

CERAMICS, GLASS AND REFRACTORIES

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1) INTRODUCTION

The word ceramic is derived from the Greek *keramos*, which means "potter's " or "pottery."

The term has long included all products made from fired clay, for example bricks, fireclay refractories, sanitary ware, and tableware. So the term "ceramic," while retaining its original sense of a product made from clay, began to include other products made by the same manufacturing process and more advance processing.

These are the technical ceramics family and most frequently they are oxides, nitrides, and carbides. However, we also classify diamond and graphite as ceramics.

Definition of Ceramics: Inorganic Materials made from Metals and Non Metals united by ionic and/or covalent bonds

Can be: crystalline, amorphous or mixture of both

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
hydrogen 1 H 1.0079																	helium 2 He 4.0026	
lithium 3 Li 6.941	beryllium 4 Be 9.0122	<div>Key:</div> <div>element name atomic number symbol atomic weight (mean relative mass)</div>										boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180	
sodium 11 Na 22.990	magnesium 12 Mg 24.305											aluminum 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948	
potassium 19 K 39.098	calcium 20 Ca 40.078	scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80	
rubidium 37 Rb 85.468	strontium 38 Sr 87.62	yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29	
cesium 55 Cs 132.91	barium 56 Ba 137.33	57-70 *	lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	renewable 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]
francium 87 Fr [223]	radium 88 Ra [226]	89-102 **	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	bohrium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	darmstadtium 110 Ds [271]	unbinilium 111 Uuu [272]	untrium 112 Uub [277]		ununquadium 114 Uuq [289]				

*lanthanoids

lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
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**actinoids

actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]
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Periodic Table - Our "Raw Material".

Material : Atoms arranged in a particular way to achieve desired properties

Material Properties and Atoms Arrangement

Material Properties (Rough Classification)

Electrical Properties

Magnetic Properties

Mechanical Properties

Thermal Properties

Optical Properties

The central question of Materials Science:

Which atoms? And, how should they be arranged to obtain desired properties?

General Properties of Ceramics

Brittleness

⇒ Mixed covalent and ionic bonding, brittle at RT but not necessary at HT

High Compressive strength

High Young's Modulus and high melting points

⇒ Strong bonds (covalent and /or ionic)

- Limited electrical and thermal conductivity

⇒ Absence of electronic cloud (directional bond)

- Low thermal shock resistance

⇒ Coefficients of thermal expansion and thermal conductivity are low

- Refractory

⇒ Stability at high temperature (NO CREEP)

- Resistance to oxidation/corrosion

⇒ Chemical stability

CLASSIFICATION

Glasses

Based on SiO_2 + additives for $\downarrow T_f$ (Temperature of Formation)

Traditional Ceramics (clay products)

- ⇒ Porous ceramics (bricks, pottery, china)
- ⇒ Compact ceramics (porcelain, earthenware)
- ⇒ Refractory ceramics

Clay: $\text{Al}_2\text{O}_3 \cdot \text{SiO}_2 \cdot \text{H}_2\text{O}$

Silica: SiO_2

Feldspar: $\text{K}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2$

Engineering Ceramics or Advanced Ceramics :

- ⇒ Refractory ceramics (SiC , Al_2O_3 , ZrO_2 , BeO , MgO).
- ⇒ Piezoelectrics and Ferroelectrics: BaTiO_3 , SrTiO_3
- ⇒ Electro-optics: LiNbO_3
- ⇒ Abrasive ceramics: nitrides and carbides Si_3N_4 , SiC
- ⇒ Molecular membranes
- ⇒ Superconductive ceramics ($\text{YBa}_2\text{Cu}_3\text{O}_7$)
- ⇒ Biomaterials : Hydroxyapatite

Areas of Applications

Property

Thermal

Insulation

Refractoriness

Thermal conductivity

Electrical and dielectric

Conductivity

Ferroelectricity

Low-voltage insulators

Insulators in electronic applications

Insulators in hostile environments

Ion-conducting

Semiconducting

Nonlinear I - V characteristics

Gas-sensitive conduct

Applications (examples)

High-temperature furnace linings for insulation (oxide fibers such as SiO_2 , Al_2O_3 , and ZrO_2)

High-temperature furnace linings for insulation and containment of molten metals and slags

Heat sinks for electronic packages (AlN)

Heating elements for furnaces (SiC , ZrO_2 , MoSi_2)

Capacitors (Ba-titanate-based materials)

Ceramic insulation (porcelain, steatite, forsterite)

Substrates for electronic packaging and electrical insulators in general (Al_2O_3 , AlN)

Spark plugs (Al_2O_3)

Sensor and fuel cells (ZrO_2 , Al_2O_3 , etc.)

Thermistors and heating elements (oxides of Fe, Co, Mn)

Current surge protectors (Bi-doped ZnO , SiC)

Gas sensors (SnO_2 , ZnO)

Property

Magnetic and superconductive

Hard magnets

Soft magnets

Superconductivity

Optical

Transparency

Translucency and
chemical inertness

Nonlinearity

IR transparency

Nuclear applications

Fission

Fusion

Applications (Example)

Ferrite magnets [(Ba, Sr)O₆Fe₂O₃]

Transformer cores [(Zn, M)Fe₂O₃, with M = Mn, Co, Mg]; magnetic tapes (rare-earth garnets)

Wires and SQUID magnetometers (YBa₂Cu₃O₇)

Windows (soda-lime glasses), cables for optical communication (ultra-pure silica)

Heat- and corrosion-resistant materials, usually for Na lamps Al₂O₃MgO)

Switching devices for optical computing (LiNbO₃)

Infrared laser windows (CaF₂, SrF₂, NaCl)

Nuclear fuel (UO₂, UC), fuel cladding (C, SiC), neutron moderators (C, BeO)

Tritium breeder materials (zirconates and silicates of Li, Li₂O); fusion reactor lining (C, SiC, Si₃N₄)

Property

Chemical

Catalysis

Anticorrosion

Biocompatibility

Mechanical

Hardness

High-temperature strength
retention

Wear resistance

Applications (Example)

Filters (zeolites); purification of exhaust gases

Heat exchangers (SiC), chemical equipment in
corrosive environments

Artificial joint prostheses (Al₂O₃)



Cutting tools (SiC whisker-reinforced Al₂O₃, Si₃N₄)

Stators and turbine blades, ceramic engines (Si₃N₄)

Bearings (Si₃N₄)

