Kirk-Othmer Encyclopedia of Chemical Technology.

CERAMICS, OVERVIEW

Ceramics may be defined as a class of inorganic, nonmetallic solids that are subjected to high temperature in manufacture or use. Ceramics are distinguished both from metals and metallic alloys and from organic materials such as polymers and plastics, and although syntheses may involve solutions or colloids, the final products are solids. The most common ceramics are oxides, carbides (qv), and nitrides (qv), but silicides, borides, phosphides, sulfides, tellurides, and selenides are ceramics, as well as elemental materials such as carbon (qv) and silicon (see Silicon and silicon alloys). Ceramic synthesis and processing generally involve high temperatures and the resulting materials are refractory or heat resistant (see Rrefractories). Ceramics are commonly thought to include only polycrystalline materials, but glasses, which are noncrystalline, and single-crystal materials such as ruby lasers, are classified as ceramics (see Glass; Lasers). Examples of applications of less common ceramics include quartz optical fibers (see Fiber optics) that are revolutionizing telecommunications, the insulating tiles on the space shuttle (see Ablative materials), silicon nitride turbocharger rotors used in some passenger automobiles, and the corderite multilayer substrates used as chip carriers in the latest generation of supercomputers (see Computer technology).

Ceramic components are frequently made by sintering of powders. Alternatives such as melt processing are often uneconomical because many ceramics have very high melting temperatures or decompose before melting. Many ceramic melts are also very reactive with container materials, which imposes additional limitations on available processing methods. A rule of thumb in ceramic processing is that the quality of a ceramic part is no better than the quality of the powder from which it is made. Thus, much effort has been directed to improving the properties of ceramic powders. Improvements include higher purity, finer particle size, less agglomeration, and better control of compositions and distributions of dopants.

One of the many possible ways of classifying ceramics is according to use. One group is the bulk or commodity ceramics that have had relatively little processing beyond the constituent raw materials. These are primarily low value-added materials such as brick, tile, pottery, and abrasive grain (see Abrasives). At the other extreme are the engineering or fine ceramics that are characterized as low volume, high value-added, highly processed materials having carefully controlled properties (see Advanced ceramics). Some of the main types of engineering ceramics include: (*1*) electronic ceramics, which include dielectrics, ferroelectrics (qv), ferromagnetic ceramics, piezoelectrics, and superconductors (see also Ceramics as electrical materials); (*2*) structural ceramics, which are strong, fracture-resistant materials such as silicon nitride [12033-89-5], Si_3N_4, silicon carbide [409-21-2], SiC, and toughened zirconium dioxide [1314-23-4], ZrO_2; (*3*) wear-resistant ceramics, such as the carbides, nitrides, and borides (see Boron compounds; Tool materials); (*4*) optical ceramics such as Cr doped Al_2O_3 (ruby [12174-49-1]); silicon dioxide [7631-86-9], SiO_2, fiber; lead lanthanum zirconium titanate (PLZT); and yttrium aluminum garnet (YAG); and (*5*) bioceramics, which are low or controlled reactivity materials for in-body use such as aluminum oxide [1344-28-1], Al_2O_3, and hydroxyapatite [1306-06-5] (see Prosthetic and biomedical devices).

Some of the many ceramic materials and precursors discussed in the following sections are listed in Table 1.

Table 1. Ceramics and Precursors Discussed in Text

Material	CAS Registry Number	Molecular formula
acetic acid	[64-19-7]	CH_3COOH
aluminum	[7429-90-5]	Al
aluminum nitride	[24304-00-5]	AlN
aluminum oxide	[1344-28-1]	Al_2O_3
aluminum silicate	[12141-46-7]	$3Al_2O_3{\cdot}2SiO_2$
ammonium hydroxide	[1336-21-6]	NH_4OH
antimony oxide	[1314-60-9]	Sb_2O_3
arsenic(III) oxide	[1327-53-3]	As_2O_3
arsenic(V) oxide	[1303-28-2]	As_2O_5
barium titanate	[12047-27-7]	$BaTiO_3$
beryllia	[1304-56-9]	BeO
beryllium oxide	[1304-56-9]	BeO
bismuth calcium strontium copper oxide		$Bi_2CaSr_2Cu_2O_x$
bismuth(III) oxide	[1304-76-3]	Bi_2O_3
boron nitride (cubic)	[10043-11-5]	BN
boron phosphide (cubic)	[12777-46-7]	BP
boron trioxide	[1303-86-2]	B_2O_3
calcium oxide	[1305-78-8]	CaO
carbon	[14762-74-4]	C
carbon dioxide	[124-38-9]	CO_2
carbonic acid	[463-79-6]	H_2CO_4
chromium dioxide	[12018-01-8]	CrO_2
cobalt ferrite	[12052-28-7]	$CoFe_2O_4$
copper	[7440-50-8]	Cu
cordierite	[1302-88-1]	$2MgO{\cdot}2Al_2O_3{\cdot}5SiO_2$
cuprous oxide	[1317-39-1]	Cu_2O
diamond	[7782-40-3]	C
diethanolamine	[111-42-2]	$(HOCH_2CH_2)_2NH$
feldspar	[68476-25-5]	$(K,Na)_2O{\cdot}Al_2O_3{\cdot}6SiO_2$
ferric oxide	[1309-37-1]	Fe_2O_3
ferrite	[1317-54-0]	$(Mn_{1-x}Mg_x)Fe_2O_4$ $(M_{1-x}Zn_x)Fe_2O_4$ M = divalent ion
ferrosoferric oxide	[1317-61-9]	Fe_3O_4
flint (fused silica)	[60676-86-0]	SiO_2
gadolinium garnet		$Gd_2O_3{\cdot}5Fe_2O_3$
gallium arsenide	[1303-00-0]	GaAs
gallium aluminum nitride	[39460-99-6]	GaAlN
gallium nitride	[25617-97-4]	GaN
gallium oxide	[12024-21-4]	Ga_2O_3
germanium dioxide	[1310-53-8]	GeO_2
graphite	[7782-42-5]	C
indium oxide	[1312-43-2]	In_2O_3
indium phosphide	[22398-80-7]	InP
iron	[7439-89-6]	Fe
2-propanol	[67-63-0]	$(CH_3)_2CHOH$
kaolin	[1332-58-7]	
lanthanum barium copper oxide		$LaBaCuO_4$
lanthanum oxide	[7439-91-0]	La_2O_3
lead	[7439-92-1]	Pb
lead acetate trihydrate	[6080-56-4]	$Pb(OOCCH_3)_2{\cdot}3H_2O$
lead lanthanum zirconate titanate		$Pb_{1-x}La\ (Zr_{1-x}Ti_x)O_3$
lead magnesium niobate (PMN)		$Pb(Mg_{1/3}Nb_{2/3})O_3$
lead monoxide	[1317-36-8]	PbO
lead oxide	[1317-36-8]	PbO
lead titanate	[12060-00-3]	$PbTiO_3$

Table 1. ***Continued***

Material	CAS Registry Number	Molecular formula
lead zirconate	[12060-01-4]	$PbZrO_3$
lead zinc niobate (PZN)		$Pb(Zn_{1/3}Nb_{2/3})O_3$
lead zirconate titanate		$Pb(Zr,Ti)O_3$
lithium niobate	[12031-63-9]	$LiNbO_3$
lithium tantalate	[12031-66-2]	$LiTaO_3$
magnesium oxide	[1309-48-4]	MgO
manganese ferrite	[12063-10-4]	$MnFe_2O_4$
methanol	[67-56-1]	CH_3OH
methoxyethanol	[109-86-4]	$CH_3OCH_2CH_2OH$
molybdenum disulfide	[1317-33-5]	MoS_2
molybdenum(VI) oxide	[1313-27-5]	MoO_3
mullite	[1302-93-8]	$3Al_2O_3{\cdot}2SiO_2$
neodymium oxide	[7440-65-5]	Nd_2O_3
nickel ferrite	[12168-54-6]	$NiFe_2O_4$
nickel monoxide	[1313-99-1]	NiO
niobium(V) oxide	[1313-96-8]	Nb_2O_5
nylon-6	[25038-54-4]	$[\text{-}NH(CH_2)_6NHCO(CH_2)_4CO\text{-}]_n$
oxalic acid	[144-62-7]	$H_2C_2O_4$
2,4-pentadione	[123-54-6]	$CH_3COCH_2COCH_3$
phosphorous pentoxide	[1314-56-3]	P_2O_5
potassium niobate	[12030-85-2]	$KNbO_3$
rhenium trioxide	[1314-28-9]	ReO_3
silica	[10097-28-6]	SiO_2
silicon	[7440-21-3]	Si
silicon carbide	[409-21-2]	SiC
silicon nitride	[12033-89-5]	Si_3N_4
sodium chloride	[7647-14-5]	$NaCl$
spinel	[1302-67-6]	$MgAl_2O_4$
stannic dioxide	[18282-10-5]	SnO_2
strontium hexaferrite		$SrO{\cdot}6Fe_2O_3$
strontium oxide	[1314-11-0]	SrO
strontium titanate	[12060-59-2]	$SrTiO_3$
tantalum(V) oxide	[1314-61-0]	Ta_2O_5
tellurium(IV) oxide	[7446-07-3]	TeO_2
thallium calcium barium copper oxide		$Tl_2Ca_2Ba_2Cu_3O_y$
titania	[13463-67-7]	TiO_2
titanium dioxide	[13463-67-7]	TiO_2
titanium isopropoxide	[546-68-9]	$Ti(OC_3H_7)_4$
titanium(IV) oxide	[1317-80-2]	TiO_2
triaxial porcelain		$Al_2O_3{\cdot}(K,Na)_2O{\cdot}SiO_2$
triethanolamine	[102-71-6]	$(HOCH_2CH_2)_3N$
tungsten(VI) oxide	[1314-35-8]	WO_3
vanadium(V) oxide	[1314-62-1]	V_2O_5
yttria	[1314-36-9]	Y_2O_3
yttrium barium copper oxide	[107539-20-8]	$YBa_2Cu_3O_{7-\delta}$
yttrium iron oxide	[12063-56-8]	$Y_2O_3{\cdot}Fe_2O_3$
yttrium oxide	[7440-65-5]	Y_2O_3
yttrium garnet		$Y_2O_3{\cdot}5Fe_2O_3$
zinc ferrite	[12063-19-3]	$ZnFe_2O_4$
zinc oxide	[1314-13-2]	ZnO
zirconia	[1314-23-4]	ZrO_2
zirconium oxide	[1314-23-4]	ZrO_2
zirconium *n*-propoxide	[23519-77-9]	$Zr(OC_3H_7)_4$

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