0*	[11]	0.12*	[11]		
Cr_3B_2	1960	[4]							6.13 / 6.7	[4]						orthorhombic	[4]
	1960	[7]							6.1	[7]							
ErB_2			137.4*	119.7*	[3]	**1.15**	278.3*	[3]	-		**41.5**			0.16*	[3]	P6/mmm	[2]
Fe_2B	1389	[13]	249.7*	60.2*	[14]	**4.15**	290	[13]	7.15	[13]	**25.7 - 41.4**	13.1+-0.5	[9]			I4/mcm	[2]
	1389	[2]	194*	67*	[14]	**2.90**	190*	[14]	~ 7.0	[2]							
	~ 1390	[4]	331*	152.8*	[14]	**2.17**	184*	[14]									
	1410	[9]					284.4	[9]									
FeB_4			253*	177*	[11]	**1.43**	475.71*	[15]				24.2*	[11]	0.2*	[15]		
			264.73*	197.97*	[15]												
GdB_2			131.2*	113.5*	[11]	**1.16**	264.3*	[3]						0.16*	[3]	P6/mmm	[2]

HfB_2	3100 / 3060 - 3065 / 3250 +-100	[4]	260.9*	233*	[3]	**1.12**	538.7*	[3]	11.2	[4]	**45.9 - 58.5**	28.4+-4.9	[9]	0.16*	[3]	hex (c-32 type)	[4]
	3250	[9]	215	233	[16]	**0.92**	514	[16]	11.19	[17]		28.0*	[16]	0.12	[16]	hex	[17]
	3380	[17]	265 - 288*	240 - 273*	[16]	**0.97 - 1.2**	554 - 614*	[16]	10.5 / {11.2}	[2,6]		21.2 - 28.4	[17]	0.124 - 0.159*	[16]	P6/mmm	[2]
	3250	[2]					530	[17]				28.4	[6]	0.12	[17]		
	3250+-100	[6]															
	3250	[7]									**~ 49.0** [7]						
LaB_6	> 2100	[4]					478.6	[9]	{4.72}	[4]	**100.5 - 101.5**	27.2	[9]			Pm3m	[2]
	2530	[2]							4.714	[2]							
									4.76 / {4.72}	[6]							
LuB_2			178.4*	173.3*	[3]	**1.03**	392.7*	[3]	{9.656} {9.76}	[9] [6]	**40.2 - 40.7**			0.13*	[3]	P6/mmm	[2]
MgB_2			151.5*	116.4*	[3]	**1.30**	278*	[3]	2.48 - 2.67 / {2.63}	[9]	**105.5 - 112.1**			0.19*	[3]		
			120		[8]				2.62 / {2.633}	[2]							
			151		[8]												
MnB_2	1988	[9]	220.1*	121.6*	[3]	**1.81**	318.4*	[3]	{5.344} {5.37}	[9] [6]	**59.3 - 59.6**	16.7+-0.5	[9]	0.31*	[3]	P6/mmm	[2]
MnB_4	2160	[9]	270*	245*	[11]	**1.10**						41.5*	[11]				
												35.3+-1	[9]				
MoB_2	2100 / 2250 +-50	[4]	302.5*	186*	[3]	**1.63**	463.1*	[3]	{7.78}	[6]	**59.4 - 59.5**	11.7 / 12.6 / 13.5	[4]	0.24*	[3]	hex. AlB2 structure	[4]
	2350	[9]							{7.78} / {7.8}	[4]						P6/mmm	[2]
MoB_4	< ~ 1600	[2]	287*	239*	[11]	**1.20**			4.8 / {4.96}	[2,6]		36.7*	[11]			P6/mmm	[2]
Mo_2B	2000 / 2165	[4]							{9.3} / {9.31} / 9.26	[4]		16.3	[4]			CuAl2 structure; c-16 type	[4]
									9.1 / {9.31}	[6]		24.5	[6,9]				
Mo_2B_5	decompose to MoB2 @ 1600 - 1650	[4]					671.8	[9]	7.01 / {7.48}	[2,4,6]	**89.8 - 95.8**	23.0	[9]			rhombohedral	[4]
	< ~ 1600	[2]														R3m	[2]

Table 1 (*continued*)

Legend: *theoretical value; {} XRD;

Phase	Melting point / °C	Ref.	**B** Bulk modulus / GPa	**G** Shear modulus / GPa	Ref.	**B / G**	***E*** Young's modulus / GPa	Ref.	Density / g cm^{-3}	Ref.	**Specific modulus / GPa cm^3 g^{-1}**	Hardness / GPa	Ref.	Poisson's ratio	Ref.	Space group / structure	Ref.
NbB_2	2900	[4]	286.3*	210.4*	[3]	**1.36**	507*	[3]	6.4 / 6.5 / 6.6 / 6.97 / {7.21}	[4]	**70.4 - 105.8**	16.7 / 25.4	[4]	0.2*	[3]	hex (c-32 type)	[4]
	~ 3000	[2]					637.5	[9]	6.6	[2]		25.5	[9]			P6/mmm	[2]
	3000	[6]					676.8	[7]	6.97 / {7.00}	[9]							
	3000	[7]							7.2	[7]							
											~ 94.0 [7]						
NbB_4			243*	194*	[11]	**1.25**						30.4*	[11]			P4/mbm	[2]
NiB	990	[2]							7.13	[2]		15.2	[9]			Cmcm	[2]
									6.5 / {7.13}	[6]							
NpB_2			206.7*	169.8*	[3]	**1.22**	399.3*	[3]	-					0.19*	[3]		
PrB_6	> 2250	[2]							{4.85}	[4]		24.2	[9]				
									4.53 / {4.84}	[2]						Pm3m	[2]
PuB_2	1825	[9]	207.4*	174.1*	[3]	**1.19**	408.1*	[3]	{12.674}	[9]	**31.9 - 36.8**	-		0.17*	[3]		
	< 1200	[2]							{11.1}	[2]						P6/mmm	[2]
									{12.81}	[6]							
ScB_2	2250	[2]	243.8*	256.6*	[3]	**0.95**	431*	[3]	3.65 / {3.667}	[9]	**117.4 - 118.1**	17.5+-2.7	[9]	0.11*	[3]		
	2250	[6]							{3.67}	[2]						P6/mmm	[2]
SmB_2			128*	110.8*	[3]	**1.16**	258*	[3]						0.16*	[3]		
TaB_2	3000 - 3150	[4]	295.8*	191.5*	[3]	**1.54**	370	[4]	11.7 / {12.6}	[4,6]	**20.4 - 40.4**	24.9 / 25.6+-1.2 / 16.7	[4]	0.23*	[3]	hex (c-32 type)	[4]
	3037	[9]					472.5*	[3]	12.38 / {12.62}	[9]		19 - 25	[17]			hex	[17]
	3040	[17]					265.9	[9]	12.54	[17]		24.5+-0.4	[9]			P6/mmm	[2]
							257	[17]									
TbB_2			131.3*	115.4*	[3]	**1.14**	267.8*	[3]	-					0.16*	[3]	P6/mmm	[2]
TiB									5.09 / {4.565}	[9]		26.5- 27.5	[9]			fcc	[4]
									5.09 / 5.26	[2]						F43m	[2]

TiB_2	3225	[18]	240	255	[19]	**0.94**	565	[19]	4.52	[18]	**81.0 - 129.9**	25.0	[19]	0.108	[19]	hex P6/mmm	[19]
	2980 / 2900 +-80	[4]	250.3*	260.7*	[3]	**0.96**	530	[13]	4.5	[19]		25 - 35	[18]	0.11*	[3]	hex	[18]
	2900	[20]	238	240.4	[21]	**0.99**	366	[4]	4.5	[13]		33.3 / 33.0 / 26.6 / 25.3	[4]	0.109 / 0.11	[22]	hex (c-32 type)	[4]
	2790	[9]					581*	[3]	4.5 / 4.52 / {4.52}	[4]		25 - 33	[17]			P6/mmm	[2]
	3225	[17]					594* / 569	[22]	4.5	[20]		33.0+-0.6	[9]			hex	[17]
	2800	[2]					370	[20]	4.52	[17]						hex	[20]
	2980	[7]					529.6	[9]	4.38	[2]							
							551	[17]	4.5 / {4.52}	[6]				0.11	[17]		
							529.6	[6]	4.5	[7]							
							535.5	[7]			**119** [7]						
TiB_4			226*	190*	[11]	**1.19**						32.2*	[11]				
TmB_2			137.5*	120.5*	[3]	**1.14**	279.7*	[3]						0.16*	[3]		
UB_2	2385	[2]	205.5*	209.5*	[3]	**0.98**	469.6	[3]	{12.692} {12.71}	[9] [4]	**36.9 - 37.0**	13.6 14.8	[4] [9]	0.12*	[3]	P6/mmm	[2]
VB	~ 2250	[2]							5.44 / {5.28} {5.44}	[4] [6]						orthorhombic / Cmcm	[2,4]
VB_2	2040 - 2160	[4]	279.5*	240.9*	[3]	**1.16**	562.2*	[3]	4.61 / 5.28 / {5.10}	[4]	**50.7 - 122.0**	20.4	[4]	0.16*	[3]	hex (c-32 type)	[4]
	~ 2400	[2]					267.7	[9]	5.06 - 5.28	[9]		27.5+-0.1	[9]			P6/mmm	[2]
	2400+-50	[6]							4.61 / {5.10}	[2]							
	2100	[7]							5.28 / {5.10}	[6]							
									5.1	[7]							
VB_4			241*	237*	[11]	**1.02**						45.2*	[11]				
W_2B	2770+-80	[4]	322.5*	164.1*	[3]	**1.97**	420.9*	[3]	16 / {10.72}	[6]	**24.5 - 39.3**	23.5	[6]	0.28*	[3]	tetragonal	[4]
									17.17 / 16 / 15.98 / {16.72}	[4]							
YB_2	2100	[2]	173.5*	145.3*	[3]	**1.19**	340.8*	[3]	{3.370} {2.91}	[9] [6]	**101.1 - 117.1**			0.17*	[3]	P6/mmm	[2]
YbB_2			153.7*	130.2*	[3]	**1.18**	304.6*	[3]						0.17*	[3]		
YbB_6	1538 +-33	[4]							5.45 / {5.56}	[4]		25.5	[9]			Pm3m	[2]

Table 1 (*continued*)

Legend: *theoretical value; {} XRD;

Phase	Melting point / °C	Ref.	**B** Bulk modulus / GPa	**G** Shear modulus / GPa	Ref.	**B / G**	***E*** Young's modulus / GPa	Ref.	Density / g cm^{-3}	Ref.	**Specific modulus / GPa cm^3 g^{-1}**	Hardness / GPa	Ref.	Poisson's ratio	Ref.	Space group / structure	Ref.
	> 2000	[9]															
ZrB	2922 / 2992 +-50	[4]							5.7 / {6.7}	[2,4,6]		69 - 72 HRA 35 - 36	[4] [9]			cubic / Fm3m	[2,4]
ZrB_2	3000	[18]	220	225	[16]	**0.98**	350	[18]	6.1	[18]	**55.6 - 104.8**	22 - 26	[18]	0.13*	[3]	hex	[18]
	2980 / 2990 +-50 / 3040 +-50	[4]	245	243	[16]	**1.01**	498 - 638	[4]	{6.09} / {6.102}	[4]		23+-0.9	[16]	0.144	[4]	hex (c-32 type)	[4]
	2990	[20]	238.6*	231.4*	[3]	**1.03**	524.6*	[3]	6.1	[20]		15.3 / 21.6 / 87 - 89 HRA	[4]	0.14	[22]	hex	[17]
	3200	[9]	238* - 276*	239* - 260*	[16]	**0.92 - 1.15**	343.2	[9]	6.1	[17]		25.3 - 28.0	[17]	0.09 - 0.28	[22]	P6/mmm	[2]
	3245	[17]	207.6	192.2	[4]		554 / 502	[16]	6.17 / {6.09}	[2]		22.1	[6]	0. 109 / 0.13	[16]		
	3040	[2]					520* - 555*	[16]	6.1	[7]		22.1+-0.2	[9]	0.137 - 0.144*	[16]		
	3060	[7]					350	[20]									
							500	[17]						0.11	[17]		
							518.5	[7]			**~ 85** [7]						
ZrB_4			199*		[11]												
Carbo-Borides																	
Hf_2BC			207	150	[23]	**1.38**	362*	[23]									
Mo_2BC	2800	[2]	313	181	[23]	**1.73**	466 - 473	[21]	8.71	[2]	**53.5 - 54.3**			0.26	[21]	Cmcm	[2]
			324	185 - 188	[21]	**1.72 - 1.75**											
Nb_2BC			259	163	[23]	**1.59**	404*	[23]									
Ta_2BC			286	168	[23]	**1.70**	421*	[23]									
Ti_2BC			208	158	[23]	**1.32**	378*	[23]									
V_2BC			260	178	[23]	**1.46**	435*	[23]									
W_2BC			350	184	[23]	**1.90**	468*	[23]									

Zr_2BC			187	128	[23]	**1.46**	312*	[23]									
Carbides																	
B_4C	2350	[13]	247*	200*	[11]	**1.24**	448	[13]	2.52	[18]	**177.8 - 191.1**	37 - 47	[18]			orthorhombic	[18]
	2450	[18]	175 (graph)		[24]		450	[18]	2.52	[20]		30 (graph)	[24]			orthorombic	[20]
	2450	[20]					472*	[11]	2.51 / 2.484 / 2.47	[2]		31.7*	[11]			R3m	[2]
	2450	[2]					450	[20]									
	2420	[7]															
Cr_3C_2	1800	[13]					371	[13]	6.74	[13]	**55.0 - 55.8**	17.7	[9]			orthorhombic	[4]
	1830 - 1890	[4]					370 @ 449 °C	[25]	6.68 - 6.7	[4]						Pnma	[2]
	1895	[9]					372.7	[9]									
	~ 1900	[2]															
	1985	[7]															
Cr4C	1510	[7]															
Cr_7C_3	1782	[2]	311.7* / 309*	143.9*	[14]	**2.15**	371 / 374	[14]	6.9	[2]	**53.8 - 54.2**	18.5	[9]			P31c	[2]
	1780	[7]															
Fe_3C			259.2*	119.6*	[14]	**2.17**	177	[26]	7.4	[4]	**23.9**			0.26	[26]		
HfC	3000–3900	[13]					317	[13]	12.2	[13]	**24.8 - 23.8**	24.8 - 31.4	[9]				[13]
	3890	[20]					400	[20]	12.3	[20]		26.0	[17]			cubic	[20]
	3900	[17]					352.1	[9]	12.76	[17]		29.0+-3.0	[27]			fcc	[17]
	3890	[2]					352	[17]								Fm3m	[2]
Mo_2C	2410	[28]					228	[13]	8.9	[13]	**24.8 - 59.9**	14.7+-1.3	[9]			P63/mmc	[2]
	2522	[2]					530 @ 390 °C	[25]	9.04 / {9.18}	[9]							
							533.5	[9]									
NbC	1900	[13]					338	[13]	7.6	[13]	**43.2 - 72.7**	23.0+-3.0	[27]			B1 fm3m	[29]
	3613	[9]					492.93 - 549.66	[30]	7.56 / {7.82}	[9]						Fm3m	[2]
	3600	[2]					338.3	[9]	7.8	[7]							
	3775	[7]					540 @ 474 °C	[25]									
							350 - 500	[31]									
							546	[7]			**70.0** [7]						
Nb_2C	3100	[28]							7.86 / {7.85}	[9]						Pnma	[2]
	3035	[9]							6.7	[7]							
	2675	[7]															
PKD				540*	[32]	**0.82**		[33]	3.51	[33]		70.0	[32]		[33]	cubic	[33]

Table 1 (*continued*)

Legend: *theoretical value; {} XRD;

Phase	Melting point / °C	Ref.	**B** Bulk modulus / GPa	**G** Shear modulus / GPa	Ref.	**B / G**	***E*** Young's modulus / GPa	Ref.	Density / g cm^{-3}	Ref.	**Specific modulus / GPa cm^3 g^{-1}**	Hardness / GPa	Ref.	Poisson's ratio	Ref.	Space group / structure	Ref.
			463.1* / 442*				1013 ± 52.6				**273.6 - 303.6**			0.144 ± 0.055			
			368	397.5	[15]		1185.3	[15]						0.0077	[15]		
SiC	2200	[18]					480	[18]	3.2	[18]	**117.1 - 158**	20 - 35	[18]	0.17	[34]	hex	[18]
	2300	[20]		200	[34]		480	[20,34]	3.21	[20]		32.0	[17]	0.17	[35]	hex	[20]
	2820	[17]					386.4	[9]	3.21	[17]				0.16	[17]	polymorphic	[17]
	2750	[7]					427	[35]	3.123 / 3.213	[2]						F43m	[2]
							415	[17]	3.3	[7]							
							495	[7]			**150** [7]						
TaC	3880 - 3915	[13]					336	[13]	13.9	[13]	**19.7 - 24.2**	18.2	[17]			Fm3m	[2]
	3880	[20]					290	[20]	14.5	[20]		16.0+-2.0	[27]			cubic	[20]
	3985	[9]					285.4	[9]	14.5	[17]						cubic	[17]
	3800	[17]					285	[17]									
	3780	[2]															
TiC	3140	[28]	242.2	188.5	[36]	**1.28**	400	[18]	4.93	[18]	**64.8 - 110.2**	24 - 32	[18]	0.1908	[36]	fcc	[18]
	3067	[18]	240		[37]		462.9	[36]	4.905*	[36]		31.4	[9]	0.17	[25]	cubic	[20]
	3140	[20]					320	[20]	4.93	[20]		30.0	[17]			cubic	[17]
	3100	[17]					451	[17]	4.94	[17]		32+-2.0	[27]			Fm3m	
	3150	[2]					451.1	[9]	4.2	[7]							
	3250	[7]					450 @ 617 °C	[25]									
							460	[31]									
							420	[7]			**100** [7]						
UC	2520	[9]	163.6	82.6	[36]	**1.98**	212.1	[36]	12.97 / {13.63}	[9]	**15.6 - 17.0**	6.9+-1.5	[9]	0.284	[36]		
							220.7	[9]				9.5+-1.0	[27]				
VC	2730	[13]					434	[13]	5.77	[13]	**72.6 - 85.1**	27.5 / 20.4 - 24.6 / 20.4 / 92 HRA	[4]	0.32 @ 552 °C	[25]	cubic fm3m	[29]
	2810 - 2865	[4]					421.7	[9]	5.36 - 5.81	[4]						B1 fcc	[4]
	2648	[9]					420 @ 552 °C	[25]	5.1	[7]							

	2750	[7]														
V_2C	2200	[28]						{5.75}	[9]							
	2187	[9]						5.8	[7]							
	2150	[7]														
WC	2800–2860	[13]	577		[38]		669	[13]	15.63	[13]	**32.8 - 47.1**	20 - 24	[18]	0.31 @ 347 °C	[25]	hex	[18]
	2600	[18]					720	[18]	15.7	[18]		21.6	[9]			hex	[4]
	2867+-50 / 2870 / 2900 / 2777 / 2867 / 2627	[4]					519 / 539.8 / 601.2 / 668.2 / 706.7	[4]	15.60 / 15.63 / 15.7 / {15.8}	[4]		17 / 23.5 / 18.3 / 18.4 / 92 HRA	[4]			Fm3m	[2]
	2780	[20]					730	[20]	15.7	[20]						hex	[20]
	2785	[2]					696.3	[9]	15.5 - 15.7 / {15.77}	[9]							
	2777	[7]					700 @ 347 °C	[25]	15.7	[7]							
ZrC	3400	[13]	223.1	169.7	[36]	**1.31**	359	[13]	6.73	[13]	**28.3 - 83.8**	25.5 / 27.8 - 34.1 / 21 / 20.5 / 92.5 HRA	[4]	0.197	[36]	B1 fcc	[4]
	3532+-125 / 3532 / 3530 / 3550 / 3540 / 3175	[4]	214.2	124	[9]	**1.31**	406.2	[36]	6.606*	[36]		27.0	[17]	0.257	[9]	Fm3m	[2]
	3420	[2]					195.1 / 317.8 / 337.8 / 479.9	[4]	6.9 / {6.661. 6.73. 6.70. 6.44}	[4]		30+-3.0	[27]				
	3420	[20]					390	[20]	6.6	[20]						cubic	[20]
	3400	[17]					550 @ 505 °C	[25]	6.56	[17]						fcc	[17]
	3525	[7]					348.1	[9]	6.8	[7]							
							348	[17]									
							408	[7]			**60** [7]						
Oxides																	
Al_2O_3	2045	[13]	264.5	156.6	[39]	**1.69**	379 @ 1090 °C	[13]	3.98	[13]	**99.2 - 104.1**	20.7	[40]	0.27	[41]	hex	[18]
	2046.7+-8	[40]	136.67*	165	[34]	**0.83**	395.8	[39]	3.97	[40]		18 - 21	[18]		[40]		[40]

Table 1 (*continued*)

Legend: *theoretical value; {} XRD;

Phase	Melting point / °C	Ref.	**B** Bulk modulus / GPa	**G** Shear modulus / GPa	Ref.	**B / G**	***E*** Young's modulus / GPa	Ref.	Density / g cm^{-3}	Ref.	**Specific modulus / GPa cm^3 g^{-1}**	Hardness / GPa	Ref.	Poisson's ratio	Ref.	Space group / structure	Ref.
														0.13 - 0.45		hex. cubic. monoclinic	
	2050	[20]	251.2	163.4	[42]	**1.54**	410	[20,34]	3.94	[39]		23.0	[20]	0.254	[39]		
				124.55 - 347.36	[40]				3.99	[20]				0.23	[34]		
				186.33 (single crystal)	[40]												
B_2O_3	450	[40]							1.84	[40]							
BaO	~ 1923	[40]							5.72	[40]							
BeO	2527	[13]	464.29*		[20]	**3.29**	190 @ 1090 °C	[13]	3.01	[13]	**122.8 - 129.6**	7.8 / 10 / 12.3 / 14.9	[40]	0.36 - 0.38	[40]	hex	[40]
	2570+-30	[40]		95.91 - 100.03	[40]		372	[39]	3.03	[40]							
	2570	[20]		141	[39]		390	[20]	3.01	[20]							
CaO	2580	[20]	120	74.05	[43]	**1.62**	181	[43]	3.32	[20]	**53.2 - 54.5**	6.0	[40]	0.22	[43]	cubic	[40]
	2587	[40]		74.0	[40]				3.4	[40]		6.0+-0.8	[27]	0.22	[40]		
	2614	[7]	218		[42]												
CeO_2	2000	[13]		62.47	[40]		185	[13]	7.13	[40]	**25.9**						
	2397	[40]							7.13	[13]							
Ce_2O_3	2142+-30	[40]	109*	50.8*	[44]	**2.15**	132		6.9 - 7.0	[40]	**18.9 - 19.1**						
	2210																
Co_2O_3	894	[40]							5.18	[40]							
Cr_2O_3	2300	[40]	240		[45]				5.21	[40]		29.1	[40]			hex	[40]
FeO	1368	[40]	154		[46]				5.7	[40]		5.4	[40]			hex. cub.	[40]
			162.7		[47]							5.4+-0.5	[27]			fcc	[46]
Fe_2O_3	1562	[40]	99.6	94.8	[42]	**1.05**	261	[48]	6.51	[40]	**40.1**	10.8 / 5 - 6.8 / 6.8 - 10.9 / 9 / 9.9 / 9 - 10.4 / 3.5 - 3.8	[40]			hex. cub.	[40]
HfO_2	2810	[7]							9.68	[7]							
MgO	2800+-13	[40]	156.4	124.3	[39]	**1.26**	317 @ 1090 °C	[13]	3.65	[40]	**68.2 - 88.4**	9.1 - 9.3 / 7.5 / 11.2	[40]	0.36	[40]	cubic	[40]

	2800	[7]	156.57*	130	[34]	**1.20**	249.09	[49]	3.58	[13]		11.0+-1.5	[27]				
			155	130.1	[42]	**1.19**			3.585	[49]							
				77.48 - 113.76	[40]		294.7	[39]	3.506	[39]							
	2840	[20]	162.3		[47]		310	[20,34]	3.58	[7]				0.17	[34]		
MgO_2	2832	[7]															
$MgAl_2O_3$	2135	[7]							3.51	[7]							
MgV_2O_4	2050	[7]															
MnO	1785	[40]							5.18	[40]		5.7	[40]			cubic	[40]
												5.7+-0.8	[27]				
MnO_2	847	[40]	34.4						5.026	[40]						tetra. rhom.	[40]
NbO	1937	[7]															
NbO_2	1902	[7]															
Nb_2O_3	1772	[40]					134.1	[50]									
Nb_2O_5	1510	[40]							5.98	[40]		7.3	[40]			rhom.	[40]
	1512	[7]															
NiO	1957	[40]							7.45	[40]		4.4	[40]			cubic	[40]
Sc_2O_3	2405	[40]							3.864	[40]						cubic	[40]
SiO_2	1600–1725		37.02	31.14	[39]	**1.19**	73	[13]	2.66	[13]	**27.4 - 33.1**			0.17	[40]	**hex** - rhom - tetra - cub	[40]
	1720	[40]	36.98*		[13,39]		72.97	[39]	2.32 - 2.651	[40]		7.5 - 12.3	[40]	0.171	[39]		
	1710	[7]							2.203	[39]							
									2.32	[7]							
Sm_2O_3	~ 2320	[40]	127.99*	53.1	[39]	**2.41**	139	[39]						0.319	[39]	monoclinic	[40]
Ta_2O_5	1877	[40]					179.1	[50]	8.73	[40]	**20.5**					rhom.	[40]
	1785	[7]															
ThO_2	3300	[40]	69.34*	98.07 (303 K)	[40]	**0.71**	137.3	[40]	10	[40]	**13.7 - 32.0**	9.7 - 10.9	[40]	0.17	[40]	cubic	[40]
	3220	[20]	178.5	94.2	[39]	**1.89**	240.4	[39]	9.722	[39]							
	3390	[7]					240	[20]	10.05	[20]				0.275	[39]		
							310.4	[7]	9.7	[7]	**32** [7]						
TiO	1737	[40]	270		[37]				4.93 - 5.53	[40]		19.6	[40]	0.28		cubic	[40]
												16.0+-3.5	[27]				
TiO_2	1855	[40]	210	113.1	[39]	**1.86**	272	[39]	3.84 - 4.24	[40]	**64.2 - 70.8**	6.0 - 10.7	[40]			tetra. rhom.	[40]
	1857	[7]	210.3	113.5	[42]	**1.85**			4.24	[39]							
			215.2	113.54 (single crystal)	[40]	**1.90**											
Ti_2O_3	2127	[40]	148.9	69.2	[51]	**2.15**	179.8	[51]	5.02	[51]	**35.8**			0.299	[51]	cubic	[51]
																hex	[40]
UO_2	2760	[40]					192.9	[39]	10.5	[40]		7.7 - 8.2	[40]	0.302	[39]	cubic	[40]

Table 1 (*continued*)

Legend: *theoretical value; {} XRD;

Phase	Melting point / °C	Ref.	**B** Bulk modulus / GPa	**G** Shear modulus / GPa	Ref.	**B / G**	***E*** Young's modulus / GPa	Ref.	Density / g cm^{-3}	Ref.	**Specific modulus / GPa cm^3 g^{-1}**	Hardness / GPa	Ref.	Poisson's ratio	Ref.	Space group / structure	Ref.
	2800	[20]	162	74.1	[39]	**2.19**	162.8 - 245.18	[40]	10.37	[39]	**17.6 - 18.6**						
	2875	[7]							10.97	[20]							
VO_2	1545	[40]							4.4	[4]						monoclinic	[40]
V_2O_3	2376	[40]							4.87	[4]						hex	[40]
WO_3	1470	[40]							7.16	[4]						tetra. monoclinic	[40]
	1470	[7]															
Y_20_3	2450	[20]	148.9+-3	69.2+-2	[51]	**2.15**	179.8 +-4.8	[51]	5.02	[51]	**34.1 - 41.0**	6.8	[40]	0.299	[51]	cubic	[40]
			135.7	66.5	[39]	**2.04**	171.5	[39]	5.03	[39]				0.298	[39]		
			141.5*		[39]		180	[20]	4.5	[20]							
									4.84	[40]							
ZnO	1975	[40]	134	44	[39]	**3.05**	199+-2			[40]	**21.2 - 35.9**	1.5 - 3.1	[40]	0.351	[39]	tet - mono @ 1170 °C	[52]
			143.6	45.5	[42]	**3.16**	119	[39]								hex	[40]
				45.5	[40]												
ZrO_2	2690	[40]	137.68*	75	[34]	**1.84**	190	[34]	5.56	[40]	**30.3 - 35.4**	16.6	[40]	0.27	[34]	monoclinic	[40]
	2700	[7]		77.9	[39]		197	[39]	6.27	[40]						cubic	[40]
									5.75	[7]							
Nitrides																	
AlN	2300	[20]	159.9 - 207	126.4	[53]	**1.64**	350	[20]	3.25	[20]	**90.5 - 110**					hex	[20]
	2375	[7]					350	[9]	3.2	[54]							
							294.2 - 323.6 / 343.7	[7]	3.2	[7]							
							352	[7]			**110** [7]						
BC_2N			408	445	[11]	**0.92**	980	[24]				65.2		0.096	[24]		[24]
BN	2730	[7]							2.1	[7]							
c-BN	2973		400	405	[11]	**0.99**	909	[24]	3.45 - 3.48	[33]	**261.2 - 263.5**	48*	[11]	0.121	[55]	cub (hex)	[24]
			405	400	[55]	**1.01**	909*	[55]					[24]	0.119	[15]	cubic [F 4 3 m]	[33]

												61 (graph)					
			376	383.67	[21]	**0.98** [21]	921	[15]									
			415 (graph)	405	[24]	**1.02**											
hex-BN									2.2	[54]							
CrN												15.4+-0.5	[9]				
HfN	3385	[17]					341.66 - 355.46	[30]	13.9	[17]	**24.6-25.6**	15.7	[9]			fcc	[17]
	3225	[7]										17.0+-2.0	[27]				
NbN	2300	[9]					483.5	[9]	3.26	[7]	**60 - 148.3**					cubic	[9]
	2330	[7]					195.6	[7]									
Si_3N_4	1900	[13]	290	120	[13]	**2.42**	295	[34]	3.18	[13]	**66.7 - 92.8**	15.5	[18]	0.29	[34]	hex	[20]
	1900	[24]		115	[34]		220	[20]	3.2	[7]						hex	[18]
	1900	[7]							3.2-3.3	[54]							
	1900	[20]							3.2	[20]							
TaN	2700	[17]							14.3	[17]		23.7	[9]			cubic	[17]
	3075	[7]							13.8 / {14.36}	[9]							
TiN	2930	[13]	295	212.23*	[21]	**1.39 [21]**	600	[13]	5.44	[13]	**46.2 - 115.4**	21.0+-3.0	[27]			cubic	[20]
	2950	[20]	320*		[37]		260	[20]	5.4	[20]						fcc	[17]
	2950	[9]					251.1	[9]	5.43 / {5.44}	[9]							
	2950	[17]					445 - 472.06	[30]	5.39	[17]							
	2900	[7]							5.2	[7]							
VN	2050	[9]							6.040 / 6.102	[6]		**15.5+-1.5**	[27]				
	2200	[7]							6	[7]							
ZrN	2980	[20]							7.3	[20]	**50** [7]	**18.0+-2.0**	**[27]**			cubic	[20]
	2980	[9]							7.29	[17]						fcc	[17]
	3950	[17]															
	2950	[7]															
Intermetallics																	
$Be_{12}Ti$	1593	[2]	117	128	[56]	**0.91**	282	[56]	2.3	[2]	**122.6**			0.099	[56]	D2b tI26 P6/mmm	[56] [2]
CoAl	1635	[56]	162	114	[56]	**1.42**	278	[56]				5.2	[80Sam]	0.214	[56]	B2cP2	[56]
$CoSi_2$	1326	[2]	210.1	67.5	[56]	**3.11**	182.9	[56]	4.94 / {4.95}	[9]	**36.9 - 37.0**	5.4	[9]	0.355	[56]	Fm3m	[2]

Table 1 (*continued*)

Legend: *theoretical value; {} XRD;

Phase	Melting point / °C	Ref.	**B** Bulk modulus / GPa	**G** Shear modulus / GPa	Ref.	**B / G**	***E*** Young's modulus / GPa	Ref.	Density / g cm^{-3}	Ref.	**Specific modulus / GPa cm^3 g^{-1}**	Hardness / GPa	Ref.	Poisson's ratio	Ref.	Space group / structure	Ref.
	1277	[6]															
$CrSi_2$	1475	[2]	172	153.3	[56]	**1.12**	354.6	[56]	4.91	[2]	**71.1 - 72.1**	6.9	[9]	0.156	[56]	P6222	[2]
	1500 +-20	[6]							4.91 / {4.978}	[9]							
Fe_3Al									{6.648}	[9]							
FeAl							261	[56]	5.585	[9]	**46.7**					B2cP2	[56]
$MoSi_2$	2050	[56]	209.7	191.1	[56]	**1.10**	384		5.9 - 6.3 / {6.24}	[6]	**60.3 - 71.5**	12.95 - 15.2	[6]	0.151	[56]	tet	[18,56]
	2030	[20]					380	[20]	6.2	[20]		6.9	[9]			tet	[20]
	2030	[6]					421.7	[6]								I4/mmm	[2]
Ni_3Al			173	77.3	[56]	**2.24**	201.9	[56]	{7.293}	[9]				0.305	[56]		[56]
Ni_3Fe			180.6	85.5	[56]	**2.11**	221.4	[56]						0.296	[56]		[56]
NiAl	1638	[56]	166	70	[56]	**2.37**	184.1	[56]	5.85		**31.5**			0.315	[56]		[56]
$TaSi_2$							338	[13]	9.1	[13]	**37.1 - 38.3**	9.8 - 11.8	[9]			P6222	[2]
									9.1	[2]							
									8.83 / {9.1}	[9]							
Ti_3Sn			97.5	41.9	[56]	**2.33**	110	[56]						0.312	[56]		[56]
TiAl			110	70	[56]	**1.57**	173	[56]	3.84 / {3.63}	[9]	**45.1 - 47.7**	1.8	[9]	0.234	[56]	L10 tP4	[56]
$TiAl_3$	1375	[56]	105.6	93	[56]	**1.14**	215.7	[56]	3.31 / {3.371}	[9]	**64.0 - 65.2**	6.7	[9]	0.16	[56]		[56,57]
$TiCr_2$	1550	[56]	159	71	[56]	**2.24**	184	[56]						0.31	[56]	C14. hP12	[56]
$TiSi_2$			148.9	116.7	[56]	**1.28**	277.8	[56]	4.39 / {4.13}	[6]	**59.0 - 69.1**	6.78	[9]	0.189	[56]	Fddd	[6]
							258.9	[6]	4.02 / {4.043}	[9]							
Ti_5Si_3	2150	[7]							4.2	[7]							
VSi_2			166 - 167.2	142 - 147.9	[56]	**1.12**	331 - 342.6	[56]	4.34 / {4.627}	[9]	**71.5 - 78.9**	8.7 - 9.4	[9]	0.158	[56]		[56]
V_5Si_3									5.1	[7]							
WSi_2	2180	[7]	222.4	203.6	[56]	**1.09**	467.9	[56]	9.25 / [9.857]	[9]	**47.5-50.6**	10.5	[9]	0.149	[56]		[56]
									9.25	[7]							
YAl_2			89.2	65.5	[56]		158	[56]	{3.933}	[9]	**40.2**			0.205	[56]	C15 cF24	[56]
YFe_2			97	49.6	[56]	**1.36**	127	[56]								C15 cF24	[56]
$ZrAl_2$	1645	[56]	117	93.8	[56]	**1.25**	222	[56]		[9]				0.184	[56]	C14. HP12	[56]

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Transparency document. Supplementary material

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