HIGH FREQUENCY CERAMIC INSULATORS

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Abstract

High electrical resistance and low dielectric loss at high temperature. Easily de-gassed and free from gas inclusion. Must be shaped to very accurate dimensions into intricate shapes. The relative importance of the requirement varies with the specific application so that a number of different bodies have been developed with particular properties.

1.0 Introduction

Porousityis glassy matter giving closed pores so that the material can be readily de-gassed. The electrical properties resemble those of other steatite bodies except that the dielectric loss is somewhat higher.
Vacuum tube spacers – Filament support the spaces in electronic power tubes. Gas burner tips. Test and experimental parts and small orders of special shapes, eliminating cost of press dies.

Requirements
1. Low power loss, therefore low dielectric constant except for capacitors when high dielectric constant required
2. High dielectric strength
3. High specific resistance
4. Small temperature coefficient of items (1) (2) (3)
5. Smooth non-absorbent surface
6. High mechanical strength
7. Capable of being easily shaped to close tolerances
8. Relatively low thermal expansion

The relative importance of the requirement varies with the specific application so that a number of different bodies have been developed with particular properties, their grading being according to their loss factor. Four more specialized, groupings, of high frequency insulators are

1. General insulating purposes: Vitrified, mechanically strong materials with low dielectric constant and low power factor
2. Capacitors; vitrified materials with high dielectric constant and low power factors
3. For temperature independent oscillation circuits. Insulating materials with low dielectric constant and low loss factor.

1.2 Block Talc Pieces ("Lava")

Characteristics: Ware prepared by machining natural steatite talc to the required shape, having very small firing shrinkage and therefore great dimensional accuracy. Although porous is glassy matter giving closed pores so that the material can be readily de-gassed. The electrical properties resemble those of other steatite bodies except that the dielectric loss is somewhat higher.
Uses: Vacuum tube spacers – Filament support the spaces in electronic power tubes. Gas burner tips. Test and experimental parts and small orders of special shapes, eliminating cost of press dies.
Body Type: Steatite
Raw Material: Natural steatite talc free of chlorite, quartz, mica and other contaminants.

Shaping: Machining with lashes, drills, etc.

Firing: 1010^oC (1850^oF)

1.3 Phosphate-Bonded Talc Blanks or Pieces

Characteristics: A fabricated uniform body that can be machined to close tolerances, price. The properties are relatively insensitive to normal production variables.
Uses: As for block talc, especially for experimental shapes
Body Type: Steatite
Raw Materials: Normal ceramic powered talcs, orthophosphoric acid, H_3O_4 (or aluminum, dihydrogen, $Al(H_2Po_4^3)_3$ magnesium dihydrogen phosphate Mg $(H_2Po_4)_2$
Preparation: Grinding-grading-mixing in of phosphate solution
Shaping: Dry pressing, hydrostatic pressing, hot pressing
Firing: 1000C (1832^oF) gas fired

1.4 Low-Loss Steatite Bodies

Characteristics: Dense, tough and strong low-loss body with high elasticity, which can be economically manufactured to close tolerances and complicated shapes. Power factor remains almost constant from 0-100°C (32-212°F) and rises only slightly up to 300°C (572°F). a highly coherent layer of silver can be electroplated, soldered, etc.

Uses: Most widely use ceramic in electronic application, eg radio industry aerial equipment, wave band switches, tub sockets and supports, trimmer bases, condenser plates, stators and axles; coil formers; variometers, crystal holders, coaxial cable insulator lead-in and standoff antenna insulators; resistor shafts, stator supports for air condensers, relay insulators, valve holders, bases and spacers, mast bases, wire resistor cores, ball and socket insulator beads for higher temperature wire insulation.

Preparation: For plastic making: wet milling – sieve – magnets – filter press – mullers – de-airing pug

1.5 Dry Pressing:

1. Wet grinding in ball mills – filter pressing – drying of filter cake – grinding – moistening with binder solution – mixing 0 perforated drying – tabletting machine (5690 – 7110lb/m^2) 400 -500kg/cm^2 – perforated dry pan – size grinding
2. Wet grinding – sieves – magnets – spray drying – pressing into bricks – disintegrator – size grading
3. Wet grinding – centrifuge – dry grinding – mixing with metted paraffin 10% - sieve – press (4270 lb/m^2) 300kg/cm^{2}gamulate

1.6 Dry Method

4. Ready ground raw materials – weighed and proportionate – dry ground in pebble mill to mix – Simpson mixer 13% water and 3% dextrin added – granulated by rubbing through vibration sieve – rotating dryer with direct flame – very hard grains – mixing of hard grains with undried materials to give correct water content for different processes
5. Dry body mixture – dry milling – addition of olein, petroleum, water, sulphite 1ye 0.5-5% - mixer – press (7110lb/m^2) 500kg/cm^2 – edge runner mill or crushing rolls – size grading sieve

Shaping: Extrusion, cutting and turning 20 – 28% water, horizontal extrusion; 16-20%, water, vertical extrusion

Slip casting (avoid if possible, steatite shows poor castability because a high water content, slow build-up and lower precision).

Plasting pressing, 12-16% water + 2% vegetable oil (lamination may occur) firing shrinkage 16-20%.

Dry Pressing: Bodies of high talc content can be pressed with zero moisture content and therefore required no drying. No lamination occurs. With properly granulated body very high production rates are possible in dry pressing. Firing shrinkage 6-10%

1.7 Praying

Fettling, etc

Firing: 1250 – 1400°C (2282 – 2552°F), cone 8-14, steatite has very small firing range, 30-40°C for ultra low loss only 10-20°C

Electric – gas – or oil fired tunnel kilns. Small intermittent electric or gas kiln Coal-fired round intermittent kiln.

Finishing: If fired to only 900°C can be sawn, drilled, ground, shaped, milled, gears and screw cut, etc, grinding, lapping, honing, tumbling, polishing, fully vitrified pieces can be highly polished. Metallising and metal assembly

Glazing: spraying

Glost Firing: Circular tunnel kiln

1.8 Low Loss Cordierite Bodies

Characteristics: Dense bodies of very low thermal expansion and therefore very high thermal resistance. They are different to glaze successfully, suitable both for high-frequency and for high-tension application

Uses: Resistance wire supports, coil forms, especially in radio where dimensional stability means constancy of inductance of the oil. Electric water-boiler insulators. Arc chutes fuse cores and casings for high current oil burners ignition insulators, rheostat blocks and dimmer winding cores. Resistor bobbins and spool

Body Type: cordierite

Raw Material: Talc, clay, alumina

Manufacture: similar to steatite. The firing range tends to be very small

1.9 Low Loss Forsterite Bodies

Characteristic: Dense ware consisting largely of forsterite crystals with excellent dielectric properties at elevated temperatures. The resistivity falls to 10^6 only above 1000C (1832°F). The expansion coefficient is high so that thermal shock resistance is low, but expansion is practically linear from room temperature to 1000°C (1832°F). The expansion matches that of some nickel-iron alloys so that strain-free vacuum – or pressure-tight metal – ceramic seals can be made. The power factor remains low at centimeter wave lengths when steatite bodies become quite lossy.

Uses: low-loss electronic uses

Body Type: Forsterite

Raw Material: Talc, magnesium hydroxide, clay, alkaline earth compound

Manufacture: As for steatite

Firing: 1250-1400°C (2282-2552°F) cone 8-14 wider firing range than steatite.

Finishing: sealing into suitable nickel iron alloy

(a) Small assemblies, not required to insulate high voltages at high frequencies; molybdenum meltallising process. (iron and molybdenum or iron and manganese powders are fused to the ceramics in a hydrogen atmosphere. The conductive coating is electroplated and can then be brazed or soft soldered)
(b) Large assemblies; vacuum-hydride process, (hydrides of titanium, zirconium, thorium or tatanlum are applied as a bond between metal and ceramic and decomposed to the metal by firing vacuo

2.0 Low-Loss Zircon Porcelain Pieces
Characteristic: many properties lie between those of porcelain and steatite. Very good heat-shock resistance because of a low expansion coefficient, also good mechanical strength complete vitrification (impervious to high-pressure dye solutions) Low power factor and low loss factor up 200°C (392°F). these bodies contain clay and can be shaped by plastic method, their firing range is much greater than other low-loss bodies so that they can be mass produced much more easily. However, zircon is very abrasive towards dies.
For many electrical purposes zircon porcelain is superior to all but sinter-alumina which is too expensive to be competitive.
Uses: High frequency work, sparkling plugs, circuit breakers (using high strength), supporting base for tube resistors. High temperature, high voltage insulation, terminal and switch plates

Body Type: Zircon porcelain

Raw Material: Zircon, double zirconium alkaline earth silicate clay, bentonite

Preparation: Zircon grinding, wet or dry mixing of materials, normal method.

Shaping: The body is plastic, casting dry pressing. Throwing and turning, extrusion and turning, plastic forming (13-17% moisture). The zircon sand is very abrasive and wears out dies and tools easily. Tungsten carbide tools must be used. Wet methods, in which an evacuated die is used, reduce wear.

Glazing: Normal glazes are absorbed by zircon bodies unless very heavily applied and in any case craze. Special glazes give compression

Firing: According to body cones 6 upward to 26, but normally cone 10-13, 1300-1380°C (2372-2516°F)

2.1 Lithia Porcelain
Characteristics: A body that can be adjusted to have small positive, negative or zero expansion. The last type can be used for completely temperature stable pieces. Very high thermal shock resistance shown by resistance to 100 repeated cycles between 1090°C and 190°C (1994 – 310°F)

Uses: Temperature stable dielectric pieces

Body Type: Lithia porcelain

Raw Materials: Lithium Carbonate, clay, flint, alumina

Preparing, shaping, firing, normal technical porcelain method

2.2 Low-Loss Wollastonite Pieces
Characteristics: very low dielectric loss combined with good mechanical strength. Vitrification occurs at considerably lower temperature than steatite, zircon and other low-loss bodies. High frequency applications

Body Type: Wollastonite

Raw Material: wollastonite, ball clay (bentonite). Barium carbonate, boron phosphate, zircon, alumina, barium zirconium silicate. Organic binders, methocel, carbon ax

Preparation: Grinding – grading – dry mixing in Lancaster mixer – solution of binders added, 17% moisture – mix – condminuting machine to give correct particles size for extrusion. Extrusion scrap dried and graded for dry pressing.

Shaping: Horizontal ram extrusion, dry pressing

Firing: 1200-1250°C (2192-2282°F) core 6 – 8

2.3 Ceramic Insulators as Spacers in Vacuum Tubes

Requirements: High electrical resistance and low dielectric loss at high temperature. Easily de-gassed and free from gas inclusion. Must be shaped to very accurate dimensions into intricate shapes

Bodies: High alumina, high beryllia, high magnesia, high zirconia, special non-shrinking body; 60% constituents melting above 2000°C, 40% constituents melting below 1000°C, binders, this is fired to slightly above the low-melting constituent

Special Shaping Method for Alumina or Zirconia: Make into thick paste with water, press into mould dry and fire to 1000°C (1822°F) machine to accurate shape with high-sppeed tools allowing for 10% shrinkage – fire 1700°C (3092°F)

2.4 Rutile Bodies

Characteristics: Bodies of dielectric constant up to about 85, and a negative temperature coefficient of dielectric constant. Small alterations by composition can be made to give predetermined values of E and the temperature coefficient. By suitable blending with materials of positive temperature coefficient a body of zero coefficient can be made. Bodies of very low power factor can be made.

Uses: Capacitors and condensers for trimming circuit components of opposite temperature drift to maintain constant frequency characteristic e.g tuned wireless circuits

Body Type: Rutile

Raw Materials: Purified fine titania, fluxes, titanates, oxides, clay

Preparation: Grinding – mixing – sieving – filter pressing – granulating – size grading

Shaping:
(1) Dry pressing, with and of wax or dextrin
(2) Hydrostatic pressing and turning
(3) Extrusion, with plastiasers
(4) Plastic method
(5) Casting, deflocculated with sodium pyrophosphate

Firing: 1300 – 1400°C (2372-2552°F) cone 10-13/14. Place on calcined or fused alumina. Highly oxidizing atmosphere with carefully regulated heating and cooling schedule essential.

2.5 High PermitivityRutyice Bodies

Characteristic: Dielectric constant from 100-2000, and positive temperature coefficient. Some samples show different colours in the light and dar, probably due to some photo-electric effect. Transparent to ultraviolet light

Uses: Capacitors, optical and electrical lenses. VHF antennae increasing voltage and power output of electrostatic generators e.gwimshurst machines, condensers microphones.

2.6 Magnesium Titanate Bodies

Characteristics: Very low power factor below 1 x 10^{-4} at 1mc/s 20°C dielectric constant about 10-20 at 25°C and slightly positive to zero temperature coefficient of capacity.

Uses: Temperature-stable radio equipment

Making: Low clay and high alkalinity leads to poor plasticity. Small pieces, pressing extrusion, large pieces, pressing followed by turning

Firing: 1400°C – 1600°C (2552-2912F)

2.7 High Permitivity Capacitors

Characteristics: High permittivity allowing much smaller capacitors but generally high temperature coefficient and some undesirable ageing effect.
Uses: By-pass and coupling capacitors
Body Type at Room Temperature
Barium titanate bodies 1200 – 1500
Barium-strontium titanate bodies10 – 000
Strontium titanate bodies
225 – 250
Calcium titanate bodies
150 – 175 (H100)
Compare heavy grade titanate
95 – 105
Magnesium titanate
13 – 18 (k 56)

Raw Materials: prepared pure titanates, bentonite 1-2%, other binders
Firing: Pure Ba$\pi$$O_3$-1400 – 1450°C (2552-2640°F) Ba$\pi$$O_3$ with 1-2% clay 1350°C (2462°F)

Conclusion

For many electrical purposes zircon porcelain is superior to all but sinter-alumina which is too expensive to be competitive.

High frequency work, sparkling plugs, circuit breakers (using high strength), supporting base for tube resistors. High temperature, high voltage insulation, terminal and switch plates

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