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ABSTRACT

Fracture toughness data, as represented by the critical stress intensity factor, K_{Ic}, and the fracture energy, γ, have been compiled from publicly accessible sources for a wide range of brittle materials with an emphasis on structural ceramics and closely related materials. The results are organized according to the material designation and are presented in annotated tables.

Key Words

Brittle materials; ceramics; data; database; fracture toughness; structural ceramics

Table of Contents

1. Introduction

Brittle materials are subject to rapid crack extension upon the application of tensile stresses. The capacity of a material to resist the extension of a crack is called fracture toughness.[1,2]

Analytical descriptions of fracture behavior are commonly based on linear stress analysis. In this approach, the focus is on the stress in the vicinity of a crack tip where the curved boundaries lead to an enhanced stress state. A parameter, K, called the stress intensity factor, is introduced as a measure of the enhanced value of the stress. The symbol K_I, called the Mode I stress intensity factor, is used for the particular case of tensile crack extension. The critical value of the stress intensity factor, K_{Ic}, commonly called the fracture toughness, is defined as the value at which bond rupture occurs at the crack tip. Linear stress analysis for tensile cracks leads to the relation

$$K_{Ic}^2 = \Gamma E' = 2\gamma E' \qquad \textbf{(1)}$$

where $E' = E$ for plane stress and $E' = E/(1-\nu^2)$ for plane strain; E is the elastic modulus; ν is Poisson's ratio; Γ is the mechanical energy release rate for fracture; and $2c_0$ is the initial crack size. The quantity, $\gamma = \Gamma/2$, is often called the fracture energy and is reported more commonly than Γ. Values of K_{Ic} and γ are given in the present compiliation.

Several procedures for estimating fracture toughness involve measuring the fracture strength, σ_f, of a cracked specimen and then evaluating the fracture toughness in the form

$$K_{Ic} = Y\sigma_f c_0^{1/2} \qquad \textbf{(2)}$$

where Y is a dimensionless numeric factor that depends on the test configuration and the shape of the initial crack.[3] Numerous experimental designs have been developed in attempts to minimize the uncertainties in the value of K_{Ic} arising from the geometric uncertainties of the test configuration and the initial crack.

The present report presents a compilation of fracture toughness (K_{Ic}) and fracture energy (γ) values for a wide range of brittle materials determined by a variety of test methods. The results are obtained primarily from publicly accessible published sources; in all cases, the sources of the data and the methods used in the measurements are cited explicitly. The measurement methods are described in Section 3.1.

Overviews of the data are provided by Fig. 1, which shows a distribution of all the fracture toughness values reported in the compilation, and Fig. 2, which shows a distribution of the fracture energy values. It can be seen that most of the toughness values are less than 8 $MPa \cdot m^{1/2}$. The smallest reported value is 0.16 $MPa \cdot m^{1/2}$ for cracks parallel to a cleavage plane of a sodium β-alumina single crystal.[4] Normal to that plane, the toughness for this crystal is 2.0 $MPa \cdot m^{1/2}$. The unusual toughness values greater than 10 $MPa \cdot m^{1/2}$ were reported for various stabilized tetragonal zirconia polycrystals.[5,6]

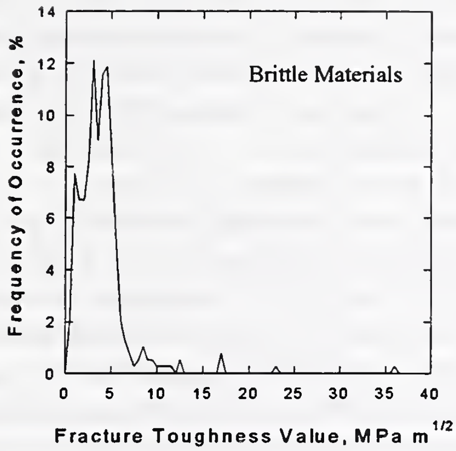

Figure 1: Distribution of Fracture Toughness Values

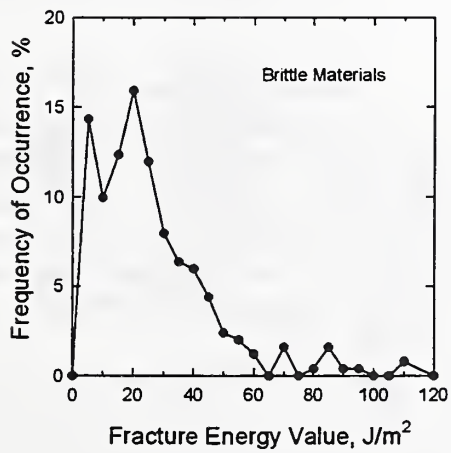

Figure 2: Distribution of Fracture Energy Values

References for the Introduction

1. A. A. Griffith, "Phenomena of Rupture and Flow in Solids," Philosophical Transactions of the Royal Society of London, Vol. 221, pp. 163-198 (1921).
2. G. R. Irwin and P. C. Paris, "Fundamental Aspects of Crack Growth and Fracture" in *Fracture, An Advanced Treatise*, Vol. III, edited by H. Liebowitz, Academic Press, New York (1971), pp. 1-46.
3. J. B. Wachtman, *Mechanical Properties of Ceramics*, John Wiley & Sons, Inc., New York (1996).
4. D. C. Hitchcock and L. C. De Jonghe, "Fracture Toughness Anistropy of Sodium Beta-Alumina," Journal of the American Ceramic Society, Vol. 66, No. 11, pp. C-204 - C-205 (1983).
5. J. Wang, W.M. Rainforth, T. Wadsworth, and R. Stevens, "The Effects of Notch Width on the SENB Toughness for Oxide Ceramics," Journal of the European Ceramic Society, Vol. 10, pp. 21-31 (1992).
6. K. Tsukuma and M. Shimada, "Strength, Fracture Toughness and Vickers Hardness of CeO_2-Stabilized Tetragonal ZrO_2 Polycrystals (Ce-TZP)," Journal of Materials Science, Vol. 20, pp. 1178-1184 (1985); and K. Tsukuma, "Mechanical Properties and Thermal Stability of CeO_2 -Containing Tetragonal Zirconia Polycrystals," American Ceramic Society Bulletin, Vol. 65, pp. 1386-1389 (1986).

2. Organization of the Data

Results are grouped by the material designation (a chemical formula, a common name, or a commercial name). A list of designations is given in section 4. Each material designation is presented separately. Therefore, each table begins with a brief description of the material, starting with the material designation . The references for the data are given in each case after the material is defined. Each table ends with an annotated summary of the numeric data which are presented in a fixed format. In all cases, the column headers clearly define the content.

3. Notation and Conventions

A small number of conventions, abbreviations, and special symbols are used in this report so that the space allocated for comments within the data tables can be used efficiently. For example, abbreviations and acronyms are used to indicate the measurement methods used in determining the property values.

3.1 Measurement Methods

AMDCB = Applied Moment Double Cantilever Beam
CF = Controlled Flaw
CNB = Chevron Notch Beam
DCB = Double Cantilever Beam
DT = Double Torsion
HI = Hertzian Indentation
ICS = Indentation Crack Size
IS = Indentation Strength
NDC = Notched Diametral Compression
SCF = Surface Crack in Flexure
SENB = Single-Edge Notched-Beam
SEPB = Single-Edge Precracked Beam
SR = Short Rod
TDCB = Tapered Double Cantilever Beam
WOF = Work of Fracture

Extensive discussions of measurement methods and their relative merits are given by S. W. Freiman, American Ceramic Society Bulletin, Vol. 67, pp. 392-402 (1988); S. W. Freiman in *Fracture Mechanics of Ceramics*, Vol. 6, edited by R. C. Bradt *et al.*, Plenum, New York (1983), pp. 27-45; and J. B. Wachtman, *Mechanical Properties of Ceramics*, John Wiley & Sons, Inc., New York (1996), chapter six. A summary of the methods noted in the present compilation is given here, along with additional references, as needed.

Many of the test methods involve a notched specimen. To unify the summaries of those methods, let us assume that the specimen, Fig. 3, is a parallellapiped whose pairs of opposite faces may be referred to as (top and bottom), (front and back), and (left side and

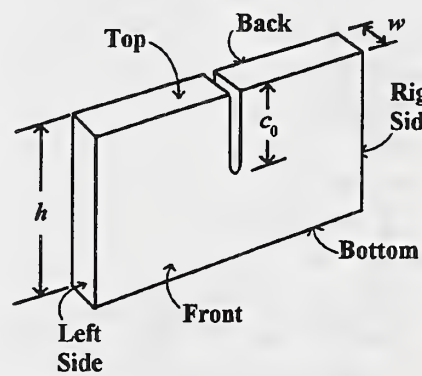

Figure 3: Schematic of a notched specimen

right side). The notch can then be assumed to be cut into the top surface towards the bottom surface, parallel to the sides, and extending completely across the specimen from the front surface to the back surface. The depth of the cut, c_0, is less than the distance, h, from the top surface to the bottom surface.

3.1.1 AMDCB = Applied Moment Double Cantilever Beam

This method is also known as the constant moment double cantilever beam method. The AMDCB method is similar to the DCB method, but the applied load is replaced by an applied moment, M, applied to the top surface. If a load P is applied at a distance s from a fulcrum, then a moment $M = Ps$ is generated. A moment, M, is applied to each arm of the notched specimen. Then, $K_{Ic} = M/(Id)^{1/2}$, where I is the moment of inertia of a single arm and d is the distance from the front surface to the back surface. The applied stress intensity factor is independent of the initial crack length.

3.1.2 CF = Controlled Flaw

The name "controlled flaw" has been superseded by the name "surface crack in flexure" although the older name still enjoys some usage. The controlled surface flaw and controlled microflaw methods are equivalent also. See SCF for further discussion.

3.1.3 CNB = Chevron Notch Beam

The notch is cut in the shape of a chevron, and the specimen is subjected to either three-point or four-point bending. In three-point bending, the central load point is on the bottom surface under the notch, and the latteral load points are on the top surface; the loads are normal to the top and bottom surfaces. In four-point bending, the central load point on the bottom surface is replaced by a pair of load points, one on each side of the notch.

3.1.4 DCB = Double Cantilever Beam

The specimen is notched, and the load is applied normal to the crack plane on each arm of the specimen at the top surface of the specimen.

3.1.5 DT = Double Torsion

In the DT method, a notched specimen is loaded at four points. Two of the loads are applied normal to the front surface at the top of the specimen, one load point next to each side of the notch. The other two loads are applied normal to the back surface at the top of the specimen, one load point near to each side of the specimen. Evaluation of K_{Ic} requires the additional knowledge of the value of Poisson's ratio for the specimen.

3.1.6 HI = Hertzian Indentation

[P. D. Warren, Determining the Fracture Toughness of Brittle Materials by Hertzian Indentation, Journal of the European Ceramic Society, Vol. 15, pp. 201-207 (1995)]

A hard sphere is pressed into the surface of the specimen to generate ring cracks initiating at the edge of the contact zone. Fracture toughness is related to the radius of the ring cracks. Additional knowledge of the elastic modulus and Poisson's ratio is required.

3.1.7 ICS = Indentation Crack Size

In the ICS method, a diamond indentor is pressed into the surface of the specimen under a known load. The indentation produces radial cracks extending from the vertices of the impression, and the resulting crack length can be related to the fracture toughness of the specimen. Additional knowledge of the ratio, E/H, of the elastic modulus, E, and the hardness, H, is required for the evaluation of K_{Ic}.

3.1.8 IS = Indentation Strength
The IS method involves two parts. First, an indentation is made in the specimen as in the ICS method. Then, the strength of the indented specimen is measured in four-point bending. The measured strength and the additional knowledge of the ratio, E/H, of the elastic modulus, E, and the hardness, H, are required for the evaluation of K_{Ic}. This method has the advantage that the crack size does not have to be measured.

3.1.9 NDC = Notched Diametral Compression
[D. K. Shetty et al., J. Am. Ceram. Soc., Vol. 68, pp. c-325 - c-327 (1985)]
A specimen in the shape of a disk is used in the diametral compression test. The load is applied along a diameter of the disk. The maximum tensile stress develops transverse to the load axis. For the NDC, notches are machined through the thickness of the disk, one notch at each end of the load axis. The diametral configuration has the advantage of simple specimen manufacture. Additionally, values for the elastic modulus and Poisson's ratio are required for the evaluation of K_{Ic}.

3.1.10 SCF = Surface Crack in Flexure
[C. A. Tracy and G. D. Quinn, Fracture Toughness by the Surface Crack in Flexure (SCF) Method, Ceramic Engineering and Science Proceedings, Vol. 15, pp. 837-845 (1994)]
In the SCF method, an indentation is made in the surface of the specimen, as in the IS method, to create an initial crack (called a precrack). The surface is then lapped to remove the residual surface impression leaving only the precrack in the surface. The strength of the specimen is then determined in four-point bending. The size of the precrack is determined by post-test fractography. K_{Ic} is evaluated from the measured strength, the size of the precrack, and a geometric shape factor.

3.1.11 SENB = Single-Edge Notched-Beam
A straight notch is cut by means of a saw blade or a wire, and the specimen is subjected to either three-point or four-point bending. In three-point bending, the central load point is on the bottom surface under the notch, and the latteral load points are on the top surface; the loads are normal to the top and bottom surfaces. In four-point bending, the central load point on the bottom surface is replaced by a pair of load points, one on each side of the notch. SENB results may overestimate K_{Ic} and may have lower reproducibility than other methods because the notch tip is not sharp.

3.1.12 SEPB = Single-Edge Precracked Beam
SEPB is a variation on the SENB test. Prior to testing, the specimen is stressed so that the notch is extended in the form of a sharp crack. Additional post-test fractography is required to assess the initial crack size.

3.1.13 SR = Short Rod
[L. M. Barker, Engineering Fracture Mechanics, Vol. 9, pp. 361-369 (1977)]
The SR method is a variation on the DCB method. The SR specimen is a rod with a diameter that is typically two-thirds the size of the length. A V-shaped notch is cut into

one end of the rod. A pretest load creates an initial crack in the specimen in the region of the vertex of the V-shaped notch. The precrack is stable if the crack length is less than a critical length, a_c. A distinctive feature of this test is that a_c is essentially independent of the material being tested if the size of the plastic zone in the crack region is small compared to the dimensions of the specimen. Once a_c is determined for a given configuration, the fracture toughness is determined by the peak load at fracture.

3.1.14 TDCB = Tapered Double Cantilever Beam
[C. St. John, The Brittle-to-Ductile Transition in Pre-Cleaved Silicon Single Crystals, Philosophical Magazine, Vol. 32, pp. 1193-1212 (1975).]
The TDCB method is similar to the DCB method except that the sides of the specimen are tapered such that the distance between the sides at the top surface is less than the distance at the bottom surface. The tapered configuration produces a higher stress intensity for lower applied stress than in the DCB configuration; the result is a reduction of plasticity in regions away from the crack tip.

3.1.15 WOF = Work of Fracture
[H. G. Tattersall and G. Tappin, Journal of Materials Science, Vol. 1, pp. 296-301 (1966).]
The WOF method is similar to the CNB method except that the load *vs.* displacement curve is measured and integrated to determine the work done in fracture. However, since this procedure determines the total work of fracture, there is an open question of how this value is related to γ. WOF values are included in this compilation for completeness.

3.2 Property Symbols
The following symbols are used in the comments portion of the data tables.

K_{Ic} = Fracture toughness
E = Elastic modulus (Young's modulus)
H = Hardness (Vickers, unless noted)
ν = Poisson's ratio
Tc = Superconducting critical temperature

3.3 Units
SI units, unit symbols, and unit prefixes are used exclusively. For a comprehensive discussion of the use of SI units, see "Guide for the Use of the International System of Units (SI)," by B. N. Taylor, NIST Special Publication 811.

3.4 Uncertainties
No attempt has been made to assign uncertainties to the individual values obtained from the literature. A survey of data in the NIST Structural Ceramics Database [Standard Reference Data Program, NIST, Gaithersburg, Maryland 20899] indicates that relative combined standard uncertainties in the range of 5 % to 15 % are not unusual for fracture toughness measurements. Exceptional cases having reported uncertainties as low as 1 % or as high as 30 % can be found, but such cases are very unusual. For a comprehensive discussion on estimates of uncertainty, see "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results," by B. N. Taylor and C. E. Kuyatt, NIST Technical Note 1297.

4. Index of Materials

5. Tables of Data

Data for all of the materials listed in the preceding section are given on the following pages.

ADP ($NH_4H_2PO_4$; ammonium dihydrogen phosphate)

Material Summary:

[Ref. 1]
Manufacturer........: NRL
Material Designation: ADP
Material Form.......: Single Crystal
Composition.........: $NH_4H_2PO_4$
Processing..........:

References:

[1] J.J. Mecholsky, S.W. Freiman, and R.W. Rice, "Fracture Surface Analysis of Ceramics" Journal of Materials Science, Vol. 11, pp. 1310-1319 (1976).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
			2	AMDCB	air	{110} plane; *E* = 9 GPa

AlN (Aluminum Nitride)

Material Summary:

	[Ref. 1]
Manufacturer........:	Dow Chemical Co.
Material Designation:	aluminum nitride
Material Form.......:	polycrystal
Composition.........:	AlN
Processing..........:	Hot pressed

References:

[1] G. D. Quinn, J. J. Swab, and M. D. Hill, "Fracture Toughness by the Surface Crack in Flexure (SCF) Method: New Test Results," Ceramic Engineering and Science Proceedings, Vol. 18 (4), pp. 163-172 (1997).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
		2.79		SCF	air	Ref. 1; E = 323 GPa; density = 3.26 g/cm^3

Al_2O_3 (alumina; aluminum oxide)

Material Summary:

	[Ref. 1-9]	[Ref. 10]	[Ref. 11]	[Ref. 12]
Manufacturer........:	Unknown	Smith Industries	NRL	Avco Corp.
Material Designation:	alumina	alumina	alumina	alumina
Material Form.......:	polycrystal	polycrystal	polycrystal	polycrystal
Composition.........: (mass Fraction)	Al_2O_3	Al_2O_3	99% Al_2O_3	98.7% Al_2O_3
Processing..........:				

	[Ref. 13,14]	[Ref. 15,16]
Manufacturer........:	Unknown	In laboratory
Material Designation:	alumina	alumina
Material Form.......:	single crystal	polycrystal
Composition.........:	Al_2O_3	Al_2O_3
Processing..........:		Sintered

References:

[1] D. B. Binns and P. Popper, "Mechanical Properties of Some Commercial Alumina Ceramics" Proceedings of the British Ceramic Society, No. 6, pp. 71-82 (1966).

[2] P. L. Pratt, "Grain Size and Fracture Toughness," Fracture, Vol. 3, pp. 909-912 (1977).

[3] R. W. Rice, S. W. Freiman, and P. F. Becher, "Grain-Size Dependence of Fracture Energy in Ceramics: I, Experiment," Journal of the American Cermic Society, Vol. 64, No. 6, pp. 345-350 (1981).

[4] H. Meredith and P. L. Pratt, "The Observed Fracture Stress and Measured Values of K(Ic) in Commercial Polycrystalline Aluminas" Proceedings of the British Ceramic Society, No. 20, pp. 107-122 (1972).

[5] S. S. Smith and B. J. Pletka, "Indentation Fracture of Single Crystal and Polycrystalline Aluminum Oxide" Fracture Mechanics of Ceramics, Vol. 6, pp. 189-209 (1983).

[6] N. Claussen, B. Mussler, and M. V. Swain, "Grain-Size Dependence of Fracture Energy in Ceramics" Journal of the American Ceramic Society, Vol. 65, No. 1, pp. C-14-C-16 (1982).

[7] K. Kromp and R.F. Pabst, "Application of the J Concept to Alumina at High Temperatures" Journal of the American Ceramic Society, Vol. 66, No. 2, pp. 106-110 (1983).

[8] G. De With, "Fracture of Translucent Alumina: Temperature Dependence and Influence of CaO Dope" Journal of Materials Science, Vol. 19, pp. 2195-2202 (1984).

[9] B. Mussler, M. V. Swain, and N. Claussen, "Dependence of Fracture Toughness of Alumina on Grain Size and Test Technique" Journal of the American Ceramic Society, Vol. 65, No. 11, pp. 566-572 (1982).

[10] B.J. Dalgleish, A. Fakhr, P. L. Pratt, and R. D. Rawlings, "Acoustic Emission as a Means of Assessing the Validity of Fracture Toughness Tests"

Proceedings of the Institute of Acoustics, pp. 1-5 (1977).
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[12] G. K. Bansal, "Effects of Ceramic Microstructure on Strength and Fracture Surface Energy" Microstructures, Proceedings of the Sixth International Materials Symposium, pp. 860-871 (1976).
[13] D. K. Shetty, A. R. Rosenfield, and W. H. Duckworth, "Fracture Toughness of Ceramics Measured by a Chevron-Notch Diametral-Compression Test" Journal of the American Ceramic Society, Vol. 68, No. 12, pp. C-325-C-327 (1985).
[14] M. Iwasa and R.C. Bradt, "Fracture Toughness of Single-Crystal Alumina," Advances in Ceramics, Vol. 10, pp. 767-779 (1984).
[15] J. Wang, W.M. Rainforth, T. Wadsworth, and R. Stevens, "The Effects of Notch Width on the SENB Toughness for Oxide Ceramics," Journal of the European Ceramic Society, Vol. 10, pp. 21-31 (1992).
[16] W.H. Tuan, M.J. Lai, M.C. Lin, C.C. Chan, and S.C. Chiu, "The Mechanical Performance of Alumina as a Function of Grain Size," Materials Chemistry and Physics, Vol. 36, pp. 246-251 (1994).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
					air	Ref. 1; mass fraction of Al_2O_3
50	0		36	WOF		99.9%
4	1		34	WOF		99.5%
15			54	WOF		99.2%
25			54	WOF		99.0%
5	2		30	WOF		95.6%
20	3		29	WOF		98.6%
10			48	WOF		98.5%
30	5		53	WOF		97.3%
10	11		25	WOF		95.4%
5	9		51	WOF		94.5%
8	8		40	WOF		94.1%
8	7		40	WOF		94.0%
4	9		40	WOF		93.1%
15	8		29	WOF		92.9%
10	12		51	WOF		93.1%
8	13		48	WOF		87.8%

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
4		5.5		DCB	air	Ref. 2
10		5.0		DCB		
20		4.9		DCB		
20		6.4		DCB		
4		5.1		DT		
10		5.2		DT		
20		5.2		DT		
4		5.0		SEPB		Firings repeated manually to obtain coarser grain sizes.
10		4.7		SENB		
20		4.0		SENB		
4		4.5		SENB		Firings repeated manually to obtain coarser grain sizes. Sample was blunt-notched.
10		4.2		SENB		
20		4.1		SENB		
120			4.6	AMDCB	air	Ref. 3
200			22.5	AMDCB		
400			6	AMDCB		
3.5	11	4.56		SENB	air	Ref. 4; Material isostatically cold pressed; starter cracks were used; E = 337 GPa
		5.01		CT		
		4.70		DCB		
5.0	19	3.13		SENB		E = 227 GPa
		3.32		CT		
		3.12		DCB		

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
12.0	21	2.68		SENB		*E* = 253 GPa
		2.77		CT		
		2.70		DCB		
2		2.36		ICS	oil	Ref. 5; *E* = 415 GPa
9		4.38		ICS		*E* = 369 GPa
2		5.73		SENB		
9		4.35		DT		
18		6.81		DT		
		1.91		ICS		single crystal
		2.66		ICS		single crystal
		2.61		ICS		single crystal
		1.68		ICS		single crystal
		2.04		ICS		single crystal
		2.08		ICS		single crystal
		2.13		ICS		single crystal
2.5			38	SENB	air	Ref. 6; the fracture energy value is an approximate value.
6			25	SENB		
13.5			27	SENB		
18			21.5	SENB		
24			20	SENB		
30			21	SENB		
11		3.8		SENB	air	Ref. 7; 97.0 % Al_2O_3 + 3.0 % SiO_2; *E* = 350 GPa
6		3.73		SENB		99.7 % Al_2O_3 + 0.3 % MgO,SiO_2; E= 389 GPa
23	0.06	3.71		SENB	N2	Ref. 8; 0.0092% MgO, 0.0002% CaO; *E* = 406 GPa
	0.08	3.28		SENB		0.0092% MgO, 0.0041% CaO; *E* = 397 GPa

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
31.4		3.9		SENB	air	Ref. 9; Notch radius = 70 μm
31.4		4.0		SENB		
30.7		3.8		SENB		
30.7		4.1		SENB		
30.5		3.9		SENB		
29.0		4.05		SENB		
24.0		4.0		SENB		
23.0		3.95		SENB		
18.0		4.0		SENB		
14.5		4.5		SENB		
12.9		4.5		SENB		
12.5		4.5		SENB		
9.0		4.2		SENB		
8.8		4.55		SENB		
6.9		4.65		SENB		
5.7		4.1		SENB		
5.0		4.25		SENB		
5.0		4.3		SENB		
5.0		4.5		SENB		
5.0		4.7		SENB		
4.0		5.15		SENB		
3.0		4.3		SENB		
3.0		4.5		SENB		
3.0		4.9		SENB		
3.0		5.0		SENB		
3.0		5.35		SENB		
2.0		5.15		SENB		
2.0		5.25		SENB		
2.0		5.8		SENB		
2.0		5.85		SENB		
2.0		5.9		SENB		
1.7		5.75		SENB		
1.4		6.25		SENB		
1.4		6.05		SENB		
1.4		5.9		SENB		
30.0		3.6		SENB		
12.9		4.1		SENB		
3.0		4.5		SENB		

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
2.0		5.3		SENB		
1.7		4.85		SENB		
1.4		5.3		SENB		
30.0		5.45		IS		Notch radius = 40 μm
24.0		5.1		IS		
23.5		5.3		IS		
18.0		5.2		IS		
14.5		5.3		IS		
12.5		5.25		IS		
8.5		4.75		IS		
8.0		4.5		IS		
7.0		4.2		IS		
5.0		4.0		IS		
5.0		4.15		IS		
5.0		4.25		IS		
2.0		4.3		IS		
1.5		3.75		IS		
4-6		3.95		SENB	air	Ref. 10
10-12		3.51		SENB		
4-6		4.13		DT		
4-6		5.4		DCB		
10-12		5.0		DCB		
1-10			20	AMDCB	air	Ref. 11; Material hot pressed; and E = 300 GPa
2	0.5		42.2	SENB	air	Ref. 12
			21.2	SENB		
			20.1	SENB		
		2.1		DT	dry N2	Ref. 13; H = 23.0 GPa
		4.6		CF	air	Ref. 14; $(00\underline{0}1)$ crystal plane
		3.2		CF		$(10\underline{1}0)$
		2.5		CF		$(11\underline{2}0)$

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
2.6		4.1		SENB	air	Ref. 15; 260 μm notch width
2.6		3.5		SENB		510 μm
2.6		3.2		SENB		800 μm
2.6		3.3		SENB		1800 μm
4.2		4.6		SENB		260 μm
4.2		4.3		SENB		510 μm
4.2		4.3		SENB		800 μm
4.2		4.5		SENB		1800 μm
6.3		5.5		SENB		260 μm
6.3		4.6		SENB		510 μm
6.3		4.9		SENB		800 μm
6.3		4.3		SENB		1800 μm
1.8	1.8	3.0		SEPB	air	Ref. 16
1.9	2.1	3.4		SEPB		
2.3	1.9	3.7		SEPB		
3.1	1.5	4.4		SEPB		
5.4	2.3	4.9		SEPB		
8.7	1.5	4.9		SEPB		
13.3	1.7	5.0		SEPB		

Al_2O_3 (beta alumina)

Material Summary:

	[Ref. 1]	[Ref. 2a]	[Ref. 2b]
Manufacturer........:	NRL	Union Carbide	Cerametec
Material Designation:	beta alumina	beta alumina	beta alumina
Material Form.......:	polycrystal	single crystal	polycrystal
Composition.........: (mass fraction)	Al_2O_3	93.6% Al_2O_3, 6.4% Na_2O	90.55% Al_2O_3, 8.7% Na_2O, 0.75% Li_2O
Processing..........:			

References:

[1] J. J. Mecholsky, S. W. Freiman, and R. W. Rice, "Fracture Surface Analysis of Ceramics" Journal of Materials Science, Vol. 11, pp. 1310-1319 (1976).

[2] D. C. Hitchcock and L. C. De Jonghe, "Fracture Toughness Anistropy of Sodium Beta-Alumina" Journal of the American Ceramic Society, Vol. 66, No. 11, pp. C-204-C-205 (1983),

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
5-20			13	AMDCB	air	Ref. 1; E = 210 GPa
		0.16		ICS	air	Ref. 2a; Plane of indentation = prismatic, E = 174 GPa
		1.97		ICS		2a; Plane of indentation = basal, E = 215 GPa
1.1		1.98		ICS		2b

Al_2O_3 (sapphire)

Material Summary:

	[Ref. 1]	[Ref. 2]	[Ref. 3]	[Ref. 4]	[Ref. 5]
Manufacturer........:	Union Carbide	Unknown	Unknown	Unknown	Unknown
Material Designation:	sapphire	sapphire	sapphire	sapphire	Sapphire
Material Form.......:	single crystal	single crystal	polycrystal	single crystal	single crystal
Composition.........:	Al_2O_3	Al_2O_3	Al_2O_3	Al_2O_3	Al_2O_3
Processing..........:					

References:

[1] J. J. Mecholsky, S. W. Freiman, and R. W. Rice, "Fracture Surface Analysis of Ceramics" Journal of Materials Science, Vol. 11, 1310-1319 (1976).

[2] M. Iwasa and T. Ueno, "Fracture Toughness of Quartz and Sapphire Single crystals at Room Temperature" Zairyo, Vol. 30, No. 337, pp. 1001-1004 (1981).

[3] S. W. Wiederhorn, "Fracture of Sapphire" Journal of the American Ceramic Society, Vol. 52, No. 9, pp. 485-491 (1969).

[4] G. R. Anstis, P. Chantikul, B. R. Lawn, and D. B. Marshall, "A Critical Evaluation of Indentation Techniques for Measuring Fracture Toughness: I, Direct Crack Measurements" Journal of the American Ceramic Society, Vol. 64, No. 9, pp. 533-538 (1981).

[5] A. G. Evans and E. A. Charles, "Fracture Toughness Determinations by Indentation" Journal of the American Ceramic Society, Vol. 59, No. 7-8, pp. 371-372 (1976).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [MPa·m$^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
			7	AMDCB	air	Ref. 1; {10-10} plane; E=340 GPa
		4.54		CF	air	Ref. 2; KIC-plane (0001), direction [1120]
		3.14		CF		KIC-plane (1100), direction [0001]
		2.38		CF		KIC-plane (1102), direction [1120]
		2.43		CF		KIC-plane (1120), direction [0001]
			7.3	DCB	N2	Ref. 3; {1010} plane
			6.0	DCB		{1012} plane E=31 GPa; perpendicular to {1010} plane
		1.89		ICS	air	Ref. 4; E=425 GPa
		2.55		IS		
		2.1		ICS	dry N2	Ref. 5; Material hot-pressed with MgO; *H* = 23 GPa

Al_2O_3 (AD-85)

Material Summary:

[Ref. 1,2,3]

Manufacturer........: Coors Porcelain Co.
Material Designation: AD-85
Material Form.......: polycrystal
Composition.........: 85% Al_2O_3
(mass fraction)
Processing:

References:

[1] S. W. Freiman, K. R. McKinney, and H. L. Smith, "Slow Crack Growth in Polycrystalline Ceramics" Fracture Mechanics of Ceramics, Vol. 2, pp. 659-676 (1974).

[2] L. M. Barker, "Short Rod K(Ic) Measurements of Al_2O_3" Fracture Mechanics of Ceramics, Vol. 3, pp. 483-493 (1973).

[3] G. D. Swanson, "Fracture Energies of Ceramics" Journal of the American Ceramic Society, Vol. 55, No. 1, pp. 48-49 (1972).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
7		3.0	20	AMDCB	air	Ref. 1; K_{Ic} obtained at a velocity of 10^{-4} m/s
6		2.98		SR	air	Ref. 2; E = 221 GPa
15			20.7	DCB	air	Ref. 3; E = 228 GPa

Al_2O_3 (AD-90)

Material Summary:

[Ref. 1,2]

Manufacturer........: Coors Porcelain Co.
Material Designation: AD-90
Material Form.......: polycrystal
Composition.........: 90% Al_2O_3
(mass fraction)
Processing..........:

References:

[1] G. R. Anstis, P. Chantikul, B. R. Lawn, and D. B. Marshall, "A Critical Evaluation of Indentation Techniques for Measuring Fracture Toughness: I, Direct Crack Measurements" Journal of the American Ceramic Society, Vol. 64, No. 9, 533-538 (1981).

[2] L. M. Barker, "Short Rod K(Ic) Measurements of Al_2O_3" Fracture Mechanics of Ceramics, Vol. 3, pp. 483-493 (1973).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
4		2.9		DCB	air	Ref. 1; E = 406 GPa
		2.83		ICS		E = 386 GPa
		2.54		IS		E = 386 GPa
4 [2-10]		3.06		SR	air	Ref. 2; E = 276 GPa

Al_2O_3 (AD-94)

Material Summary:

	[Ref. 1]
Manufacturer........:	Coors Porcelain Co.
Material Designation:	AD-94
Material Form.......:	polycrystal
Composition.........: (mass fraction)	94% Al_2O_3
Processing..........:	Sintered

References:

[1] C.A. Tracy and G.D. Quinn, "Fracture Toughness by the Surface Crack in Flexure (SCF) Method," Ceramic Engineering and Science Proceedings, Vol. 15, pp. 837-845 (1994).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa\cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
<20		3.8		SCF		*E* = 407 GPa

Al_2O_3 (AD-96)

Material Summary:

	[Ref. 1]	[Ref. 2]
Manufacturer........:	Coors Porcelain Co.	Coors Porcelain Co.
Material Designation:	AD-96	ADS96R
Material Form.......:	polycrystal	polycrystal
Composition.........: (mass fraction)	96% Al_2O_3	96% Al_2O_3
Processing..........:		

References:

[1] L. M. Barker, "Short Rod K(Ic) Measurements of Al_2O_3" Fracture Mechanics of Ceramics, Vol. 3, pp. 483-493 (1973).

[2] D. Sherman, "Fracture Toughness Evaluation of Small Thin Ceramic Specimens," Journal of the American Ceramic Society, Vol. 80, pp. 1904-1906 (1997).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
11 [2-20]		3.31		SR	air	Ref. 1; E = 303 GPa
5 [4-7]		3.27		SEPB	air	Ref. 2; density = 3.75 g/cm^3

Al_2O_3 (AD-995)

Material Summary:

[Ref. 1,2]
Manufacturer........: Coors Porcelain Co.
Material Designation: AD-995
Material Form.......: polycrystal
Composition.........: 99.5% Al_2O_3
(mass fraction)
Processing..........:

References:

[1] S. W. Freiman, K. R. McKinney, and H. L. Smith, "Slow Crack Growth in polycrystalline Ceramics" Fracture Mechanics of Ceramics, Vol. 2, pp. 659-676 (1974).

[2] L. M. Barker, "Short Rod K(Ic) Measurements of Al_2O_3" Fracture Mechanics of Ceramics, Vol. 3, pp. 483-493 (1973).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
4 [3-5]		3.7	19	AMDCB	air	Ref. 1; K_{Ic} obtained at a velocity of 10^{-4} m/s
17 [5-50]		4.08		SR	air	Ref. 2; E = 372 GPa

Al_2O_3 (AD-999)

Material Summary:

[Ref. 1,2,3,4,5,6]

Manufacturer........: Coors Porcelain Co.
Material Designation: AD-999
Material Form.......: polycrystal
Composition.........: 99.9% Al_2O_3
(mass fraction)
Processing..........: Sintered

References:

[1] L. A. Simpson, "Microstructural Considerations for the Application of Fracture Mechanics Techniques"
Fracture Mechanics of Ceramics, Vol. 2, pp. 567-577 (1974).
[2] G. R. Anstis, P. Chantikul, B. R. Lawn, and D. B. Marshall, "A Critical Evaluation of Indentation Techniques for Measuring Fracture Toughness: I, Direct Crack Measurements"
Journal of the American Ceramic Society, Vol. 64, No. 9, 533-538 (1981).
[3] L. M. Baker, "Short Rod K(Ic) Measurements of Al_2O_3"
Fracture Mechanics of Ceramics, Vol. 3, pp. 483-493 (1973).
[4] G. D. Swanson, "Fracture Energies of Ceramics"
Journal of the American Ceramic Society, Vol. 55, No. 1, 48-49 (1972).
[5] C.A. Tracy and G.D. Quinn, "Fracture Toughness by the Surface Crack in Flexure (SCF) Method," Ceramic Engineering and Science Proceedings, Vol. 15, pp. 837-845 (1994).
[6] R. J. Gettings and G. D. Quinn, "Surface Crack in Flexure (SCF) Measurements of the Fracture Toughness of Advanced Ceramics," Ceramic Engineering and Science Proceedings, Vol. 16, pp. 539-547 (1995)

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
3			19.7	SENB	air	Ref. 1
			19.05	DCB		
3		3.9		DCB		Ref. 2; *E* = 406 GPa
		3.32		ICS		*E* = 386 GPa
		3.09		IS		*E* = 386 GPa
3 [1-6]		3.12		SR		Ref. 3; *E* = 386 GPa
3			24.3	DCB		Ref. 4; *E* = 386 GPa
<10		3.6		SCF		Ref. 5; *E* = 401 GPa
		3.39		SCF	air	Ref. 6; *E* = 386 GPa, ν = 0.21, density = 3.96 g/cm^3

Al_2O_3 (AlSiMag 614)

Material Summary:

	[Ref. 1]	[Ref. 2]	[Ref. 3]	[Ref. 4]	[Ref. 5]
Manufacturer........:	Am. Lava Corp.	Am. Lav. Corp.	3M Co.	3M Co	3M Co.
Material Designation:	AlSiMag 614	AlSiMag 614	AlSiMag 614	AlSiMag 614	AlSiMag 614
Material Form.......:	polycrystal	polycrystal	polycrystal	polycrystal	polycrystal
Composition.........: (mass fraction)	96 % Al_2O_3	Al_2O_3	96% Al_2O_3	Al_2O_3	Al_2O_3
Processing..........:					

References:

[1] S.W. Freiman, K. R. McKinney, and H. L. Smith, "Slow Crack Growth in polycrystalline Ceramics" Fracture Mechanics of Ceramics, Vol. 2, 659-676 (1974).

[2] J. J. Mecholsky, S. W. Freiman, and R. W. Rice, "Fracture Surface Analysis of Ceramics" Journal of Materials Science, Vol. 11, pp. 1310-1319 (1976).

[3] G. K. Bansal, "Effects of Ceramic Microstructure on Strength and Fracture Surface Energy" Microstructures, pp. 860-871 (1976).

[4] D. Munz, R. T. Bubsey, and J. L. Shannon, "Fracture Toughness Determination of Al_2O_3 Using Four-Point-Bend Specimens with Straight-Through and Chevron Notches" Journal of the American Ceramic Society, Vol. 63, No. 5-6, pp. 300-305 (1980).

[5] D. K. Shetty, A. R. Rosenfield, and W. H. Duckworth, "Fracture Toughness of Ceramics Measured by a Chevron-Notch Diametral-Compression Test" Journal of the American Ceramic Society, Vol. 68, No. 12, pp. C-325-C-327 (1985).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
4 [2-12]		3.2	17	AMDCB	air	Ref. 1
2-40			20	AMDCB	air	Ref. 2; E = 300 GPa
5	5		23.2	SENB	air	Ref. 3; E = 318 GPa; hot pressed and sintered
10 [2-30]		3.49		CNB	air	Ref. 4; K_{Ic} calculated using Buhm's slice method
		3.3		CNDCT	drg N2	Ref. 5

Al_2O_3 (GMB-352)

Material Summary:

	[Ref. 1]
Manufacturer........:	Gladding McBean
Material Designation:	GMB-352
Material Form.......:	polycrystal
Composition.........: (mass fraction)	99.3% Al_2O_3
Processing..........:	

References:

[1] S.W. Freiman, K. R. McKinney, and H. L. Smith, "Slow Crack Growth in polycrystalline Ceramics" Fracture Mechanics of Ceramics, Vol. 2, 659-676 (1974).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [MPa·m$^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
20 [10-50]		4.7	32	AMDCB	air	K_{Ic} obtained at a velocity of 10^{-4} m/s

Al_2O_3 (GMB-395)

Material Summary:

	[Ref. 1]
Manufacturer........:	Gladding McBean
Material Designation:	GMB-395
Material Form.......:	polycrystal
Composition.........: (mass fraction)	95% Al_2O_3
Processing..........:	

References:

[1] S.W. Freiman, K. R. McKinney, and H. L. Smith, "Slow Crack Growth in polycrystalline Ceramics" Fracture Mechanics of Ceramics, Vol. 2, 659-676 (1974).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [MPa·m$^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
20 [10-50]		4.9	44	AMDCB	air	K_{Ic} obtained at a velocity of 10^{-4} m/s

Al_2O_3 (Lucalox)

Material Summary:

	[Ref. 1-5]
Manufacturer........:	GE
Material Designation:	Lucalox
Material Form.......:	polycrystal
Composition.........: (mass fraction)	99.9% Al_2O_3
Processing..........:	

References:

[1] S. W. Freiman, K. R. McKinney, and H. L. Smith, "Slow Crack Growth in polycrystalline Ceramics" Fracture Mechanics of Ceramics, Vol. 2, pp. 659-676 (1974).

[2] L. A. Simpson, "Microstructural Considerations for the Application of Fracture Mechanics Techniques" Fracture Mechanics of Ceramics, Vol. 2, pp. 567-577 (1974).

[3] P. L. Gutshall and G. E. Gross, "Obervations and Mechanisms of Fracture in polycrystalline Alumina" Engineering Fracture Mechanics, Vol. 1, pp. 463-471 (1969).

[4] G. D. Swanson and G. E. Gross, "Factor Analysis of Fracture-Toughness Test Parameters for Al_2O_3" Journal of the American Cermic Society, Vol. 54, No. 8, pp. 382-384 (1971).

[5] S. S. Smith and B. J. Pletka, "Indentation Fracture of single crystal and polycrystalline Aluminum Oxide" Fracture Mechanics of Ceramics, Vol. 6, pp. 189-209 (1983).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
35 [30-40]		4.1	22	AMDCB	air	Ref. 1; K_{Ic} obtained at a velocity of 10^{-4} m/s
35			20.3	SENB	air	Ref. 2
			32.1	DCB		
10			18	DCB	air	Ref. 3
30			27	DCB		
45			46	DCB		
10		3.38		DCB		Ref. 4
30		5.26		DCB		
18		5.25		ICS	air	Ref. 5; *E* = 354 GPa

Al_2O_3 (Lucalox-HS)

Material Summary:

[Ref. 1,2]

Manufacturer........: GE
Material Designation: Lucalox-HS
Material Form.......: polycrystal
Composition.........: 99.9% Al_2O_3
(mass fraction)
Processing..........:

References:

[1] S. W. Freiman, K. R. McKinney, and H. L. Smith, "Slow Crack Growth in polycrystalline Ceramics" Fracture Mechanics of Ceramics, Vol. 2, pp. 659-676 (1974).
[2] S. W. Freiman, private communication (1977).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
8 [6-10]		3.7	18	AMDCB	air	Ref. 1; as received
		5.0	32	AMDCB		after grain growth
						K_{Ic} was obtained using a velocity of 10^{-4} m/s; E = 393 GPa
10			21.9	AMDCB	air	Ref. 2

Al_2O_3 (McDanel 998)

Material Summary:

[Ref. 1]
Manufacturer........: McDanel Refractory Porcelain Co.
Material Designation: McDanel 998
Material Form.......: polycrystal
Composition.........: 99.8% Al_2O_3
(mass fraction)
Processing..........:

References:

[1] S. W. Freiman, K. R. McKinney, and H. L. Smith, "Slow Crack Growth in polycrystalline Ceramics" Fracture Mechanics of Ceramics, Vol. 2, pp. 659-676 (1974).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
20 [5-30]		4.9	35	AMDCB	air	K_{Ic} obtained at a velocity of 10^{-4} m/s

Al_2O_3 (Monofrax A)

Material Summary:

[Ref. 1]
Manufacturer........: Unknown
Material Designation: Monofrax A
Material Form.......: polycrystal
Composition.........: Al_2O_3
Processing..........:

References:

[1] S. W. Freiman, private communication (1977).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [MPa·m$^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
		2.47	13.25	AMDCB	air	E = 241 GPa

Al_2O_3 (Monofrax M)

Material Summary:

[Ref. 1]
Manufacturer........: Unknown
Material Designation: Monofrax M
Material Form.......: polycrystal
Composition.........: Al_2O_3
Processing..........:

References:

[1] S. W. Freiman, private communication (1977).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
400 [50-1000]		1.09	3.3	AMDCB	air	

Al_2O_3 (Vistal)

Material Summary:

	[Ref. 1]
Manufacturer........:	Coors Porcelain Co.
Material Designation:	Vistal
Material Form.......:	polycrystal
Composition.........: (mass fraction)	99.9% Al_2O_3
Processing..........:	

References:

[1] L. M. Barker, "Short Rod K(Ic) Measurements of Al_2O_3" Fracture Mechanics of Ceramics, Vol. 3, pp. 483-493 (1973).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
20 [15-45]		4.41		SR	air	E = 393 GPa

Al_2O_3 (XA16)

Material Summary:

	[Ref. 1,2,3]
Manufacturer:	Alcoa
Material Designation:	XA16
Material Form:	polycrystalline
Composition:	Al_2O_3
Processing:	Sintered at various temperatures and times.

References:

[1] L. A. Simpson, "Effect of Microstructure on Measurements of Fracture Energy of Al_2O_3" Journal of the American Ceramic Society, Vol. 56, No. 1, pp. 7-11 (1973).

[2] L. A. Simpson, "Microstructural Considerations for the Application of Fracture Mechanics Techniques" Fracture Mechanics of Ceramics, Vol. 2, pp. 567-577 (1974).

[3] A. G. Evans and G. Tappin, "Effects of Microstructure on the Stress to Propagate Inherent Flaws" Proceedings of the British Ceramic Society, No. 20, pp. 275-297 (1972).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
0.53	10		11.5(20)	WOF	air	Ref. 1; Connected porosity
			11.9(17)	SENB		
1.3	8		15.3(28)	SENB		
			15.8(15)	SENB		
			17.9(22)	WOF		
0.89	6		26.8(15)	SENB		
1.5	6		15(3)	WOF		
			22.5(20)	SENB		
1.8	6		27.1(41)	SENB		
1.3	5		31.4(83)	SENB		

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
3.3	5		22.7(31)	WOF	air	Ref. 1; Partially connected porosity
			22.6(10)	SENB		
4.1	5		23.1(14)	WOF		
			24.5(46)	SENB		
1.8	2.5		30	WOF(extrapolated)		
			22.2(9)	SENB		
1.9	2.5		26	WOF(extrapolated)		
			25.1(31)	SENB		
2.6	2.5		24.7(28)	SENB		
1.3	4.1		36.7(60)	SENB	air	Ref. 1; Closed porosity
1.3	2.9		35	WOF(extrapolated)		
			43.2(14)	SENB		
2.7	2.9		38.0(32)	SENB		
3.7	2.0		36.3(20)	SENB		
5.0	1.2		36.5(12)	SENB		
7.2	1.0		31.1(25)	SENB		
14.1	1.5		47.3(16)	WOF		
			30.0(28)	SENB		
15.6	4.0		38.9(28)	WOF		
17.8	3.0		38.6(44)	SENB		
18.5	1.5		39.6(31)	SENB		
22.8	3.5		36.2(20)	WOF		
			22.6(14)	SENB		
22.8	2.0		30.0(32)	SENB		

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
3			22.5(30)	SENB	air	Ref. 2
			20.8(11)	DCB		
20			21.1(20)	SENB		
			38.8(30)	DCB		
3	5		20(4)	SENB	air	Ref. 3
30	5		20(4)	SENB		
100	5		10(3)	SENB		
3	20		16(4)	SENB		
3	50		10(3)	SENB		

Mullite ($3Al_2O_3 \cdot 2SiO_2$)

Material Summary:

	[Ref. 1]	[Ref. 2,3,4,5,7]	[Ref. 6]
Manufacturer........:	Lehigh University	In laboratory	In laboratory
Material Designation:	mullite	mullite	mullite
Material Form.......:	polycrystal	polycrystal	polycrystal
Composition.........:	$3Al_2O_3 \cdot 2SiO_2$	$3Al_2O_3 \cdot 2SiO_2$	$3Al_2O_3 \cdot 2SiO_2$
Processing..........:		Sintered	Hot pressed

References:

[1] J. J. Mecholsky, S. W. Freiman, and R. W. Rice, "Fracture Surface Analysis of Ceramics" Journal of Materials Science, Vol. 11, pp. 1310-1319 (1976).

[2] S. Kanzaki and H. Tabata, "Sintering and Mechanical Properties of Mullite Derived Via Spray Pyrolysis," Ceramic Transactions, Vol. 6, pp. 339-351 (1990).

[3] S. Kanzaki, H. Tabata, T. Kumazawa, and S. Ohta, "Sintering and Mechanical Properties of Stoichiometric Mullite," Journal of the American Ceramic Society, Vol. 68, pp. C-6 - C-7 (1985).

[4] M.G.M.U. Ismail, Z. Nakai, and S. Somiya, "Microstructure and Mechanical Properties of Mullite Prepared by the Sol-Gel Method," Journal of the American Ceramic Society, Vol. 70, pp. C-7 - C-8 (1987).

[5] Y. Okamoto, H. Fukudome, K. Hayashi, and T. Nishikawa, "Creep Deformation of polycrystalline Mullite," Journal of the European Ceramic Society, Vol. 6, pp. 161-168 (1990).

[6] T. Mah and K.S. Mazdiyasni, "Mechanical Properties of Mullite," Journal of the American Ceramic Society, Vol. 66, pp. 699-703 (1983).

[7] M. I. Osendi and C. Baudin, "Mechanical Properties of Mullite Materials," Journal of the European Ceramic Society, Vol. 16, pp. 217-224 (1996).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
			11	AMDCB	air	Ref. 1; *E* = 222 GPa
		2.83		SENB	air	Ref. 2; 64 % Al_2O_3 mass fraction
		2.57		SENB		68 %
		2.62		SENB		70 %
		2.45		SENB		72 %
		2.69		SENB		74 %
		2.79		SENB		75 %
		2.48		SENB		78 %
	5	2.8		SENB	air	Ref. 3
		2.7		ICS	air	Ref. 4; 3.15 g/cm^3
		2.7		ICS	air	Ref. 5
		1.8		CF	air	Ref. 6
		2.5		SENB	air	Ref. 7; *E* = 200 GPa

Al_2TiO_5 (Aluminum Titanate)

Material Summary:

	[Ref. 1]
Manufacturer........:	Unknown
Material Designation:	aluminum titanate
Material Form.......:	polycrystal
Composition.........:	Al_2TiO_5; also written as $Al_2O_3 \cdot TiO_2$
Processing..........:	

References:

[1] J. Cleveland, M.Sc. Thesis, Pennsylvania State University (1977).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
5			2	WOF	air	
8			1	WOF		
12			1	WOF		
16			1	WOF		
25			1	WOF		

BaF_2 (Barium Fluoride)

Material Summary:

	[Ref. 1]
Manufacturer........:	Unknown
Material Designation:	barium fluoride
Material Form.......:	single crystal
Composition.........:	BaF_2
Processing..........:	

References:

[1] P. F. Becher and S. W. Freiman, "Crack Propagation in Alkaline-Earth Fluorides" Journal of Applied Physics, Vol. 49, No. 7, pp. 3779-3783 (1978).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
			0.35	AMDCB	air	Crack plane {111} and crack direction [110]

$BaO \cdot 6Fe_2O_3$ (Barium Ferrite)

Material Summary:

	[Ref. 1]
Manufacturer........:	Unknown
Material Designation:	barium ferrite
Material Form.......:	polycrystal
Composition.........:	$BaO \cdot 6Fe_2O_3$; also written as $BaFe_{12}O_{19}$
Processing..........:	

References:

[1] M. Iwasa, E. C. Liang, R. C. Bradt, and Y. Nakamura, "Fracture of Isotropic and Textured Ba Hexaferrite" Journal of the American Ceramic Society, Vol. 64, No. 7, 390-393 (1981).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
	5	0.96	2.82	CF	air	Intergranular fracture; E = 154 GPa
		1.57	6.35			Isotropic; E = 183 GPa
		2.83	11.92			Transgranular fracture; E = 317 GPa

$3BaO \cdot SiO_2$ (Barium Oxide Silicate)

Material Summary:

	[Ref. 1]
Manufacturer........:	NRL
Material Designation:	barium oxide silicate
Material Form.......:	polycrystal
Composition.........:	$3BaO \cdot SiO_2$
Processing..........:	

References:

[1] J. J. Mecholsky, S. W. Freiman, and R. W. Rice, "Fracture Surface Analysis of Ceramics' Journal of Materials Science, Vol. 11, pp. 1310-1319 (1976).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
[3-5]			17	AMBDC	air	Ref. 1; *E* = 90 GPa

$BaTiO_3$ (Barium Titanate)

Material Summary:

	[Ref. 1]	[Ref. 2,a]	[Ref. 2,b]
Manufacturer........:	Channel Indust.	Clevite Corp.	NRL
Material Designation:	barium titanate	barium titanate	barium titanate
Material Form.......:	polycrystal	polycrystal	polycrystal
Composition.........:	$BaTiO_3$	$BaTiO_3$	$BaTiO_3$
Processing..........:			

References:

[1] S. W. Freiman, K. R. McKinney, and H. L. Smith, "Slow Crack Growth in polycrystalline Ceramics" Fracture Mechanics of Ceramics, Vol. 2, pp. 659-676 (1974).

[2] J. J. Mecholosky, S. W. Freiman, and R. W. Rice, "Fracture Surface Analysis of Ceramics" Journal of Materials Science, Vol. 11, pp. 1310-1319 (1976).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa\cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
		1.05	4.5	AMDCB	air	Ref. 1; K_{Ic} obtained at a velocity of 10^{-4} m/s
5			5	AMDCB		Ref. 2a; E = 120 GPa
1-20			6	AMDCB		Ref. 2b; LiF and MgO are main impurities, and E = 120 GPa

B_4C (Boron Carbide)

Material Summary:

	[Ref. 1]	[Ref. 2]	[Ref. 3]	[Ref. 4]	[Ref. 5]
Manufacturer........:	Norton Co.	ESK	laboratory	laboratory	laboratory
Material Designation:	boron carbide	boron carbide	boron carbide	boron carbide	boron carbide
Material Form.......:	polycrystal	polycrystal	polycrystal	polycrystal	polycrystal
Composition.........:	B_4C	B_4C	B_4C	B_4C	B_4C
Processing..........:		Hot pressed	Hot pressed	Hot pressed	Hot pressed

	[Ref. 6]
Manufacturer........:	Ceradyne
Material Designation:	boron carbide
Material Form.......:	polycrystal
Composition.........:	B_4C
Processing..........:	Hot pressed

References:

[1] J. J. Mecholsky, S. W. Freiman, and R. W. Rice, "Fracture Surface Analysis of Ceramics" Journal of Materials Science, Vol. 11, pp. 1310-1319 (1976).

[2] G. De With, "High Temperature Fracture of Boron Carbide: Experiments and Simple Theoretical Models," Journal of Materials Science, Vol. 19, pp. 457-466 (1984).

[3] G.A. Gogotsi, Y.L. Groushevsky, O.B. Dashevskaya, Y.G. Gogotsi, and V.A. Lavrenko, "Complex Investigation of Hot-Pressed Boron Carbide," Journal of the Less-Common Metals, Vol. 117, pp. 225-230 (1986).

[4] G.W. Hollenberg and G. Walther, "The Elastic Modulus and Fracture of Boron Carbide," Journal of the American Ceramic Society, Vol. 63, pp. 610-613 (1980).

[5] W. F. Du and T. Watanabe, "High-Toughness B_4C-AlB_{12} Composites Prepared by Al Infiltration," Journal of the European Ceramic Society, Vol. 17, pp. 879-884 (1997).

[6] R. J. Gettings and G. D. Quinn, "Surface Crack in Flexure (SCF) Measurements of the Fracture Toughness of Advanced Ceramics," Ceramic Engineering and Science Proceedings, Vol. 16, pp. 539-547 (1995)

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
20			15	AMDCB	air	Ref. 1; E = 450 GPa
		3.7	11.8	SENB	air	Ref. 2
		3.2		SENB	air	Ref. 3
[2-7]	8	1.8	4.6	DT	air	Ref. 4
		4.2		ICS	air	Ref. 5
		3.08		SCF	air	Ref. 6; E = 455 GPa, density = 2.48 g/cm^3

BeO (Beryllia; beryllium oxide)

Material Summary:

	[Ref. 1]	[Ref. 2]	[Ref. 3]
Manufacturer........:	AERE Harwell	Unknown	Unknown
Material Designation:	beryllia	beryllia	beryllia
Material Form.......:	polycrystal	polycrystal	polycrystal
Composition.........: (mass fraction)	BeO	BeO	99.99% BeO
Processing..........:			

References:

[1] F. J. P. Clarke, H. G. Tattersall, and G. Tappin, "Toughness of Ceramics and their Work of Fracture" Proceedings of the British Ceramic Society, Vol. 6, pp. 163-172 (1966).
[2] S. Freiman, private communications (1977).
[3] P. L. Gutshall and G. E. Gross, "Fracture Energy of polycrystalline Beryllium Oxide" Journal of the American Ceramic Society, Vol. 51, No. 10, p. 602 (1968).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
5			15	WOF	air	Ref. 1
		3.68		AMDCB	air	Ref. 2
3			32.3	DCB	air	Ref. 3; E = 310 GPa

$Bi_{2-x}Pb_xSr_2Ca_2Cu_3O_{10+y}$ (Bi(Pb):2223)

Material Summary:

	[Ref. 1]	[Ref. 2]	[Ref. 3]
Manufacturer........:	Authors' laboratories	Authors' laboratories	Authors' laboratories
Material Designation:	Bi(Pb):2223	Bi(Pb):2223	Bi(Pb):2223
Material Form.......:	polycrystal	polycrystal	polycrystal
Composition.........:	$Bi_{1.2}Pb_{0.8}Sr_2Ca_2Cu_3O_{10+x}$	$Bi_{1.7}Pb_{0.3}Sr_2Ca_2Cu_3O_{10+x}$	$Bi_{1.8}Pb_{0.3}Sr_2Ca_{1.9}Cu_3O_{10+x}$
Processing..........:			

References:

[1] N. M. Alford, T. W. Button, and J. D. Birchall, "Processing, Properties and Devices in High-Tc Superconductors," Superconductor Science and Technology, Vol. 3, pp. 1-7 (1990).

[2] I. M. Low, H. Wang, and R. D. Skala, "Epoxy-Modified Bi(Pb)SrCaCuO Superconductors with Improved Mechanical Properties," Journal of Materials Science Letters, Vol. 14, pp. 384-386 (1995).

[3] Y. S. Yuan, M. S. Wong, and S. S. Wang, "Mechanical Behavior of Mg)-whisker Reinforced $(Bi,Pb)_2Sr_2Ca_2Cu_3O_y$ High-Temperature Superconducting Composite," Journal of Materials Research, Vol. 11, pp. 1645-1652 (1996).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
		1.3		SENB	air	Ref. 1
		0.3		SENB	air	Ref. 2
		2.6		SENB	air	Ref. 3

$Bi_2Sr_2CaCu_2O_{8+x}$ (Bi:2212)

Material Summary:

	[Ref. 1,a]	[Ref. 1,b]	[Ref. 2,3]
Manufacturer........:	Authors' laboratories	Authors' laboratories	Authors' laboratories
Material Designation:	Bi:2212	Bi:2212	Bi:2212
Material Form.......:	polycrystal	polycrystal	polycrystal
Composition.........:	$Bi_2Sr_2CaCu_2O_{8+x}$	$Bi_2Sr_2CaCu_2O_{8+x}$	$Bi_2Sr_2CaCu_2O_{8+x}$
Processing..........:	Hot isostatically pressed	Sinter forged	

References:

[1] C. Y. Chu, J. L. Routbort, N. Chen, A. C. Biondo, D. S. Kupperman, and K. C. Goretta, "Mechanical Properties and Texture of Dense polycrystalline $Bi_2Sr_2CaCu_2O_x$," Superconductor Science and Technology, Vol. 5, pp. 306-312 (1992).

[2] J. Joo, J. P. Singh, T. Warzynski, A. Grow, and R. B. Poeppel, "Role of Silver Addition on Mechanical and Superconducting Properties of High-Tc Superconductors," Applied Superconductivity, Vol. 2, pp. 401-410 (1994).

[3] L. J. Martin, K. C. Goretta, J. Joo, J. P. Sing, S. R. Olson, S. Wasylenko, R. B. Poeppel, and N. Chen, "Mechanical Properties of BiSrCaCuO/Ag Superconductors," Materials Letters, Vol. 17, pp. 232-236 (1993).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
		3.2		SENB	air	Ref. 1,a; notch perpendicular to pressing direction
		3.9		SENB	air	Ref. 1,a; notch parallel to pressing direction
		2.7		SENB	air	Ref. 1,b; notch perpendicular to pressing direction
		3.2		SENB	air	Ref. 1,b; notch parallel to pressing direction
	10	1.9		SENB	air	Ref. 2
	23	1.2		SENB	air	Ref. 3
	23	1.8		SENB	air	
	10	1.4		SENB	air	
	10	1.8		SENB	air	
	1	2.9		SENB	air	
	1	2.8		SENB	air	
	1	2.4		SENB	air	

BN(Boron Nitride, cubic)

Material Summary:

	[Ref. 1]
Manufacturer........:	In laboratory
Material Designation:	cubic boron nitride
Material Form.......:	polycrystal
Composition.........:	BN
Processing..........:	High pressure, high temperature synthesis

References:

[1] T. Taniguchi, M. Akaishi, and S. Yamaoka, "Mechanical Properties of Polycrystalline Translucent Cubic Boron Nitride as Characterized by the Vickers Indentation Method," Journal of the American Ceramic Society, Vol. 79, pp. 547-549 (1996).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
3 [2-5]		5.0		ICS	air	*H/E* = 0.08

CaF_2 (calcium fluoride; fluorspar)

Material Summary:

	[Ref. 1a]	[Ref. 1b]	[Ref. 1c, 2]
Manufacturer........:	Unknown	Harshaw Co.	Eastman Kodak Co.
Material Designation:	calcium fluoride	calcium fluoride	calcium fluoride
Material Form.......:	single crystal	polycrystal	single crystal
Composition.........:	CaF_2		
Processing..........:		Hot worked	Hot pressed

References:

[1] P. F. Becher and S. W. Freiman, "Crack Propagation in Alkaline-Earth Fluorides" Journal of Applied Physics, Vol. 49, No. 7, pp. 3779-3783 (1978).

[2] R. W. Rice, S. W. Freiman, and J. J. Mecholsky, "The Dependence of Strength-Controlling Fracture Energy on the Flaw-Size to Grain-Size Ratio" Journal of the American Ceramic Society, Vol. 63, No. 3-4, pp. 129-136 (1980).

Property Table:

Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
			0.51	AMDCB	air	Ref. 1a Crack plane {111} and crack direction [1$\bar{1}$c]
			0.51	AMDCB		Ref. 1a Crack plane {111} crack direction [1$\bar{1}$c]; ^{12}Eu impurity
			0.80	AMDCB		Ref. 1a Material unannealed; crack plane {111}, crack direction [112]
			0.52	AMDCB		1,a Material annealed; crack plane {111}, crack direction [112]
			1.6	AMDCB		Ref. 1b; crack plane {111}
50-100			3.6	AMDCB		Ref. 1c; crack plane {111}
75	0.1		3.3	AMDCB	air	Ref. 2

Cervit 126 (Unknown Composition)

Material Summary:

	[Ref. 1]
Manufacturer........:	Owens Illinois
Material Designation:	Cervit 126
Material Form.......:	polycrystal
Composition.........:	Unknown
Processing..........:	

References:

[1] J. J. Mecholsky, S. W. Freiman, and R. W. Rice, "Fracture Surface Analysis of Ceramics" Journal of Materials Science, Vol. 11, pp. 1310-1319 (1976).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
1			17	AMDCB	air	E = 92 GPa

Diamond (C)

Material Summary:

	[Ref. 1]	[Ref. 2]
Manufacturer........:	In laboratory	Natural specimen
Material Designation:	diamond (CVD)	diamond
Material Form.......:	polycrystal	single crystal
Composition.........:	C [diamond]	C [diamond]
Processing..........:	Chemical vapor deposition	Natural specimen

References:

[1] M. D. Drory, C. F. Gardinier, and J. S. Speck, "Fracture Toughness of Chemically Vapor-Deposited Diamond," Journal of the American Ceramic Society, Vol. 74, pp. 3148-3150 (1991).

[2] N. V. Novikov and S. N. Dub, "Hardness and Fracture Toughness of CVD Diamond Film," Diamond and Related Materials, Vol. 5, pp. 1026-1030 (1996).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
		5.3		ICS	air	Ref. 1; E = 1000 GPa; H = 81 GPa
		14.0		ICS	air	Ref. 2; Indent diagonal parallel to <011>
		6.6		ICS	air	Indent diagonal parallel to <001>
		6.7		ICS	air	Radial cracks along (111) planes

FeO (Iron Oxide)

Material Summary:

	[Ref. 1]
Manufacturer........:	Unknown
Material Designation:	iron oxide; also known as ferrous oxide
Material Form.......:	polycrystal
Composition.........:	$Fe_{0.94}O$
Processing..........:	

References:

[1] M. I. Mendelson and M. E. Fine, "Fracture of Wustite and Wustite-Fe_3O_4-5v/o Fe Versus Grain Size" Fracture Mechanics of Ceramics, Vol. 2, pp. 527-539 (1974).

Property Table:

Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
9 [8-12]			8.1	DCB	air	All specimens were rapidly cooled from about 600 °C after pressure sintering to retain the metastable wustite phase.
21 [16-27]			6.8	DCB		
38 [33-44]			7.5	DCB		
58 [56-60]			8.2	DCB		
71 [65-76]			7.1	DCB		
88 [86-95]			7.6	DCB		

Fe_2O_3-Ni-Zn (Nickel Zinc Ferrite)

Material Summary:

	[Ref. 1]
Manufacturer........:	Unknown
Material Designation:	nickel zinc ferrite
Material Form.......:	polycrystal
Composition.........:	Ni-Zn-Fe_2O_3
Processing..........:	

References:

[1] G. De With and N. Hattu, "On the Use of Small Specimens in the Measurement of the Fracture Toughness for Brittle Materials" Journal of Materials Science Letters, Vol. 16, 1702-1704 (1981).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
6		1.36		SENB	air	Specimen size: 3 mm x 9 mm x 45 mm
		1.42		SENB		Specimen size: 1 mm x 3 mm x 15 mm

Fe_2O_3-Mn-Zn (Manganese Zinc Ferrite)

Material Summary:

	[Ref. 1]
Manufacturer........:	Unknown
Material Designation:	manganese zinc ferrite
Material Form.......:	polycrystal
Composition.........:	Mn-Zn-Fe_2O_3
Processing..........:	

References:

[1] G. De With and N. Hattu, "On the Use of Small Specimens in the Measurement of the Fracture Toughness for Brittle Materials" Journal of Materials Science Letters, Vol. 16, 1702-1704 (1981).

Property Table:

Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
18		1.54		SENB	air	Specimen size: 3 mm x 9 mm x 45 mm
		1.40		SENB		Specimen size: 1 mm x 3 mm x 15 mm
12		1.52		SENB		Specimen size: 3 mm x 9 mm x 45 mm
		1.50		SENB		Specimen size: 1 mm x 3 mm x 15 mm

$SrO \cdot 6Fe_2O_3$ (Strontium Ferrite)

Material Summary:

	[Ref. 1]
Manufacturer........:	Unknown
Material Designation:	strontium ferrite
Material Form.......:	polycrystal
Composition.........:	$SrO \cdot 6Fe_2O_3$; also written as $SrFe_{12}O_{19}$
Processing..........:	

References:

[1] G. De With and N. Hattu, "On the Use of Small Specimens in the Measurement of the Fracture Toughness for Brittle Materials" Journal of Materials Science Letters, Vol. 16, 1702-1704 (1981).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
1		1.80		SENB	H_2O	Specimen size: 3 mm x 9 mm x 45 mm
		1.71		SENB		Specimen size: 1 mm x 3 mm x 15 mm

GaN (Gallium Nitride)

Material Summary:

[Ref. 1]
Manufacturer........: In laboratory
Material Designation: gallium nitride
Material Form.......: single crystal
Composition.........: GaN
Processing..........: Crystal growth

References:

[1] M. D. Drory, J. W. Ager, T. Suski, I. Grzegory, and S. Porowski, "Hardness and Fracture Toughness of Bulk Single Crystal Gallium Nitride," Applied Physics Letters, Vol. 69, pp. 4044-4046 (1996).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
		0.8		ICS	air	Single crystal

$Gd_3Ga_5O_{12}$ (Gadolinium Gallium Garnet)

Material Summary:

	[Ref. 1]
Manufacturer........:	Unknown
Material Designation:	gadolinium gallium garnet
Material Form.......:	polycrystal
Composition.........:	$Gd_3Ga_5O_{12}$
Processing..........:	

References:

[1] M. Pardavi-Horvath, "Microhardness and Brittle Fracture of Garnet single crystals" Journal of Materials Science, Vol. 19, pp. 1159-1170 (1984).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
		1.2		ICS	air	K_{Ic} is an average for 5 crystal growth conditions

Graphite (C)

Material Summary:

[Ref. 1]

Manufacturer........: Poco Graphite Inc.
Material Designation: Graphite
Material Form.......: polycrystal
Composition.........: C [graphite]
Processing..........:

References:

[1] J. J. Mecholsky, S. W. Freiman, and R. W. Rice, "Fracture Surface Analysis of Ceramics" Journal of Materials Science, Vol. 11, pp. 1310-1319 (1976).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
8			85	AMDCB	air	E = 12 GPa

Graphite (HPD-1; C)

Material Summary:

[Ref. 1]
Manufacturer........: Poco Graphite Inc.
Material Designation: HPD-1
Material Form.......: polycrystal
Composition.........: C [graphite]
Processing..........:

References:

[1] G. D. Swanson, "Fracture Energies of Ceramics"
Journal of the American Ceramic Society, Vol. 55, No. 1, pp. 48-49 (1972).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa\cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
			68.1	DCB	air	E = 14.7 GPa

KCl (Potassium Chloride)

Material Summary:

	[Ref. 1]
Manufacturer........:	Unknown
Material Designation:	potassium chloride
Material Form.......:	single crystal
Composition.........:	KCl
Processing..........:	

References:

[1] S. W. Freiman, P. F. Becher, and P. H. Klein, "Initiation of Crack Propagation in KCL" The Philosophical Magazine, Vol. 31, No. 4, pp. 829-837 (1975).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
			0.14	AMDCB	air	Loading rate = 5 cm/min
			0.27	AMDCB		Loading rate = 2 cm/min

$Li_2O \cdot 2SiO_2$ (Lithium Silicate Glass)

Material Summary:

	[Ref. 1]
Manufacturer........:	NRL
Material Designation:	lithium silicate glass
Material Form.......:	polycrystal
Composition.........:	$Li_2O \cdot 2SiO_2$
Processing..........:	

References:

[1] J. J. Mecholsky, S. W. Freiman, and R. W. Rice, "Fracture Surface Analysis of Ceramics" Journal of Materials Science, Vol. 11, pp. 1310-1319 (1976).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
10-20			95	AMDCB	air	E = 90 GPa
10-20			34	AMDCB		E = 90 GPa

$MgO \cdot xAl_2O_3$ (Magnesium Aluminate Spinel)

Material Summary:

	[Ref. 1,2,3a]	[Ref. 3b]	[Ref. 4,5,7]	[Ref. 6]
Manufacturer........:	Unknown	Unknown	Unknown	Hrand Djevahirdijian Ltd.
Material Designation:	magnesium aluminate	magnesium aluminate	magnesium aluminate	magnesium aluminate
Material Form.......:	polycrystal	polycrystal	single crystal	single crystal
Composition.........: (mass fraction)	$MgAl_2O_4$; also $MgO \cdot Al_2O_3$	$MgAl_2O_4$ +0.01% $CaZrO_4$	$MgAl_2O_4$	$MgO \cdot 3.5Al_2O_3$ (nonstoichiometric)
Processing..........:				

	[Ref. 8]
Manufacturer........:	In laboratory
Material Designation:	magnesium aluminate
Material Form.......:	polycrystal
Composition.........:	$MgAl_2O_4$
Processing..........:	Sintered

References:

[1] R. W. Rice, S. W. Freiman, and P. F. Becher, "Grain-Size Dependence of Fracture Energy in Ceramics: I, Experiment" Journal of the American Ceramic Society, Vol. 64, No. 6, pp. 345-350 (1981).

[2] R. L. Stewart and R. C. Bradt, "Fracture of polycrystalline $MgAl_2O_4$" Journal of the American Ceramic Society, Vol. 63, No. 11-12, pp. 619-623 (1980).

[3] G. D. Swanson, "Fracture Energies of Ceramics" Journal of the American Ceramic Society, Vol. 55, No. 1, pp. 48-49 (1972).

[4] R. L. Stewart and R. C. Bradt, "Fracture of single crystal $MgAl_2O_4$" Journal of Materials Science, Vol. 15, 67-72 (1980).

[5] A. G. Evans and E. A. Charles, "Fracture Toughness Determinations by Indentation" Journal of the American Ceramic Society, Vol. 59, No. 7-8, pp. 371-372 (1985).

[6] G. K. Bansal and A. H. Heuer, "Precipitation Strengthening in Non-Stoichiometric Mg-Al Spinel" Fracture Mechanics of Ceramics, Vol. 2, pp. 677-690 (1973).

[7] R. W. Rice, C. C. Wu, and K. R. McKinney, "Fracture and Fracture Toughness of Stoichiometric $MgAl_2O_4$ Crystals at Room Temperature," Journal of Materials Science, Vol. 31, pp. 1353-1360 (1996).

[8] C. Baudin, R. Martinez, and P. Pena, "High-Temperature Mechanical Behavior of Stoichiometric Magnesium Spinel," Journal of the American Ceramic Society, Vol. 78, pp. 1857-1862 (1995).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [MPa·m$^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
1.5			8	AMDCB	air	Ref. 1
2			7.5	AMDCB		
6			8	AMDCB		
100			7	AMDCB		
5		1.94		CF	air	Ref. 2; Material was hot pressed, and E = 258 GPa
12		1.98		CF		
25		1.83		CF		
38		1.97		CF		
0.3			10.4	DCB	air	Ref. 3a; E = 241 GPa
0.3			11.2	DCB		3b; E = 241 GPa
6			16.9	DCB		3a; E = 241 GPa
6			9.1	DCB		3b; E = 241 GPa
		1.18		CF		Ref. 4; {100} crack plane
		1.54		CF		{110} crack plane
		1.90		CF		{111} crack plane
		1.3		ICS	dry N2	Ref. 5; H = 16.0 GPa
		1.5		DT	toluene	Ref. 6; Plates with faces parallel to {100} spinel planes
		1.0		DCB	air	Ref. 7; {100} surface; <100> axis
		1.7		DCB	air	{100} surface; <110> axis
		1.6		DCB	air	{110} surface; <110> axis
		1.2		DCB	air	{111} surface; <110> axis
1.5		3.0		SENB	air	Ref. 8; density = 3.491 g/cm^3 E = 258 GPa

MgF_2 (Magnesium Fluoride)

Material Summary:

	[Ref. 1]	[Ref. 2]
Manufacturer........:	Kodak	unknown
Material Designation:	magnesium fluoride	magnesium fluoride
Material Form.......:	polycrystal	polycrystal
Composition.........:	MgF_2	MgF_2
Processing..........:		Hot pressed

References:

[1] J. J. Mecholsky, S. W. Freiman, and R. W. Rice, "Fracture Surface Analysis of Ceramics" Journal of Materials Science, Vol. 11, pp. 1310-1319 (1976).

[2] G. D. Quinn, J. J. Swab, and M. D. Hill, "Fracture Toughness by the Surface Crack in Flexure (SCF) Method: New Test Results," Ceramic Engineering and Science Proceedings, Vol. 18 (4), pp. 163-172 (1997).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
1			4	AMDCB	air	Ref. 1; E = 110 GPa
		0.98		SCF	air	Ref. 2; density = 3.18 g/cm^3

MgO (Magnesium Oxide)

Material Summary:

	[Ref. 1,a]	[Ref. 1,b]	[Ref. 2,3]	[Ref. 4]
Manufacturer........:	Thermal Syndicate Ltd.	Eastman Kodak	Unknown	Norton
Material Designation:	magnesium oxide	magnesium oxide	magnesium oxide	magnesium oxide
Material Form.......:	polycrystal	polycrystal	polycrystal	single crystal
Composition.........:	MgO	MgO	MgO	MgO
Processing..........:				

	[Ref. 5]
Manufacturer........:	In laboratory
Material Designation:	magnesium oxide
Material Form.......:	polycrystal
Composition.........:	MgO
Processing..........:	Hot pressed

References:

[1] F. J. P. Clarke, H. G. Tattersall, and G. Tappin, "Toughness of Ceramics and Their Work of Fracture" Proceedings of the British Ceramic Society, Vol. 6, 163-172 (1966).

[2] R. W. Rice, S. W. Freiman, and P. F. Becher, "Grain-Size Dependence of Fracture Energy in Ceramics: I, Experiment" Journal of the American Ceramic Society, Vol. 64, No. 6, pp. 345-350 (1981).

[3] J. B. Kessler, J. E. Ritter, and R. W. Rice, "The Effects of Microstructure on the Fracture Energy of Hot Pressed MgO" Surface and Interface of Glasses and Ceramics", pp. 529-544 (1974).

[4] J. J. Mecholsky, S. W. Freiman, and R. W. Rice, "Fracture Surface Analysis of Ceramics" Journal of Materials Science, 11, pp. 1310-1319 (1976).

[5] K. Yasuda, S. D. Kim, Y. Kanemichi, Y. Matsuo, and S. Kimura, "Influence of Grain Size and Temperature On Fracture Toughness of MgO Sintered Bodies," Journal of the Ceramic Society of Japan, Int. Edition, Vol. 98, pp. 44-49 (1990).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
10			16	WOF	air	Ref. 1,a
50			19.5	WOF		1,a
100			35	WOF		1,a
7			4.2	WOF		1,b
13			8.9	WOF		1,a
23			16	WOF		1,a
38			17	WOF		1,b
130			14	WOF		1,a
150			7.9	WOF		1,a
1			6	AMDCB	air	Ref. 2
10			18	AMDCB		
15			14	AMDCB		
30			4	AMDCB		
75			11	AMDCB		
6			0.95	WOF	air	Ref. 3; Up to 1.0% porosity
13			0.9	WOF		Up to 1.0% porosity
30			22	WOF		Up to 1.0% porosity
55			21	WOF		Up to 1.0% porosity

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
95			29	WOF		Up to 1.0% porosity
10			11	WOF		Less than 0.1% porosity
100			11	WOF		Less than 0.1% porosity
			3	AMDCB	air	Ref. 4; {100} plane; E = 280 GPa
10		1.8		CNB	air	Ref. 5
28		1.6		CNB		
58		1.3		CNB		
90		2.0		CNB		
139		1.9		CNB		
188		2.0		CNB		

$MgTi_2O_5$ (Magnesium Dititanate)

Material Summary:

	[Ref. 1]
Manufacturer........:	Unknown
Material Designation:	magnesium dititanate
Material Form.......:	polycrystal
Composition.........:	$MgTi_2O_5$
Processing..........:	

References:

[1] J. A. Kuszyk and R. C. Bradt, "Influence of Grain Size on Effects of Thermal Expansion Anisotropy in $MgTi_2O_5$" Journal of the American Ceramic Society, Vol. 56, No. 8, pp. 420-423 (1973).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
1			11	WOF	air	E = 241 GPa
5			33	WOF		E = 72 GPa
9			39	WOF		E = 55 GPa
15			35	WOF		E = 48 GPa
25			35	WOF		E = 35 GPa
48			34	WOF		E = 29 GPa
76			25	WOF		---

Pyroceram 9606 (Unknown Composition)

Material Summary:

[Ref. 1,2,3,4,5,6]
Manufacturer........: Corning Glass
Material Designation: Pyroceram 9606
Material Form.......: polycrystal
Composition.........: Unknown
Processing..........:

References:

[1] G. R. Anstis, P. Chantikul, B. R. Lawn, and D. B. Marshall, "A Critical Evaluation of Indentation Techniques for Measuring Fracture Toughness: I, Direct Crack Measurements" Journal of the American Ceramic Society, Vol. 64, No. 9, pp. 533-538 (1981).
[2] T. T. Shih, "An Evaluation of the Chevron V-Notched Bend Bar Fracture Toughness Specimen" Engineering Fracture Mechanics, Vol. 14, No. 4, pp. 821-832 (1981).
[3] D. K. Shetty, A. R. Rosenfield, and W. H. Duckworth, "Fracture Toughness of Ceramics Measured by a Chevron-Notch Diametral-Compression Test" Journal of the American Ceramic Society, Vol. 68, No. 12, pp. C-325-C-327 (1985).
[4] D. K. Shetty, A. R. Rosenfield, and W. H. Dockworth, "Indenter Flaw Geometry and Fracture Toughness Estimates for a Glass-Ceramic" Journal of the American Ceramic Society, Vol. 68, No. 10, pp. C-282-C-284 (1985).
[5] G. K. Bansal, "Effects of Ceramic Microstructure on Strength and Fracture Surface Energy" Ceramic Microstructures, pp. 860-871 (1976).
[6] G. D. Quinn, J. J. Swab, and M. D. Hill, "Fracture Toughness by the Surface Crack in Flexure (SCF) Method: New Test Results," Ceramic Engineering and Science Proceedings, Vol. 18 (4), pp. 163-172 (1997).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
		2.5		DCB	air	Ref. 1; E = 108 GPa
		3.17		ICS		E = 120 GPa
		2.69		IS		E = 120 GPa
		2.14		CNB	air	Ref. 2
		2.07		CNDC	dry N2	Ref. 3
		2.8		ICS	air	Ref. 4
		2.5		IS		
2			24.8	SENB	air	Ref. 5; E = 114 GPa
		2.25		SCF	air	Ref. 6; E = 132 GPa; density = 2.59 g/cm^3

PZT (Lead Zirconate Titanate; $PbZr_xTi_yO_3$)

Material Summary:

	[Ref. 1]	[Ref. 2,3]	[Ref. 4]
Manufacturer........:	Channel Ind.	Unknown	Morgan
Material Designation:	Lead Zirconate Titanate (PZT)	Lead Zirconate Titanate (PZT)	Lead Zirconate Titanate
Material Form.......:	polycrystal	polycrystal	polycrystal
Composition.........:	$PbZr_xTi_yO_3$	$PbZr_xTi_yO_3$	$PbZr_xTi_yO_3$
Processing..........:			

References:

[1] J. J. Mecholsky, S. W. Freiman, and R. W. Rice, "Fracture Surface Analysis of Ceramics" Journal of Materials Science, Vol. 11, 1310-1319 (1976).
[2] J. B. Bruce and B. G. Koepke, "Evaluation of K(Ic) by the Double-Torsion Technique" Journal of the American Ceramic Society, Vol. 60, No. 5-6, pp. 284-285 (1977).
[3] G. G. Pisarenko, V. M. Chushko, and S. P. Kovalev, "Anisotropy of Fracture Toughness of Piezoelectric Ceramics" Journal of the American Ceramic Society, Vol. 68, No. 5, 259-265 (1985).
[4] G. D. Quinn, J. J. Swab, and M. D. Hill, "Fracture Toughness by the Surface Crack in Flexure (SCF) Method: New Test Results," Ceramic Engineering and Science Proceedings, Vol. 18 (4), pp. 163-172 (1997).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
5			4	AMDCB	air	Ref. 1; *E* = 80 GPa
		0.81		DT	toluene	Ref. 2
		0.76		DT	air	
5		1.35 1.50		DT ICS	air; 70%-80% relative humidity	Ref. 3; Ba doped; crack plane = rz
5		0.70		ICS		Ba doped; crack plane = xy
6		1.82		ICS		Nb doped; crack plane = rz
6		0.77		ICS		Nb doped; crack plane = xy
4		1.52		DT		W doped; crack plane = rz
4		1.38		DT		W doped and crack plane = xy
		1.08 0.88		SCF SCF	air	Ref. 4; poled; E = 140 GPa; depoled; density = 7.58 g/cm^3

Si (Silicon)

Material Summary:

	[Ref. 1]	[Ref. 2]
Manufacturer........:	Texas Instruments	Unknown
Material Designation:	silicon	silicon
Material Form.......:	single crystal	single crystal
Composition.........:	Si	Si
Processing..........:		

References:

[1] G. R. Anstis, P. Chantikul, B. R. Lawn, and D. B. Marshall, "A Critical Evaluation of Indentation Techniques for Measuring Fracture Toughness: I, Direct Crack Measurements", Journal of the American Ceramic Society, Vol. 64, No. 9, pp. 533-538 (1981)

[2] C. St. John, "The Brittle-To-Ductile Transition in Pre-Cleaved Silicon Single Crystals", Philosophical Magazine, Vol. 32, pp. 1194-1212, (1975).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
		0.79 0.95		ICS IS	air	Ref. 1; E = 168 GPa
			2.7	TDCB	air	Ref. 2; The crystal was boron doped (P type)

Sialon ($Si_{6-x}Al_xO_xN_{8-x}$)

Material Summary:

	[Ref. 1]	[Ref. 2]	[Ref. 3]
Manufacturer........:	In laboratory	In laboratory	In laboratory
Material Designation:	sialon	sialon	sialon
Material Form.......:	polycrystal	polycrystal	polycrystal
Composition.........: (mass fraction)	$Si_{6-x}Al_xO_xN_{8-x}$ $Si_{6-x}Al_xO_xN_{8-x}$	$Si_{6-x}Al_xO_xN_{8-x}$ + 1 % Y_2O_3	
Processing..........:	Hot isostatic pressed and sintered	Hot isostatic pressed and sintered	Hot pressed

	[Ref. 4]	[Ref. 5]
Manufacturer........:	In laboratory	In laboratory
Material Designation:	sialon (x-phase)	sialon
Material Form.......:	polycrystal	polycrystal
Composition.........:	$Si_{6-x}Al_xO_xN_{8-x}$ $Si_{6-x}Al_xO_xN_{8-x}$	
Processing..........:	Sintered	Sintered

References:

[1] T. Ekstrom and P.O. Olsson, "Beta-Sialon Ceramics Prepared at 1700 °C by Hot Isostatic Pressing," Journal of the American Ceramic Society, Vol. 72, pp. 1722-1724 (1989).

[2] T. Ekstrom, P.O. Kall, M. Nygren, and P.O. Olsson, "Dense Single-Phase Beta-Sialon Ceramics by Glass-Encapsulated Hot Isostatic Pressing," Journal of Materials Science, Vol. 24, pp. 1853-1862 (1989).

[3] K. Kishi, S. Umebayashi, and E. Tani, "Influence of Microstructure on Strength and Fracture Toughness of Beta-Sialon," Journal of Materials Science, Vol. 25, pp. 2780-2784 (1990).

[4] C. C. Anya and A. Hendry, "Hardness, Indentation Fracture Toughness, and Compositional Formula of X-Phase Sialon," Journal of Materials Science, Vol. 29, PP. 527-533 (1994).

[5] J. Piekarczyk, J. Lis, and J. Bialoskorski, "Elastic Properties, Hardness, and Indentation Fracture Toughness of β-Sialons," Key Engineering Materials, Vol. 89-91, pp. 541-546 (1994).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
		3.05		ICS	air	Ref. 1; 0.1 = x of Al_x; 3.16 g/cm^3
		2.90		ICS		0.5 = x of Al_x; 3.14 g/cm^3
		2.75		ICS		1.0 = x of Al_x; 3.10 g/cm^3
		2.70		ICS		1.4 = x of Al_x; 3.09 g/cm^3
		2.65		ICS		1.75 = x of Al_x; 3.06 g/cm^3
		3.15		ICS		2.0 = x of Al_x; 3.14 g/cm^3
		3.75		ICS		2.25 = x of Al_x; 3.29 g/cm^3
		3.80		ICS	air	Ref. 2; 0.25 = x of Al_x; 3.18 g/cm^3
		3.72		ICS		0.35 = x of Al_x; 3.17 g/cm^3
		3.52		ICS		0.50 = x of Al_x; 3.16 g/cm^3
		3.44		ICS		0.75 = x of Al_x; 3.16 g/cm^3
		3.26		ICS		1.50 = x of Al_x; 3.13 g/cm^3
		2.99		ICS		2.00 = x of Al_x; 3.11 g/cm^3
		2.79		ICS		3.00 = x of Al_x; 3.08 g/cm^3
		3.00		ICS		4.00 = x of Al_x; 3.08 g/cm^3
		3.18		ICS		4.20 = x of Al_x; 3.14 g/cm^3
		3.66		ICS		4.50 = x of Al_x; 3.22 g/cm^3
		3.2		ICS	air	Ref. 3; 0.5 = x of Al_x; 3.14 g/cm^3
1.6		3.3		ICS	air	Ref. 4; density = 3.01 g/cm^3
2.0		3.5		ICS		density = 3.11 g/cm^3
2.7		3.1		ICS		density = 3.01 g/cm^3
		4.65	87.9	ICS	air	Ref. 5; 1 = x of Al_x; 3.09 g/cm^3 H/E = 0.055
		3.42	55.4	ICS		2 = x of Al_x; 3.05 g/cm^3 H/E = 0.054
		3.38	56.0	ICS		3 = x of Al_x; 3.06 g/cm^3 H/E = 0.058
		3.29	60.5	ICS		4 = x of Al_x; 3.00 g/cm^3 H/E = 0.065

SiC (Silicon Carbide)

Material Summary:

	[Ref. 1,a, 2]	[Ref. 1,b]	[Ref. 3,4,6]	[Ref. 5]
Manufacturer........:	UKAEA Springfields Lab.	Carborundum Co.	Unknown	Unknown
Material Designation:	silicon carbide	silicon carbide	silicon carbide	silicon carbide
Material Form.......:	polycrystal	polycrystal	polycrystal	single crystal
Composition.........:	SiC	SiC	SiC	SiC
Processing..........:				

	[Ref. 7,a]	[Ref. 7,b]
Manufacturer........:	Norton Co.	General Electric
Material Designation:	silicon carbide	silicon carbide
Material Form.......:	polycrystal	polycrystal
Composition.........:	SiC	SiC
Processing..........:		

References:

[1] L. A. Simpson, "Microstructural Considerations for the Application of Fracture Mechanics Techniques" Fracture Mechanics of Ceramics, Vol. 2, pp. 567-577 (1974).

[2] J. R. McLaren, G. Tappin, and R. W. Davidge, "The Relationship Between Temperature and Environment, Texture and Strength of Self-Bonded Silicon Carbide" Proceedings of the British Ceramic Society, No. 20, pp. 259-274 (1972).

[3] R. B. Matthews, W. G. Hutchings, and F. Havelock, "A Relation Between Fracture and Flaws in Reaction-Bonded Silicon Carbide" Journal of the Canadian Ceramic Society, Vol. 42, pp. 1-9 (1973).

[4] R. W. Rice, S. W. Freiman, and P. F. Becher, "Grain-Size Dependence of Fracture Energy in Ceramics: I, Experiment" Journal of the American Ceramic Society, Vol. 64, No. 6, pp. 345-350 (1981).

[5] J. L. Henshall, D. J. Rowcliffe, and J. W. Edington, "Fracture Toughness of Single-Crystal Silicon Carbide" Journal of the American Ceramic Society, Vol. 60, No. 7-8, pp. 373-375 (1977).

[6] G. D. Swanson, "Fracture Energies of Ceramics" Journal of the American Ceramic Society, Vol. 55, No. 1, 48-49 (1972).

[7] A. G. Evans and E. A. Charles, "Fracture Toughness Determinations by Indentation" Journal of the American Ceramic Society, Vol. 59, No. 7-8, pp. 371-372 (1976).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [MPa·m$^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
20			25.6	SENB	air	Ref. 1,a
			15.4	DCB		1,a
100			15.2	SENB	air	1,b
			22.3	DCB		1,b
			27	SENB	argon	Ref. 2; A starter crack was used, and E = 410 GPa
20			15	DCB	air	Ref. 3
100			22	DCB		
36			20	AMDCB	air	Ref. 4
11			22	AMDCB		
21			25.5	AMDCB		
22			18	AMDCB		
37			25	AMDCB		
54			20	AMDCB		
120			22	AMDCB		
120			16	AMDCB		
		3.3		SENB	air	Ref. 5; Notch plane (1120) crack direction [1100]
40			32.4	DCB	air	Ref. 6; E = 335 GPa
		4.0		ICS	dry N2	Ref. 7,a; Hot-pressed with Al_2O_3 H = 19.3 GPa; ν = 0.22
		3.1		ICS		7,b; H = 21 GPa; ν = 0.2

SiC (Beta Silicon Carbide)

Material Summary:

	[Ref. 1]
Manufacturer........:	General Electric Co.
Material Designation:	beta silicon carbide
Material Form.......:	polycrystal
Composition.........:	SiC
Processing..........:	Sintered

References:

[1] M.J. Slavin and G.D. Quinn, "Mechanical Property Evaluation at Elevated Temperature of Sintered beta-Silicon Carbide," International Journal of High Technology Ceramics, Vol. 2, pp. 47-63 (1986).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
	4.1	2.8		ICS	air	Ref. 1; 3.08 g/cm^3 E = 395 GPa; H = 23.9 GPa

SiC (CVD Silicon Carbide)

Material Summary:

	[Ref. 1]
Manufacturer........:	Composites and Deposits
Material Designation:	CVD silicon carbide
Material Form.......:	polycrystal
Composition.........:	SiC
Processing..........:	

References:

[1] S. W. Freiman, A. Williams, J. J. Mecholsky, and R. W. Rice, "Fracture of Si_3N_4 and SiC" Ceramic Microstructures, pp. 824-834 (1976).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
1-3			16	AMDCB	air	Ref. 1; Fracture parallel to deposition
1-3			21	AMDCB		Fracture perpendicular to deposition

SiC (Ceralloy 146 I)

Material Summary:

[Ref. 1,2]
Manufacturer........: Ceradyne Corp.
Material Designation: Ceralloy 146 I
Material Form.......: polycrystal
Composition.........: SiC, 2% B_4C
(mass fraction)
Processing..........:

References:

[1] S. Freiman, private communications (1977).
[2] S. W. Freiman, A. Williams, J. J. Mecholsky, and R. W. Rice, "Fracture of Si_3N_4 and SiC" Ceramic Microstructures, pp. 824-834 (1976).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [MPa·m$^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
10			13.41	AMDCB	air	Ref. 1
1-3			24	AMDCB	air	Ref. 2

SiC (Hexoloy SA)

Material Summary:

```
                          [Ref. 1,2,3,4,5,6]
Manufacturer........: Carborundum Co.
Material Designation: Hexoloy SA
Material Form.......: polycrystal
Composition.........: SiC (alpha)
  (mass fraction)       + 0.4 % B
                        + 0.5 % free C
Processing..........: Sintered
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References:

[1] A. Ghosh, M.G. Jenkins, K.W. White, A.S. Kobayashi, and R.C. Bradt, "Elevated-Temperature Fracture Resistance of a Sintered alpha-Silicon Carbide," Journal of the American Ceramic Society, Vol. 72, pp. 242-247 (1989).

[2] D.E. McCullum, N.L. Hecth, L. Chuck, and S.M. Goodrich, "Summary of Results of the Effects of Environment on Mechanical Behavior of High-Performance Ceramics," Ceramic Engineering and Science Proceedings, Vol. 12, pp. 1886-1913 (1991).

[3] T.E. Easler, R.C. Bradt, and R.E. Tressler, "Strength Distributions of SiC Ceramics After Oxidation and Oxidation Under Load," Journal of the American Ceramic Society, Vol. 64, pp. 731-734 (1981).

[4] K. D. McHenry and R. E. Tressler, "Fracture Toughness and High-Temperature Slow Crack Growth in SiC," Journal of the American Ceramic Society, Vol. 63, pp. 152-156 (1980).

[5] M. Srinivasan and S. G. Seshadri, "Application of Single Edge Notched Beam and Indentation Techniques to Determine Fracture Toughness of Alpha Silicon Carbide," in Fracture Mechanics for Ceramics, Rocks, and Concrete, ASTM Special Technical Publication 745, pp. 46-68 (1981).

[6] C.A. Tracy and G.D. Quinn, "Fracture Toughness by the Surface Crack in Flexure (SCF) Method," Ceramic Engineering and Science Proceedings, Vol. 15, pp. 837-845 (1994).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
6	< 2	3.01		CF	air	Ref. 1
		2.91		CN	air	
		3.88		SENB	air	
6	< 2	2.6		CF	air	Ref. 2
		3.4		ICS	air	
6	< 2	3.8		CF	air	Ref. 3
6	< 2	3.5		CF	air	Ref. 4
6	< 2	3.31		SENB	air	Ref. 5
6	< 2	3.01		SCF	air	Ref. 6

SiC (HP-D)

Material Summary:

	[Ref. 1]
Manufacturer........:	Norton Co.
Material Designation:	HP-D
Material Form.......:	polycrystal
Composition.........:	SiC
Processing..........:	Hot pressed

References:

[1] J. A. Coppola and R. C. Bradt, "Measurement of Fracture Surface Energy of SiC" Journal of the American Ceramic Society, Vol. 55, No. 9, pp. 455-460 (1972).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
	17		44.6	DCB	air	2.65 g/cm^3 E = 209 GPa
			36.7	SENB		
			83.3	WOF		

SiC (KT)

Material Summary:

[Ref. 1,2]

Manufacturer........: Norton Co.
Material Designation: KT
Material Form.......: polycrystal
Composition.........: SiC
Processing..........:

References:

[1] S. W. Freiman, A. Williams, J. J. Mecholsky, and R. W. Rice, "Fracture of Si_3N_4 and SiC" Ceramic Microstructures, pp. 824-834 (1976).

[2] J. J. Mecholsky, S. W. Freiman, and R. W. Rice, "Fracture Surface Analysis of Ceramics" Journal of Materials Science, Vol. 11, pp. 1310-1319 (1976).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
[1-3]			19	AMDCB	air	Ref. 1
[10-100]			19	AMDCB	air	Ref. 2; E = 390 GPa

SiC (NC-203)

Material Summary:

[Ref. 1,2,3,4,5]
Manufacturer........: Norton Co.
Material Designation: NC-203
Material Form.......: polycrystal
Composition.........: SiC
Processing..........: Hot pressed

References:

[1] S. W. Freiman, A. Williams, J. J. Mecholsky, and R. W. Rice, "Fracture of Si_3N_4 and SiC" Ceramic Microstructures, pp. 824-834 (1976).
[2] S. Freiman, private communications (1977).
[3] G. R. Anstis, P. Chantikul, B. R. Lawn, and D. B. Marshall, "A Critical Evaluation of Indentation Techniques for Measuring Fracture Toughness: I, Direct Crack Measurements" Journal of the American Ceramic Society, Vol. 64, No. 9, pp. 533-538 (1981).
[4] C.A. Tracy and G.D. Quinn, "Fracture Toughness by the Surface Crack in Flexure (SCF) Method," Ceramic Engineering and Science Proceedings, Vol. 15, pp. 837-845 (1994).
[5] R. J. Gettings and G. D. Quinn, "Surface Crack in Flexure (SCF) Measurements of the Fracture Toughness of Advanced Ceramics," Ceramic Engineering and Science Proceedings, Vol. 16, pp. 539-547 (1995)

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
[1-3]			19	AMDCB	air	Ref. 1
10			18.52	AMDCB	air	Ref. 2
4		3.38 4.42		ICS IS	air	Ref. 3; E = 457 GPa E = 457 GPa
<1	1.2	3.85		SCF	air	Ref. 4; E = 450 GPa; 3.28 g/cm^3
		4.37		SCF	air	Ref. 5; E = 460 GPa, ν = 0.17, density = 3.36 g/cm^3

SiC (NC-430)

Material Summary:

	[Ref. 1]
Manufacturer........:	Norton Co.
Material Designation:	NC-430
Material Form.......:	polycrystal
Composition.........:	SiC
Processing..........:	

References:

[1] E. Fuller, private communications (1983).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
		4.3		CNB	air	Ref. 1

SiC (NC-435)

Material Summary:

	[Ref. 1]
Manufacturer........:	Norton Co.
Material Designation:	NC-435
Material Form.......:	polycrystal
Composition.........: (mass fraction)	SiC
Processing..........:	Siliconized

References:

[1] R. J. Gettings and G. D. Quinn, "Surface Crack in Flexure (SCF) Measurements of the Fracture Toughness of Advanced Ceramics," Ceramic Engineering and Science Proceedings, Vol. 16, pp. 539-547 (1995)

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
		3.70		SCF	air	Ref. 1; E = 350 GPa, ν = 0.18, density = 2.99 g/cm^3

SiC (RS-E)

Material Summary:

	[Ref. 1]
Manufacturer........:	Carborundum Co.
Material Designation:	RS-E
Material Form.......:	polycrystal
Composition.........:	SiC
Processing..........:	Reaction sintered

References:

[1] J. A. Coppola and R. C. Bradt, "Measurement of Fracture Surface Energy of SiC" Journal of the American Ceramic Society, Vol. 55, No. 9, pp. 455-460 (1972).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
	0		30.7	DCB	air	3.09 g/cm^3 E = 372 GPa
			19.0	SENB		
			23.5	WOF		

SiC (RX-A)

Material Summary:

	[Ref. 1]
Manufacturer........:	Norton Co.
Material Designation:	RX-A
Material Form.......:	polycrystal
Composition.........:	SiC
Processing..........:	Recrystallized

References:

[1] J. A. Coppola and R. C. Bradt, "Measurement of Fracture Surface Energy of SiC" Journal of the American Ceramic Society, Vol. 55, No. 9, pp. 455-460 (1972).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
	13		14.7	DCB	air	2.77 g/cm^3 E = 254 GPa
			15.8	SENB		
			11.1	WOF		

SiC (RX-B)

Material Summary:

	[Ref. 1]
Manufacturer........:	Norton Co.
Material Designation:	RX-B
Material Form.......:	polycrystal
Composition.........:	SiC
Processing..........:	Recrystallized

References:

[1] J. A. Coppola and R. C. Bradt, "Measurement of Fracture Surface Energy of SiC" Journal of the American Ceramic Society, Vol. 55, No. 9, pp. 455-460 (1972).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
	16		15.0	DCB	air	2.67 g/cm^3 E = 193 GPa
			14.4	SENB		
			12.2	WOF		

SiC (RX-C)

Material Summary:

	[Ref. 1]
Manufacturer........:	Norton Co.
Material Designation:	RX-C
Material Form.......:	polycrystal
Composition.........:	SiC
Processing..........:	Recrystallized

References:

[1] J. A. Coppola and R. C. Bradt, "Measurement of Fracture Surface Energy of SiC" Journal of the American Ceramic Society, Vol. 55, No. 9, pp. 455-460 (1972).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
	15		29.6	DCB	air	2.70 g/cm^3 E = 197 GPa
			24.5	SENB		
			26.6	WOF		

SiC (SCRB210)

Material Summary:

	[Ref. 1]
Manufacturer........:	Coors Porcelain Co.
Material Designation:	SCRB210
Material Form.......:	polycrystal
Composition.........:	SiC
Processing..........:	reaction bonded

References:

[1] R.E. Tressler, "Performance Verification of New, Low-Cost Ceramics," Projects Within the Center for Advanced Materials, Pennsylvania State University, Report No. CAM-8701, pp. 124-163 (1987).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
		5.3		SENB	air	Ref. 1

Si_3N_4 (Silicon Nitride)

Material Summary:

	[Ref. 1a]	[Ref. 1b]	[Ref. 1c]	[Ref. 1d]	[Ref. 1e]
Manufacturer........:	NRL	Toshiba	AMMRC	AMMRC	KBI
Material Designation:	silicon nitride	silicon nitride	silicon nitride	silicon nitride	silicon nitride
Material Form.......:	polycrystal	polycrystal	polycrystal	polycrystal	polycrystal
Composition.........: (mass fraction)	Si_3N_4	Si_3N_4	Si_3N_4, 19% Y_2O_3	Si_3N_4, 13% Y_2O_3	Si_3N_4
Processing..........:					

	[Ref. 2,4]	[Ref. 3]	[Ref. 5,6,7]	[Ref. 8,9]
Manufacturer........:	Unknown	Norton Co.	In laboratory	In laboratory
Material Designation:	silicon nitride	silicon nitride	silicon nitride	silicon nitride
Material Form.......:	polycrystal	polycrystal	polycrystal	polycrystal
Composition.........:	Si_3N_4	Si_3N_4	Si_3N_4	Si_3N_4
Processing..........:			Hot pressed	Hot isostatically pressed

	[Ref.10]
Manufacturer........:	Dow Chemical Co.
Material Designation:	silicon nitride
Material Form.......:	polycrystal
Composition.........:	Si_3N_4
Processing..........:	Sintered

References:

[1] S. W. Freiman, A. Williams, J. J. Mecholsky, and R. W. Rice, "Fracture of Si_3N_4 and SiC" Ceramic Microstructures, pp. 824-834 (1976).

[2] G. Himsolt, H. Knoch, H. Huebner, and F. Kleinlein, "Mechanical Properties of Hot-Pressed Silicon Nitride with Different Grain Structures" Journal of the American Ceramic Society, Vol. 62, No. 1-2, pp. 29-32 (1979).

[3] A. G. Evans, and E. A. Charles, "Fracture Toughness Determinations by Indentation" Journal of the American Ceramic Society, Vol. 59, No. 7-8, p. 371-372 (1976).

[4] F. F. Lange, "Relation Between Strength, Fracture Energy, and Microstructure of Hot-Pressed Si_2N_4" Journal of the American Ceramic Society, Vol. 56, No. 10, 518-522 (1973).

[5] D. Chakraborty, A.K. Mukhopadhyay, and J. Mukerji, "Influence of Thermal Quenching on Surface Fracture Toughness and Microhardness of Si_3N_4, SiAlON, and SiC," Rev.Internationale Des Hautes Temper. et Des Refractaires, Vol. 22, pp. 105-113 (1985).

[6] T. Ohji, S. Sakai, M. Ito, Y. Yamauchi, W. Kanematsu, and S. Ito, "Fracture Energy and Tensile Strength of Silicon Nitride at High Temperatures," Journal of the Ceramic Society

of Japan Inter. Ed., Vol. 98, pp. 244-251 (1990).
[7] C.A. Tracy and G.D. Quinn, "Fracture Toughness by the Surface Crack in Flexure (SCF) Method," Ceramic Engineering and Science Proceedings, Vol. 15, pp. 837-845 (1994).
[8] I. Tanaka, G. Pezzotti, T. Okamoto, and Y. Miyamoto, "Hot Isostatic Press Sintering and Properties of Silicon Nitride without Additives," Journal of the American Ceramic Society, Vol. 72, pp. 1656-1660 (1989).
[9] O. Unal, J.J. Petrovic, and T.E. Mitchell, "Mechanical Properties of Hot Isostatically Pressed Si_3N_4 and Si_3N_4/SiC composites," Journal of Materials Research, Vol. 8, pp. 626-634 (1993).
[10] G. D. Quinn, J. J. Swab, and M. D. Hill, "Fracture Toughness by the Surface Crack in Flexure (SCF) Method: New Test Results," Ceramic Engineering and Science Proceedings, Vol. 18 (4), pp. 163-172 (1997).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
1-3			54	AMDCB	air	Ref. 1a; Major additives/impurities were ZrC, ZrO_2 or Zr.
1-3		8.3	110	AMDCB		1b; Major additives/impurities were Y_2O_3, Al_2O_3
1-3		7.2	85	AMDCB		1c; Major additive/impurity was 19% Y_2O_3
1-3			109	AMDCB		1d; Major additive/impurity was 13% Y_2O_3
1-3			52	AMDCB		1e; Major additive/impurity was Mg
		3.2		SENB	air	Ref. 2; E = 317.5 GPa
			16.5	WOF		
		4.96		SENB		E = 311.1 GPa
			30.4	WOF		
		7.81		SENB		E = 302.8 GPa
			67.8	WOF		
		6.59		SENB		E = 309.6 GPa
			47.4	WOF		
		4.9		ICS	dry N2	Ref. 3; Material was hot pressed with MgO; H = 14.1 GPa; ν = 0.27

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
			69.5	DCB	air	Ref. 4; High alpha phase in starting powder; density = 3.20 g/cm^3
			39.6	DCB		High alpha phase in starting powder; density = 3.24 g/cm^3
			29.2	DCB		High alpha phase in starting powder; density = 3.18 g/cm^3
			54.4	DCB		High alpha phase in starting powder; density = 3.18 g/cm^3
			31.0	DCB		High alpha phase in starting powder; density = 3.01 g/cm^3
			15.8	DCB		High beta phase in starting powder; density = 3.24 g/cm^3
			42.5	DCB		Commerical hot-pressed material; density = 3.18 g/cm^3
		4.1		ICS	air	Ref. 5; H = 20 GPa
		4.5		CNB	air	Ref. 6; 3.20 g/cm^3
<5		4.7		SCF	air	Ref. 7; 3.10 g/cm^3 E = 248 GPa
		3.12		ICS	air	Ref. 8; E = 312 GPa; H = 14.6 GPa
		2.7		ICS	air	Ref. 9; H = 24 GPa
		6.75		SCF	air	Ref. 10; self-reinforced; E = 306 GPa; density = 3.20 g/cm^3

Si_3N_4 (Beta Silicon Nitride)

Material Summary:

	[Ref. 1]
Manufacturer........:	Beckwith, Inc.
Material Designation:	beta silicon nitride
Material Form.......:	polycrystal
Composition.........:	Si_3N_4
Processing..........:	

References:

[1] J. J. Mecholsky, S. W. Freiman, and R. W. Rice, "Fracture Surface Analysis of Ceramics" Journal of Materials Science, Vol. 11, pp. 1310-1319 (1976).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
1			30	AMDCB	air	E = 280 GPa

Si_3N_4 (Ceralloy 147)

Material Summary:

	[Ref. 1a]	[Ref. 1b]
Manufacturer........:	Cerdyne Corp.	Cerdyne Corp.
Material Designation:	Ceralloy 147	Ceralloy 147
Material Form.......:	polycrystal	polycrystal
Composition.........: (mass fraction)	Si_3N_4+1% MgO	Si_3N_4+15% Y_2O_3
Processing..........:		

References:

[1] S. W. Freiman, A. Williams, J. J. Mecholsky, and R. W. Rice, "Fracture of Si_3N_4" Ceramic Microstructures, pp. 824-834 (1976).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
1-3		4.6	34	AMDCB	air	Ref. 1a
1-3		7.2	83	AMDCB		1b

Si_3N_4 (EC-141)

Material Summary:

	[Ref. 1]
Manufacturer........:	NTK
Material Designation:	EC-141
Material Form.......:	polycrystal
Composition.........: (mass fraction)	Si_3N_4
Processing..........:	Gas phase sintered

References:

[1] R. J. Gettings and G. D. Quinn, "Surface Crack in Flexure (SCF) Measurements of the Fracture Toughness of Advanced Ceramics," Ceramic Engineering and Science Proceedings, Vol. 16, pp. 539-547 (1995)

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [MPa·m$^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
		5.22		SCF	air	Ref. 1; E = 310 GPa, ν = 0.26, density = 3.22 g/cm^3

Si_3N_4 (EKasin)

Material Summary:

[Ref. 1,2]

Manufacturer........: ESK
Material Designation: EKasin
Material Form.......: polycrystal
Composition.........: Si_3N_4
(mass fraction)
Processing..........: Hot isostatically pressed

References:

[1] R. J. Gettings and G. D. Quinn, "Surface Crack in Flexure (SCF) Measurements of the Fracture Toughness of Advanced Ceramics," Ceramic Engineering and Science Proceedings, Vol. 16, pp. 539-547 (1995)
[2 J. Kubler, "Fracture Toughness of Ceramics Using the SEVNB Method: Preliminary Results," Ceramic Engineering and Science Proceedings, Vol. 18 (4), pp. 155-162 (1997).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
		5.22		SCF	air	Ref. 1; E = 315 GPa, ν = 0.27, density = 3.18 g/cm^3
		5.10		SENB	air	Ref. 2; V-notch

Si_3N_4 (HS-110)

Material Summary:

	[Ref. 1]
Manufacturer........:	Norton Co.
Material Designation:	HS-110
Material Form.......:	polycrystal
Composition.........:	Si_3N_4
Processing..........:	Hot pressed

References:

[1] S. W. Freiman, A. Williams, J. J. Mecholsky, and R. W. Rice, "Fracture of Si_3N_4 and SiC" Ceramic Microstructures, pp. 824-834 (1976).

Property Table:

Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
[1-3]			45	AMDCB	air	Major additive/impurity = Mg

Si_3N_4 (HS-130)

Material Summary:

[Ref. 1,2,3]

Manufacturer........: Norton Co.
Material Designation: HS-130
Material Form.......: polycrystal
Composition.........: Si_3N_4
Processing..........: Hot pressed

References:

[1] J. L. Henshall, D. J. Rowcliffe, and J. W. Edington, "The Fracture Toughness and Delayed Fracture of Hot-Pressed Silicon Nitride" Proceedings of the British Ceramic Society, No. 6, pp. 185-198 (1975).

[2] S. W. Freiman, A. Williams, J. J. Mecholsky, and R. W. Rice, "Fracture of Si_3N_4 and SiC" Ceramic Microstructures, pp. 824-834 (1976).

[3] J. J. Mecholsky, S. W. Freiman, and R. W. Rice, "Fracture Surface Analysis of Ceramics" Journal of Materials Science, Vol. 11, pp. 1310-1319 (1976).

Property Table:

Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
		4.5		SENB	air	Ref. 1
[1-3]			43	AMDCB	air	Ref. 2; Major additive/impurity = Mg
1			45	AMDCB	air	Ref. 3; E = 310 GPa

Si_3N_4 (NAV-4)

Material Summary:

	[Ref. 1]
Manufacturer........:	Norton Co.
Material Designation:	NAV-4
Material Form.......:	polycrystal
Composition.........:	Si_3N_4
Processing..........:	Hot pressed

References:

[1] S. W. Freiman, A. Williams, J. J. Mecholsky, and R. W. Rice, "Fracture of Si_3N_4 and SiC" Ceramic Microstructures, pp. 824-834 (1976).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
[1-3]			58	AMDCB	air	Major additive/impurity = high Mg

Si_3N_4 (NAV-5)

Material Summary:

	[Ref. 1]
Manufacturer........:	Norton Co.
Material Designation:	NAV-5
Material Form.......:	polycrystal
Composition.........:	Si_3N_4
Processing..........:	Hot pressed

References:

[1] S. W. Freiman, A. Williams, J. J. Mecholsky, and R. W. Rice, "Fracture of Si_3N_4 and SiC" Ceramic Microstructures, pp. 824-834 (1976).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
[1-3]			38	AMDCB	air	Major additives/impurities = high Fe and very high Ca

Si_3N_4 (NAV-7)

Material Summary:

	[Ref. 1]
Manufacturer........:	Norton Co.
Material Designation:	NAV-7
Material Form.......:	polycrystal
Composition.........:	Si_3N_4
Processing..........:	Hot pressed

References:

[1] S. W. Freiman, A. Williams, J. J. Mecholsky, and R. W. Rice, "Fracture of Si_3N_4 and SiC" Ceramic Microstructures, pp. 824-834 (1976).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
[1-3]			62	AMDCB	air	Major additives/impurities = high Al and high Fe

Si_3N_4 (NAV-8)

Material Summary:

	[Ref. 1]
Manufacturer........:	Norton Co.
Material Designation:	NAV-8
Material Form.......:	polycrystal
Composition.........:	Si_3N_4
Processing..........:	Hot pressed

References:

[1] S. W. Freiman, A. Williams, J. J. Mecholsky, and R. W. Rice, "Fracture of Si_3N_4 and SiC" Ceramic Microstructures, pp. 824-834 (1976).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
[1-3]		5.5	49	AMDCB	air	Major additive/impurity = Zr

Si_3N_4 (NBD-200)

Material Summary:

	[Ref. 1]
Manufacturer........:	Cerbec
Material Designation:	NBD-200
Material Form.......:	polycrystal
Composition.........: (mass fraction)	Si_3N_4
Processing..........:	Hot isostatically pressed

References:

[1] R. J. Gettings and G. D. Quinn, "Surface Crack in Flexure (SCF) Measurements of the Fracture Toughness of Advanced Ceramics," Ceramic Engineering and Science Proceedings, Vol. 16, pp. 539-547 (1995)

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
		5.4		SCF	air	Ref. 1; E = 320 GPa, ν = 0.26, density = 3.16 g/cm^3

Si_3N_4 (NC-132)

Material Summary:

[Ref. 1,2,3,4,5,6,7]

Manufacturer........: Norton Co.
Material Designation: NC-132
Material Form.......: polycrystal
Composition.........: Si_3N_4
Processing..........: Hot pressed

References:

[1] S. W. Freiman, A. Williams, J. J. Mecholsky, and R. W. Rice, "Fracture of Si_3N_4 and SiC" Ceramic Microstructures, pp. 824-834 (1976).

[2] R. W. Rice, S. W. Freiman, J. J. Mecholsky, R. Ruh, and Y. Harada, "Fractograph of Si_3N_4 and SiC" Ceramics for High Performance Applications (1977).

[3] G. K. Bansal, "Effects of Ceramic Microstructures on Strength and Fracture Surface Energy" Microstructures, pp. 860-871 (1976).

[4] G. R. Anstis, P. Chantikul, B. R. Lawn, and D. B. Marshall, "A Critical Evaluation of Indentation Techniques for Measuring Fracture Toughness: I, Direct Crack-Measurements" Journal of the American Ceramic Society, Vol. 64, No. 9, pp. 533-538 (1981).

[5] J.E. Ritter, S.V. Nair, P.A. Gennari, and W.A. Dunlay, "High-Strength Reaction-Bonded Silicon Nitride," Advanced Ceramic Materials, Vol. 3, pp. 415-417 (1988).

[6] G.D. Quinn, R.J. Gettings, and J.J. Kubler, "Fracture Toughness by the Surface Crack in Flexure (SCF) Method: Results of the VAMAS Round Robin," Ceramic Engineering and Science Proceedings, Vol. 15, pp. 846-855 (1994).

[7] J. Kubler, "Fracture Toughness of Ceramics Using the SEVNB Method: Preliminary Results," Ceramic Engineering and Science Proceedings, Vol. 18 (4), pp. 155-162 (1997).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
[1-3]		4	26	AMDCB	air	Ref. 1; Major additive/impurity = Mg
			17	AMDCB	air	Ref. 2; E = 276 GPa
[1-2]			61.3	SENB	air	Ref. 3; E = 310 GPa; flaw moving parallel to HP direction.
			42.2	SENB		Flaw moving perpendicular to HP direction.
			40.1	SENB		Flaw plane perpendicular to HP direction.
2		4.0		DCB	air	Ref. 4; E = 300 GPa
		4.98		ICS		E = 370 GPa
		5.25		IS		E = 370 GPa
		4.0		ICS	air	Ref. 5; 3.18 g/cm^3
		4.6		SCF	air	Ref. 6
		4.36		SENB	air	Ref. 7; V-notch

Si_3N_4 (NC-350)

Material Summary:

[Ref. 1,2]
Manufacturer........: Norton Co.
Material Designation: NC-350
Material Form.......: polycrystal
Composition.........: Si_3N_4
Processing..........: Reaction sintered

References:

[1] G. R. Anstis, P. Chantikul, B. R. Lawn, and D. B. Marshall, "A Critical Evaluation of Indentation Techniques for Measuring Fracture Toughness: I, Direct Crack-Measurements" Journal of the American Ceramic Society, Vol. 64, No. 9, pp. 533-538 (1981).

[2] R. J. Gettings and G. D. Quinn, "Surface Crack in Flexure (SCF) Measurements of the Fracture Toughness of Advanced Ceramics," Ceramic Engineering and Science Proceedings, Vol. 16, pp. 539-547 (1995)

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
10		2.71		ICS	air	Ref. 1; E = 170 GPa
		2.13		IS		E = 170 GPa
		1.65		SCF	air	Ref. 2; E = 180 GPa, ν = 0.22, density = 2.53 g/cm^3

Si_3N_4 (NCX-34)

Material Summary:

	[Ref. 1]
Manufacturer........:	Norton Co.
Material Designation:	NCX-34
Material Form.......:	polycrystal
Composition.........:	Si_3N_4
Processing..........:	Hot pressed

References:

[1] R. J. Gettings and G. D. Quinn, "Surface Crack in Flexure (SCF) Measurements of the Fracture Toughness of Advanced Ceramics," Ceramic Engineering and Science Proceedings, Vol. 16, pp. 539-547 (1995)

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
		6.35		SCF	air	Ref. 1; E = 310 GPa, ν = 0.27, density = 3.37 g/cm^3

Si_3N_4 (NCX-5102)

Material Summary:

[Ref. 1,2]

Manufacturer........: Norton Co.
Material Designation: NCX-5102
Material Form.......: polycrystal
Composition.........: Si_3N_4 + 4 % Y_2O_3
(mass fraction)
Processing..........: Hot isostatically pressed

References:

[1] R. J. Gettings and G. D. Quinn, "Surface Crack in Flexure (SCF) Measurements of the Fracture Toughness of Advanced Ceramics," Ceramic Engineering and Science Proceedings, Vol. 16, pp. 539-547 (1995)

[2] T. Hansson, U. Ramamurty, C. Bull, and R. Warren, "Elevated Temperature Fracture Behavior of Monolithic and SiC_w-Reinforced Silicon Nitride Under Quasi-static Loads," Materials Science and Engineering, Vol. A209, pp. 137-148 (1996).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
		5.36		SCF	air	Ref. 1; density = 3.23 g/cm^3
2 [0.5-3]		6.0		SEPB	air	Ref. 2

Si_3N_4 (NT-154)

Material Summary:

[Ref. 1,2,3]

Manufacturer........: Norton/TRW
Material Designation: NT-154
Material Form.......: polycrystal
Composition.........: Si_3N_4
Processing..........: Sintered and Hot isostatically pressed

References:

[1] N.L. Hecht, D.E. McCullum, and G.A. Graves, "Investigation of Selected Si_3N_4 and SiC Ceramics," Ceramic Materials and Components for Engines, pp. 806-816 (1988).

[2] D.E. McCullum, N.L. Hecth, L. Chuck, and S.M. Goodrich, "Summary of Results of the Effects of Environment on Mechanical Behavior of High-Performance Ceramics," Ceramic Engineering and Science Proceedings, Vol. 12, pp. 1886-1913 (1991).0

[3] R. J. Gettings and G. D. Quinn, "Surface Crack in Flexure (SCF) Measurements of the Fracture Toughness of Advanced Ceramics," Ceramic Engineering and Science Proceedings, Vol. 16, pp. 539-547 (1995)

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
		3.8		ICS	air	Ref. 1; 3.24 g/cm^3 E = 314 GPa; H = 14 GPa
		3.2		CF	air	Ref. 2; 3.23 g/cm^3 E = 310 GPa; H = 15.9 GPa
		3.70		SCF	air	Ref. 3; E = 320 GPa, ν = 0.27, density = 3.23 g/cm^3

Si_3N_4 (NT-164)

Material Summary:

	[Ref. 1]
Manufacturer........:	Norton/TRW
Material Designation:	NT-164
Material Form.......:	polycrystal
Composition.........:	Si_3N_4
Processing..........:	Sintered and Hot isostatically pressed

References:

[1] G.A. Graves and N.L. Hecht, "Effects of Environment on the Mechanical Behavior of High-Performance Ceramics," Report No. UDR-TR-94-136, U.S. Department of Energy Contract DE-AC05-84R21400 (1995).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
		4.0		ICS	air	Ref. 1; 3.1 g/cm^3 E = 306 GPa; H = 18.5 GPa

Si_3N_4 (SNW-1000)

Material Summary:

[Ref. 1,2,3]

Manufacturer........: GTE Sylvania
Material Designation: SNW-1000
Material Form.......: polycrystal
Composition.........: Si_3N_4
Processing..........: Sintered

References:

[1] T.E. Easler, R.C. Bradt, and R.E. Tressler, "Effects of Oxidation and Oxidation Under Load on Strength Distributions of Si_3N_4," Journal of the American Ceramic Society, Vol. 65, pp. 317-320 (1982).

[2] C.A. Tracy and G.D. Quinn, "Fracture Toughness by the Surface Crack in Flexure (SCF) Method," Ceramic Engineering and Science Proceedings, Vol. 15, pp. 837-845 (1994).

[3] G. D. Quinn, J. J. Swab, and M. D. Hill, "Fracture Toughness by the Surface Crack in Flexure (SCF) Method: New Test Results," Ceramic Engineering and Science Proceedings, Vol. 18 (4), pp. 163-172 (1997).

Property Table:

Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
		4.0		CF	air	Ref. 1; 3.00 g/cm^3 E = 240 GPa
<5	5	4.7		SCF	air	Ref. 2; 3.26 g/cm^3 E = 248 GPa
		6.4		SCF	air	Ref. 3; 3.29 g/cm^3; E = 281 GPa

Si_2N_2O (Silicon Oxynitride)

Material Summary:

	[Ref. 1]
Manufacturer........:	In laboratory
Material Designation:	silicon oxynitride
Material Form.......:	polycrystal
Composition.........:	Si_2N_2O
Processing..........:	Hot pressed

References:

[1] M. Ohashi, K. Nakamura, K. Hirao, M. Toriyama, and S. Kanzaki, "Factors Affecting Mechanical Properties of Silicon Oxynitride Ceramics," Ceramics International, Vol. 23, pp. 27-37 (1997).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
0.8 (minor axis) 5.0 (major axis)		3.2		ICS	air	Ref. 1; E = 140 GPa, ν = 0.28, density = 4.4 g/cm^3

SiO_2 (Silicon Dioxide)

Material Summary:

[Ref. 1]

Manufacturer........: Unknown
Material Designation: silicon dioxide; also known as silica
Material Form.......: single crystal
Composition.........: SiO_2
Processing..........:

References:

[1] M. Iwasa and T. Ueno, "Fracture Toughness of Quartz and Sapphire single crystals at Room Temperature" Zairyo, Vol. 30, No. 337, pp. 1001-1004 (1981).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
		1.15		CF	air	K_{Ic} - plane [0001] Direction [1$\bar{2}$10]
		0.97		CF		K_{Ic} - plane [01$\bar{1}$0] Direction [2110]
		0.86		CF		K_{Ic} - plane [01$\bar{1}$1] Direction [2110]
		0.85		CF		K_{Ic} - plane [11$\bar{2}$0] Direction [1$\bar{1}$00]
		0.94		CF		K_{Ic} - plane [11$\bar{2}$1] Direction [1$\bar{1}$00]

SrF_2 (Strontium Fluoride)

Material Summary:

	[Ref. 1]	[Ref. 2]
Manufacturer........:	Unknown	Harshaw Chemical Co.
Material Designation:	strontium fluoride	strontium fluoride
Material Form.......:	single crystal	single crystal
Composition.........:	SrF_2	SrF_2
Processing..........:		

References:

[1] P. F. Becher and S. W. Freiman, "Crack Propagation in Alkaline-Earth Fluorides" Journal of Applied Physics, Vol. 49, No. 7, pp. 3779-3783 (1978).

[2] P. Kraatz and T. Zoltai, "Effects of Ionizing Radiation on Cleavage Surface Energy of SrF_2" Journal of Applied Physics, Vol. 45, No. 11, pp. 5093-5095 (1974).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
			0.42	AMDCB	air	Ref. 1; crack plane = {111}, crack direction = [$1\bar{1}c$]
			0.36	DCB	air	Ref. 2; crack plane = {111}

$SrZrO_3$ (Strontium Zirconate)

Material Summary:

	[Ref. 1]
Manufacturer........:	Alfred University
Material Designation:	strontium zirconate
Material Form.......:	polycrystal
Composition.........:	$SrZrO_3$
Processing..........:	

References:

[1] J. J. Mecholsky, S. W. Freiman, and R. W. Rice, "Fracture Surface Analysis of Ceramics" Journal of Materials Science, Vol. 11, pp. 1310-1319 (1976).

Property Table:

Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
[5-10]			6	AMDCB	air	E = 280 GPa

ThO_2 (Thorium Dioxide)

Material Summary:

[Ref. 1]
Manufacturer........: Unknown
Material Designation: thorium dioxide; also known as thoria
Material Form.......: polycrystal
Composition.........: ThO_2
Processing..........: Sintered

References:

[1] H. Matzke, "Hertzian Indentation of Thorium Dioxide, ThO_2" Journal of Materials Science, Vol. 15, pp. 739-746 (1980).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
22	8	1.07	2.5	HI	air	

TiB_2 (Titanium Diboride)

Material Summary:

	[Ref. 1,a]	[Ref. 1,b]	[Ref. 1,c]	[Ref. 1,d]
Manufacturer........:	ORNL	ORNL	ORNL	ORNL
Material Designation:	titanium diboride	titanium diboride	titanium diboride	titanium diboride
Material Form.......:	polycrystal	polycrystal	polycrystal	polycrystal
Composition.........:	TiB_2	TiB_2	TiB_2 + 7.9 % Ni	TiB_2 + 1.4 % Ni
Processing..........:	Hot pressed, 2000 °C	Hot pressed, 1800 °C	Hot pressed, 1425 °C	Hot pressed, 1425 °C

	[Ref. 2]	[Ref. 3]	[Ref. 4]	[Ref. 5]
Manufacturer........:	In laboratory	In laboratory	In laboratory	In laboratory
Material Designation:	titanium diboride	titanium diboride	titanium diboride	titanium diboride
Material Form.......:	polycrystal	polycrystal	polycrystal	polycrystal
Composition.........:	TiB_2	TiB_2	TiB_2	TiB_2 + 6 % TaB_2 +1 % Co
Processing..........:	Sintered, 1900 °C	Hot pressed, 1800 °C	Hot pressed	Hot pressed, 1500 °C

	[Ref. 6,a]	[Ref. 6,b]
Manufacturer........:	Sylvania	Sylvania
Material Designation:	Osram 3120	Osram 3122
Material Form.......:	polycrystal	polycrystal
Composition.........:	TiB_2	TiB_2
Processing..........:	Gas phase sintered	Gas phase sintered

References:

[1] M. K. Ferber, P. F. Becher, and C. B. Finch, "Effect of Microstructure on the Properties of TiB_2 Ceramics" Journal of the American Ceramic Society, Vol. 66, No. 1, pp. C-2-C-4 (1983).

[2] H.R. Baumgartner and R.A. Steiger, "Sintering and Properties of Titanium Diboride Made from Powder Synthesized in a Plasma-Arc Heater," Journal of the American Ceramic Society, Vol. 67, pp. 207-212 (1984).

[3] H. Itoh, S. Naka, T. Matsudaira, and H. Hamamoto, "Preparation of TiB_2 Sintered Compacts by Hot Pressing," Journal of Materials Science, Vol. 25, pp. 533-536 (1990).

[4] C.A. Tracy and G.D. Quinn, "Fracture Toughness by the Surface Crack in Flexure (SCF) Method," Ceramic Engineering and Science Proceedings, Vol. 15, pp. 837-845 (1994).

[5] V. C. Kokabi, K. Shobu, and T. Watanabe, "Studies of the Mechanical Properties of TiB_2- 6% Ta - 1% CoB - x% $mZrO_2$," Journal of the European Ceramic Society, Vol. 17, pp. 885-890 (1997).

[6] R. J. Gettings and G. D. Quinn, "Surface Crack in Flexure (SCF) Measurements of the Fracture Toughness of Advanced Ceramics," Ceramic Engineering and Science Proceedings, Vol. 16, pp. 539-547 (1995)

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
40.		3.7		ICS	air	Ref. 1,a; E = 503 GPa; ν = 0.111
4.5		5.75		ICS	air	Ref. 1,b; E = 563 GPa; ν = 0.099
7		4.25		ICS	air	Ref. 1,c; E = 536 GPa
4		6.4		ICS	air	Ref. 1,d; E = 569 GPa; ν = 0.15
		4.87		DT	air	Ref. 2; E = 537 GPa
		2.3		ICS	air	Ref. 3; density = 4.47 g/cm^3 H = 28 GPa
10	2	5.14		SCF	air	Ref. 4; E = 545 GPa
		4.6		IS	air	Ref. 5; E = 530 GPa
		6.0		SENB	air	Ref. 5; E = 530 GPa
		5.20		SCF	air	Ref. 6a; E = 542 GPa; ν = 0.12 density = 4.64 g/cm^3
		5.36		SCF	air	Ref. 6b; E = 581 GPa; ν = 0.12 density = 4.67 g/cm^3

TiC (Titanium Carbide)

Material Summary:

	[Ref. 1]	[Ref. 2]
Manufacturer........:	In laboratory	In laboratory
Material Designation:	titanium carbide	titanium carbide
Material Form.......:	polycrystal	single crystal
Composition.........:	TiC	$TiC_{0.96}$
Processing..........:		Floating zone method

References:

[1] J. L. Chermant, A. Deschanvres and F. Osterstock, "Toughness and Fractography of TiC and WC" Fracture Mechanics of Ceramics, Vol. 4, pp. 891-901 (1978).

[2] C. Maerky, M. O. Guillou, J. L. Henshall, and R. M. Hooper, "Indentation Hardness and Fracture Toughness in Single Crystal $TiC_{0.96}$," Materials Science and Engineering A, Vol. 209, pp 329-336 (1996).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
20		3.8	45	SENB	air	Technique with a starter crack; E = 400 GPa
		1.7		ICS	air	(001) plane; E = 462 GPa
		2.5		ICS	air	(110) plane; E = 449 GPa
		3.0		ICS	air	(111) plane; E = 442 GPa

TiN (Titanium Nitride)

Material Summary:

	[Ref. 1]	[Ref. 2,a]	[Ref. 2,b]	[Ref. 2,c]	[Ref. 2,d]
Manufacturer........:	In laboratory	In laboratory	In laboratory	In laboratory	In laboratory
Material Designation:	titanium nitride	titanium nitride	titanium nitride	titanium nitride	titanium nitride
Material Form.......:	polycrystal	polycrystal	polycrystal	polycrystal	polycrystal
Composition.........:	TiN	TiN	TiN + 5% Al_2O_3	TiN + 5% MgO	TiN + 5% Y_2O_3
Processing..........:	Hot isostatically pressed	Hot pressed	Hot pressed	Hot pressed	Hot pressed

References:

[1] M. Desmaison-Brut, L. Themelin, F. Valin, and M. Boncoeur, "Mechanical Properties of Hot-Isostatic-Pressed Titanium Nitride," Euro-Ceramics, Vol. 3, pp. 258-262 (1989).

[2] M. Moriyama, H. Aoki, Y. Kobayashi, and K. Kamata, "The Mechanical Properties of Hot-Pressed TiN Ceramics with Various Additives," Journal of the Ceramic Society of Japan, Vol. 101, pp. 279-284 (1993).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
		5.0		SENB	air	Ref. 1; *E* = 465 GPa; *H* = 18 GPa
	14	3.4		SENB	air	Ref. 2a; *E* = 353 GPa; *H* = 12.0 GPa
	13	5.3		SENB		Ref. 2b; *E* = 324 GPa; *H* = 13.8 GPa
	18	5.2		SENB		Ref. 2c; *E* = 288 GPa; *H* = 9.4 GPa
	15	5.5		SENB		Ref. 2d; *E* = 337 GPa; *H* = 12.3 GPa

TiO_2 (Titanium Dioxide)

Material Summary:

	[Ref. 1]	[Ref. 2]
Manufacturer........:	In laboratory	In laboratory
Material Designation:	titanium dioxide; titania	titanium dioxide; titania
Material Form.......:	polycrystal	polycrystal
Composition.........:	TiO_2	TiO_2
Processing..........:	Hot pressed	Hot isostatically pressed

References:

[1] W. P. Minnear and R. C. Bradt, "Stoichiometry Effects on the Fracture of TiO_{2-x}," Journal of the American Ceramic Society, Vol. 63, pp. 485-489 (1980).

[2] J. Li, S. Forberg, and L. Hermansson, "Evaluation of the Mechanical Properties of Hot Isostatically Pressed Titania and Titania-Calcium Phosphate Composites," Biomaterials, Vol. 12, pp. 438-440 (1991).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa\cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
21		6.1	68	DT	air	Ref. 1; density = 4.097 g/cm^3
	< 2	2.8		ICS	air	Ref. 2; density = 4.21 g/cm^3 E = 270 GPa; H = 11 GPa

UO_2 (Uranium Dioxide)

Material Summary:

	[Ref. 1,a]	[Ref. 1,a]
Manufacturer........:	UKAEA Springfields Lab.	UKAEA Springfields Lab.
Material Designation:	uranium dioxide	uranium dioxide
Material Form.......:	polycrystal	polycrystal
Composition.........:	UO_2	UO_2
Processing..........:	Sintered at 1650 °C	Sintered at 1750 °C

References:

[1] A. G. Evans and R. W. Davidge, "The Strength and Fracture of Stoichiometric polycrystalline UO_2" Journal of Nuclear Materials, Vol. 33, pp. 249-260 (1969).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
8	3		6.5	SENB	argon	Ref. 1,a; a slit crack was introduced below the notch.
25	3		3.5	SENB		Ref. 1,b; a slit crack was introduced below the notch.

VC (Vanadium Carbide)

Material Summary:

	[Ref. 1,a]	[Ref. 1,b]	[Ref. 1,c]
Manufacturer........:	Unknown	Unknown	Unknown
Material Designation:	vanadium carbide	vanadium carbide	vanadium carbide
Material Form.......:	single crystal	single crystal	single crystal
Composition.........:	$VC_{0.88}$	$VC_{0.84}$	$VC_{0.76}$
Processing..........:			

References:

[1] R. K. Govila, "Further Observations on Fracture Energies in VC Monocrystals" Scripta Metallurgica, Vol. 6, No . 5, pp. 353-356 (1972).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
			1.3	CF	air	Ref. 1,a; E = 477 GPa
			1.9	CF	air	Ref. 1,b; E = 477 GPa
			1.7	CF	air	Ref. 1,c; E = 477 GPa

WC (Tungsten Carbide)

Material Summary:

	[Ref. 1,a]	[Ref. 1,a]
Manufacturer........:	Ugine Carbone, Inc.	Ugine Carbone, Inc.
Material Designation:	tungsten carbide	tungsten carbide
Material Form.......:	polycrystal	polycrystal
Composition.........:	WC	WC
(mass fraction)	0.5% Co	
Processing..........:		

References:

[1] J. L. Chermant, A. Deschanvres and F. Osterstock, "Toughness and Fractography of TiC and WC" Fracture Mechanics of Ceramics, Vol. 4, pp. 891-901 (1978).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [MPa·m$^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
6		8.9	90	SENB	air	Ref. 1,a; technique used a starter crack, E = 680 GPa
6		7.5	80	SENB		Ref. 1,b; technique used a starter crack, E = 700 GPa

$Y_3Al_5O_{12}$ (Yttrium Aluminum Oxide)

Material Summary:

[Ref. 1]

Manufacturer........: In laboratory
Material Designation: yttrium aluminum oxide; yttrium aluminum garnet; YAG
Material Form.......: single crystal
Composition.........: $Y_3Al_5O_{12}$
Processing..........: Crystal growth

References:

[1] T. Mah and T. A. Parthasarathy, "Effects of Temperature, Environment, and Orientation on the Fracture Toughness of Single-Crystal YAG," Journal of the American Ceramic Society, Vol. 80, No. 10, pp. 2730-2734 (1997).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [MPa·m$^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
		2.2		SENB	air	Single crystal

$YBa_2Cu_3O_{7-x}$ (Y:123)

Material Summary:

	[Ref. 1-8]	[Ref. 9-13]
Manufacturer........:	Authors' laboratories	Authors' laboratories
Material Designation:	Y:123	Y:123
Material Form.......:	polycrystal	Single crystal
Composition.........:	$YBa_2Cu_3O_{7-x}$	$YBa_2Cu_3O_{7-x}$
Processing..........:		

References:

[1] R. F. Cook, T. M. Shaw, and P. R. Duncombe, "Fracture Properties of polycrystalline $YBa_2Cu_3O_x$," Advanced Ceramic Materials, Vol. 2, pp. 606-614 (1987).

[2] F. Yeh and K. W. White, "Fracture Toughness Behavior of the $YBa_2Cu_3O_{7-x}$ Superconducting Ceramic with Silver Oxide Additions," Journal of Applied Physics, Vol. 70, pp. 4989-4994 (1991).

[3] F. Osterstock, I. Monot, G. Desgardin, and B. L. Mordike, "Influence of Grain Size on the Toughness and Thermal Shock Resistance of polycrystalline $YBa_2Cu_3O_{7-x}$," Journal of the European Ceramic Society, Vol. 16, pp. 687-694 (1996).

[4] N. M. Alford, J.D. Birchall, W.J. Clegg, M.A. Harmer, K. Kendall, and D.H. Jones, "Physical and Mechanical Properties of $YBa_2Cu_3O_{7-x}$ Superconductors," Journal of Materials Science, Vol. 23, pp. 761-768 (1988).

[5] G. G. Siu and W. G. Zeng, "Phase-Transition Toughening of High-Tc Superconducting Ceramics," Journal of Materials Science, Vol. 28, pp. 5875-5879 (1993).

[6] I.M. Low, R.D. Skala, and G. Mohazzab-H, "Mechanical and Fracture Properties of Epoxy-Modified YBaCuO (123) Superconductors,", Journal of Materials Science Letters, Vol. 13, pp. 1340-1342 (1994).

[7] F. Osterstock, S. Strauss, B.L. Mordike, and G. Desgardin, "Toughness and Thermoshock Resistance of polycrystalline $YBa_2Cu_3O_{7-x}$," Journal of Alloys and Compounds, Vol. 195, pp. 679-682 (1993).

[8] K. C. Goretta, M. L. Kullberg, D. Bar, G. A. Risch, and J. L. Routbort, "Fracture Toughness of $YBa_2Cu_3O_x$ Containing Y_2BaCuO_5 and ZrO_2," Superconductor Science and Technology, Vol. 4, pp. 544-547 (1991).

[9] Q. H. Ni, D. L. Wang, and Q. P. Kong, "Mechanical Properties of YBCO Superconductors Prepared by the Melt-Textured Growth Method," Physica Status Solidi (a), Vol. 138, pp. K29-K33 (1993).

[10] V. V. Demirskii, H. J. Kaufmann, S. V. Lubenets, V. D. Natsik, and L. S. Fomenko, "Microhardness and Microbrittleness of single crystals of the High-Temperature Superconductor YBaCuO," Soviet Physics Solid State, Vol. 31, pp. 1065-1066 (1989).

[11] R. F. Cook, T. R. Dinger, and D. R. Clarke, "Fracture Toughness Measurements of $YBa_2Cu_3O_x$ single crystals," Applied Physics Letters, Vol. 51, pp. 454-456 (1987).

[12] A. S. Raynes, S. W. Freiman, F. W. Gayle, and D. L. Kaiser, "Fracture Toughness of $YBa_2Cu_3O_{7-x}$ single crystals: Anisotropy and Twinning Effects," Journal of Applied Physics, Vol. 70, pp. 5254-5257 (1991).

[13] A. Goyal, P.D. Funkenbusch, D. M. Kroeger, and S. J. Burns, "Anisotropic Hardness and Fracture Toughness of Highly Aligned $YBa_2Cu_3O_{7-x}$," Journal of Applied Physics, Vol. 71, pp. 2363-2367 (1992).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
	14	1.3		ICS	air	Ref. 1; assumes E/H = 40
	33	1.05		CNB	air	Ref. 2
	27	1.13		CNB	air	
	13	1.40		CNB	air	
1.5	19	0.70		ICS	air	Ref. 3; E = 180 GPa; H = 8.7 GPa
3.5	19	0.84		ICS	air	
5.5	22	1.64		ICS	air	
10.0	16	0.24		ICS	air	
	20	1.07		SENB	air	Ref. 4
7	11	0.94		SENB	air	Ref. 5
	40	0.5		SENB	air	Ref. 6
						Ref. 7; E = 180 GPa; H = 8.7 GPa
	19	0.70		ICS	air	Very fine grains
	19	0.84		ICS	air	Fine grains
	22	1.64		ICS	air	Medium grains
	16	0.24		ICS	air	Coarse grains
	15	1.2		SENB	air	Ref. 8
	10	1.5		SENB	air	
	7	3.1		SENB	air	

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
	0	1.85		ICS	air	Ref. 9; E = 97.1 GPa
	0	0.43		ICS	air	Ref. 10; T_c = 65 K
	0	1.1		ICS	air	Ref. 11
	0	0.8		ICS	air	Ref. 12; E = 157 GPa; twinned; cracks parallel to c
	0	0.3		ICS	air	E = 89 GPa; twinned; cracks perpendicular to c
	0	0.67		ICS	air	Ref. 13; E/H = 27; (001) face

Y_2O_3 (Yttrium Oxide)

Material Summary:

	[Ref. 1]	[Ref. 2]
Manufacturer........:	In laboratory	Raytheon Research Division
Material Designation:	yttrium oxide; yttria	yttrium oxide; yttria
Material Form.......:	polycrystal	polycrystal
Composition.........:	Y_2O_3	Y_2O_3
Processing..........:	Sintered	Hot isostatically pressed

References:

[1] L. D. Monroe and J. R. Smyth, "Grain Size Dependence of Fracture Energy of Y_2O_3" Journal of the American Ceramic Society, Vol. 61, No. 11-12, pp. 538-539 (1978).

[2] D. C. Harris, G. A. Hayes, N. A. Jaeger, L. D. Sawyer, R. C. Scheri, M. E. Hills, K. R. Hayes, S E. Homer, Y. L. Tsai, and J. J. Mecholsky, Jr., "Mechanical Strength of Hemispheric Domes of Yttria and Lanthana-Doped Yttria," Journal of the American Ceramic Society, Vol. 75, pp. 1247-1253 (1992).

Property Table:

Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
5	4		4.6	SENB	air	Ref. 1
9	2		5.0	SENB		
27	3		5.2	SENB		
42	3		4.9	SENB		
64	2		4.1	SENB		
90	2		3.8	SENB		
113	2		3.8	SENB		
450		0.71		ICS	air	Ref. 2

ZnS (Zinc Sulfide)

Material Summary:

[Ref. 1,2]

Manufacturer........: Raytheon
Material Designation: zinc sulfide
Material Form.......: polycrystal
Composition.........: ZnS
Processing..........: CVD

References:

[1] D. A. Shockey, D. J. Rowcliffe, and K. C. Dao, "Fracture Toughness of CVD ZnS" ONR Contract N00014-76-C-0657 (1977).

[2] A. G. Evans and E. A. Charles, "Fracture Toughness Determinations by Indentation" Journal of the American Ceramic Society, Vol. 59, No. 7-8, pp. 371-372 (1976).

Property Table:

Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
7		0.75		ER	air	Ref. 1; flat bottomed notch
		1.0		ICS	dry N2	Ref. 2; *H* = 1.9 GPa; ν = 0.3

ZnSe (Zinc Selenide)

Material Summary:

[Ref. 1,2]

Manufacturer........: Raytheon
Material Designation: zinc selenide
Material Form.......: polycrystal
Composition.........: ZnSe
Processing..........: CVD

References:

[1] A. G. Evans and E. A. Charles, "Fracture Toughness Determinations by Indentation" Journal of the American Ceramic Society, Vol. 59, No. 7-8, pp. 371-372 (1976).
[2] J. J. Mecholsky, S. W. Freiman, and R. W. Rice, "Fracture Surface Analysis of Ceramics" Journal of Materials Science, Vol. 11, pp. 1310-1319 (1976).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
		0.9		ICS	dry N2	Ref. 1; H = 1.0 GPa; ν = 0.3
20-30			4	AMDCB	air	Ref. 2; E = 69 GPa

ZrN (Zirconium Nitride)

Material Summary:

	[Ref. 1]
Manufacturer........:	In laboratory
Material Designation:	zirconium nitride
Material Form.......:	polycrystal
Composition.........:	ZrN
Processing..........:	Hot isostatically pressed

References:

[1] N. Alexandre, M. Desmaison-Brut, F. Valin, and M. Boncoeur, "Mechanical Properties of Hot Isostatically Pressed Zirconium Nitride Materials"
Journal of Materials Science, Vol. 28, pp. 2385-2391 (1993).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa\cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
	1.4	6.2	48	SENB	air	Ref. 1; E = 380 GPa
	1.7	4.4				E = 376 GPa
	2.9	3.7				E = 362 GPa
	3.2	3.9				E = 359 GPa
	6.0	3.6				E = 326 GPa
	8.2	3.7				E = 300 GPa

ZrO_2 (Zirconia, cubic)

Material Summary:

	[Ref. 1,2a]	[Ref. 2b]
Manufacturer........:	In laboratory	In laboratory
Material Designation:	zirconia (cubic)	zirconia (cubic)
Material Form.......:	polycrystal	polycrystal
Composition.........: (mass fraction)	$ZrO_2 \cdot xY_2O_3$	$ZrO_2 \cdot xCaO$
Processing..........:	Sintered	Sintered

References:

[1] T.E. Fischer, M.P. Anderson, and S. Jahanmir, "Influence of Fracture Toughness on the Wear Resistance of Yttria-Doped Zirconium Oxide," Journal of the American Ceramic Society, Vol. 72, pp. 252-257 (1989).

[2] R.P. Ingel, D. Lewis, B.A. Bender, and R.W. Rice, "Physical, Microstructural and Thermomechanical Properties of ZrO_2 single crystals," Advances in Ceramics, Vol. 12, pp. 408-414 (1984).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
	< 3	2.5		NDC	air	Ref. 1; 10 % Y_2O_3 (6 % mol.frac.)
		1.6		ICS	air	Ref. 2,a; 20 % Y_2O_3; *E* = 233 GPa; density = 5.91 g/cm^3
		2.5		ICS	air	Ref. 2,b; 9 % CaO; *E* = 210 GPa density = 5.68 g/cm^3

ZrO_2 (Zirconia, PSZ)

Material Summary:

	[Ref. 1,2a,3a]	[Ref. 2b]	[Ref. 3b]
Manufacturer........:	In laboratory	In laboratory	In laboratory
Material Designation:	zirconia (PSZ)	zirconia (PSZ)	zirconia (PSZ)
Material Form.......:	polycrystal	polycrystal	polycrystal
Composition.........: (mass fraction)	$ZrO_2 \cdot xMgO$	$ZrO_2 \cdot xY_2O_3$	$ZrO_2 \cdot xCaO$
Processing..........:	Sintered	Sintered	Sintered

References:

[1] J. Wang, W.M. Rainforth, T. Wadsworth, and R. Stevens, "The Effects of Notch Width on the SENB Toughness for Oxide Ceramics," Journal of the European Ceramic Society, Vol. 10, pp. 21-31 (1992).

[2] G.A. Gogotsi, A.V. Drozdov, V.P. Zavata, and M.V. Swain, "Comparison of the Mechanical Behaviour of Zirconia Partially Stabilized with Yttria and Magnesia," Journal of the Australasian Ceramic Society, Vol. 27, pp. 37-49 (1991).

[3] R.P. Ingel, D. Lewis, B.A. Bender, and R.W. Rice, "Physical, Microstructural and Thermomechanical Properties of ZrO_2 single crystals," Advances in Ceramics, Vol. 12, pp. 408-414 (1984).

Property Table:

Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
50		9.8		SENB	air	Ref. 1; 240 μm notch width; 3 % MgO
50		11.2		SENB	air	490 μm notch width
50		12.3		SENB	air	800 μm notch width
50		12.3		SENB	air	1300 μm notch width
		9.7		SENB	air	Ref. 2a; notch; *E* = 206 GPa
		12.0		SENB	air	sharp crack; density = 5.71 g/cm^3
		9.3		SENB	air	Ref. 2b; notch; 6% yttria; *E* = 185 GPa
		4.8		SENB	air	sharp crack; density = 5.81 g/cm^3
		4.8		ICS	air	Ref. 3,a; 2.8 % MgO; *E* = 200 GPa; density = 5.79 g/cm^3
		4.0		ICS	air	Ref. 3,b; 4.0 % CaO; *E* = 210 GPa; density = 5.85 g/cm^3

ZrO_2 (Zirconia, TZP)

Material Summary:

	[Ref. 1-5]	[Ref. 6-8]	[Ref. 9]
Manufacturer........:	In laboratory	In laboratory	Toyo Soda Manf. Co.
Material Designation:	zirconia (TZP)	zirconia (TZP)	zirconia (TZP)
Material Form.......:	polycrystal	polycrystal	polycrystal
Composition.........: (mole fraction)	$ZrO_2 \cdot xY_2O_3$	$ZrO_2 \cdot xCeO_2$	$ZrO_2 \cdot$ 3% Y_2O_3
Processing..........:	Sintered	Sintered	Sintered and post-hipped

References:

[1] T.E. Fischer, M.P. Anderson, and S. Jahanmir, "Influence of Fracture Toughness on the Wear Resistance of Yttria-Doped Zirconium Oxide," Journal of the American Ceramic Society, Vol. 72, pp. 252-257 (1989).

[2] G.D. Quinn, R.J. Gettings, and J.J. Kubler, "Fracture Toughness by the Surface Crack in Flexure (SCF) Method: Results of the VAMAS Round Robin," Ceramic Engineering and Science Proceedings, Vol. 15, pp. 846-855 (1994).

[3] J. Wang, W.M. Rainforth, T. Wadsworth, and R. Stevens, "The Effects of Notch Width on the SENB Toughness for Oxide Ceramics," Journal of the European Ceramic Society, Vol. 10, pp. 21-31 (1992).

[4] G.A. Gogotsi, A.V. Drozdov, V.P. Zavata, and M.V. Swain, "Comparison of the Mechanical Behaviour of Zirconia Partially Stabilized with Yttria and Magnesia," Journal of the Australasian Ceramic Society, Vol. 27, pp. 37-49 (1991).

[5] G.A. Gogotsi, E.E. Lomonova, and V.G. Pejchev, "Strength and Fracture Toughness of Zirconia Crystals," Journal of the European Ceramic Society, Vol. 11, pp. 123-132 (1993).

[6] S. Maschio, O. Sbaizero and S. Meriani, "Mechanical Properties in the Ceria-Zirconia System," Journal of the European Ceramic Society, Vol. 9, pp. 127-132 (1992).

[7] K. Tsukuma and M. Shimada, "Strength, Fracture Toughness and Vickers Hardness of CeO_2-Stabilized Tetragonal ZrO_2 polycrystals (Ce-TZP)," Journal of Materials Science, Vol. 20, pp. 1178-1184 (1985).

[8] K. Tsukuma, "Mechanical Properties and Thermal Stability of CeO_2 Containing Tetragonal Zirconia polycrystals," American Ceramic Society Bulletin, Vol. 65, pp. 1386-1389 (1986).

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Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
		11.6		NDC	air	Ref. 1; 3 % Y_2O_3
		4.4		SCF	air	Ref. 2; 3 % Y_2O_3
1.4		17.2		SENB	air	Ref. 3; 2.0 % Y_2O_3; 250 μm notch width
1.4		11.2		SENB	air	2.5 %; 93 μm notch width
1.3		12.3		SENB	air	3.0 %; 130 μm notch width
						Ref. 4; 2.6 % Y_2O_3;
		9.5		SENB	air	notch
		5.6		SENB	air	sharp crack
		10.6		SENB	air	Ref. 5; 3 % Y_2O_3
		10.0		SENB	air	Ref. 6; 10 % CeO_2
		8.5		SENB	air	12 %
		4.4		SENB	air	14 %
		4.3		SENB	air	16 %
		4.0		SENB	air	24 %
		3.2		SENB	air	32 %
		2.6		SENB	air	40 %
		2.0		SENB	air	48 %
0.5		8.7		ICS	air	Ref. 7; 8.6 % CeO_2
0.5		6.4		ICS	air	9.5 %
0.5		5.3		ICS	air	10.8 %
0.5		4.9		ICS	air	12.2 %
0.5		4.4		ICS	air	15.8 %
2.5		17.1		ICS	air	8.6 %
2.5		16.9		ICS	air	9.5 %
2.5		12.6		ICS	air	10.8 %
2.5		9.5		ICS	air	12.2 %
2.5		5.8		ICS	air	15.8 %

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
0.5		23.0		ICS	air	Ref. 8; 12 % CeO_2
0.5		8.0		ICS	air	14 %
0.5		4.0		ICS	air	16 %
1.0		36.0		ICS	air	12 %
1.0		9.0		ICS	air	14 %
1.0		5.0		ICS	air	16 %
0.45		4.7		SENB	air	Ref. 9; V-notch; 3 % Y_2O_3

ZrO_2 (Zircar)

Material Summary:

	[Ref. 1]
Manufacturer........:	Union Carbide
Material Designation:	zircar
Material Form.......:	polycrystal
Composition.........:	ZrO_2
Processing..........:	

References:

[1] J. J. Mecholsky, S. W. Freiman, and R. W. Rice, "Fracture Surface Analysis of Ceramics" Journal of Materials Science, Vol. 11, pp. 1310-1319 (1976).

Property Table:
Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
0.4			70	AMDCB	air	E = 280 GPa

ZrO_2 (Zyttrite)

Material Summary:

	[Ref. 1]
Manufacturer........:	AFML
Material Designation:	Zyttrite
Material Form.......:	polycrystal
Composition.........:	ZrO_2
Processing..........:	

References:

[1] J. J. Mecholsky, S. W. Freiman, and R. W. Rice, "Fracture Surface Analysis of Ceramics" Journal of Materials Science, Vol. 11, pp. 1310-1319 (1976).

Property Table:

Temperature = 23 °C

Grain Size [μm]	Porosity [%]	Fracture Toughness [$MPa \cdot m^{1/2}$]	Fracture Energy [J/m^2]	Measurement Method	Measurement Environment	Comments
10			13	AMDCB	air	E = 260 GPa