International Journal of Computing and Business Research (IJCBR)
ISSN (Online) : 2229-6166
Volume 6 Issue 2 March 2015
Manuscript ID: ISSN22296166V6I203042015-04

IMPACT OF HUMIDITY AND TEMPERATURE ON CERAMIC MATERIALS

Anand Kumari
Delhi, India
dash23521@gmail.com

ABSTRACT

Ceramic tile is very tolerant to temperature extremes. The effects are that ceramic tile can expand and contract, to some degree, from exposure to temperature and moisture changes. The more absorbing the ceramic tile the more it will be affected. It is never good to have extremely rapid changes in temperature or in moisture, as we know how glass can crack with rapid temperature changes. As long as you have proper placement of movement (expansion) joints in the tiled areas and you have a good quality installation, the temperature and humidity changes in seasonal changes or from warming a cold house should not affect the ceramic tile. The effects of temperature and humidity on the breakage propensity of two organic materials, Aspirin and sucrose, were investigated. The breakage propensities of both materials were found to be insensitive to humidity at ambient temperature; however they both showed a change in their impact breakage extent as a function of temperature, with Aspirin showing a more pronounced trend as compared to sucrose. This manuscript underlines the assorted dimensions associated with the humidity and temperature on ceramics.

Keywords: Ceramics, Humidity Factors, Temperature Factors

Introduction

A ceramic is an inorganic, non-metallic, solid material comprising metal, non-metal or metalloid atoms primarily held in ionic and covalentbonds. This article gives an overview of ceramic materials from the point of view of materials science.

The crystallinity of ceramic materials ranges from highly oriented to semi-crystalline, vitrified, and often completely amorphous (e.g., glasses). Most often, fired ceramics are either vitrified or semi-vitrified as is the case with earthenware, stoneware, and porcelain. Varying crystallinity and electron consumption in the ionic and covalent bonds cause most ceramic materials to be good thermal and electrical insulators(extensively researched in ceramic engineering). With such a large range of possible options for the composition/structure of a ceramic (e.g. nearly all of the elements, nearly all types of bonding, and all levels of crystallinity), the breadth of the subject is vast, and identifiable attributes (e.g. hardness, toughness, electrical conductivity, etc.) are hard to specify for the group as a whole. General properties such as high melting temperature, high hardness, poor conductivity, high moduli of elasticity, chemical resistance and low ductility are the norm,with known exceptions to each of these rules (e.g. piezoelectric ceramics, glasstransition temperature, superconduct ive ceramics, etc.). Many composites, such as fiberglass and carbon fiber, while containing ceramic materials, are not considered to be part of the ceramic family.

The earliest ceramics made by humans were pottery objects (i.e. *pots* or *vessels*) or figurines made from clay, either by itself or mixed with other materials like silica, hardened, sintered, in fire. Later ceramics were glazed and fired to create smooth, colored surfaces, decreasing porosity through the use of glassy, amorphous ceramic coatings on top of the crystalline ceramic substrates. Ceramics now include domestic, industrial and building products, as well as a wide range of ceramic art. In the 20th century, new ceramic materials were developed for use in advanced ceramic engineering, such as in semiconductors.

The word "*ceramic*" comes from the Greek word κεραμικός (*keramikos*), "of pottery" or "for pottery", from κέραμος (*keramos*), "potter's clay, tile, pottery". The earliest known mention of the root "ceram-" is the Mycenaean Greek *ke-ra-me-we*, "workers of ceramics", written in Linear B syllabic script. The word "ceramic" may be used as an adjective to describe a material, product or process, or it may be used as a noun, either singular, or, more commonly, as the plural noun "ceramics".

Until the 1950s, the most important ceramic materials were (1) pottery, bricks and tiles, (2) cements and (3) glass. A composite material of ceramic and metal is known as cermet.

Other ceramic materials, generally requiring greater purity in their make-up than those above, include forms of several chemical compounds, including:

- Barium titanate (often mixed with strontium titanate) displays ferroelectricity, meaning that its mechanical, electrical, and thermal responses are coupled to one another and also history-dependent. It is widely used in electromechanical transducers, ceramic capacitors, and data storageelements. Grain boundary conditions can create PTC effects in heating elements.
- Bismuth strontium calcium copper oxide, a high-temperature superconductor
- Boron oxide is used in body armor.
- Boron nitride is structurally isoelectronic to carbon and takes on similar physical forms: a graphite-like one used as a lubricant, and a diamond-like one used as an abrasive.
- Earthenware used for domestic ware such as plates and mugs.
- Ferrite is used in the magnetic cores of electrical transformers and magnetic core memory.
- Lead zirconate titanate (PZT) was developed at the United States National Bureau of Standards in 1954. PZT is used as an ultrasonic transducer, as its piezoelectric properties greatly exceed those of Rochelle salt.
- Magnesium diboride (MgB_2) is an unconventional superconductor.
- Porcelain is used for a wide range of household and industrial products.
- Sialon (Silicon Aluminium Oxynitride) has high strength; resistance to thermal shock, chemical and wear resistance, and low density. These ceramics are used in non-ferrous molten metal handling, weld pins and the chemical industry.
- Silicon carbide (SiC) is used as a susceptor in microwave furnaces, a commonly used abrasive, and as a refractory material.
- Silicon nitride (Si_3N_4) is used as an abrasive powder.
- Steatite (magnesium silicates) is used as an electrical insulator.
- Titanium carbide Used in space shuttle re-entry shields and scratchproof watches.
- Uranium oxide (UO_2), used as fuel in nuclear reactors.
- Yttrium barium copper oxide ($YBa_2Cu_3O_{7-x}$), another high temperature superconductor.
- Zinc oxide (ZnO), which is a semiconductor, and used in the construction of varistors.
- Zirconium dioxide (zirconia), which in pure form undergoes many phase changes between room temperature and practical sintering temperatures, can be chemically "stabilized" in several different forms. Its high oxygen ion conductivity recommends it for use in fuel cells and automotive oxygen sensors. In another variant, metastable structures can impart transformation toughening for mechanical applications; most ceramic knife blades are made of this material.
- Partially stabilised zirconia (PSZ) is much less brittle than other ceramics and is used for metal forming tools, valves and liners, abrasive slurries, kitchen knives and bearings subject to severe abrasion.

Ceramic products

For convenience, ceramic products are usually divided into four main types; these are shown below with some examples:

- Structural, including bricks, pipes, floor and roof tiles
- Refractories, such as kiln linings, gas fire radiants, steel and glass making crucibles
- Whitewares, including tableware, cookware, wall tiles, pottery products and sanitary ware
- Technical, also known as engineering, advanced, special, and fine ceramics. Such items include:
  - gas burner nozzles
  - ballistic protection
  - nuclear fuel uranium oxide pellets
  - biomedical implants

- coatings of jet engine turbine blades
- ceramic disk brake
- missile nose cones
- bearing (mechanical)
- tiles used in the Space Shuttle program

Ceramics made with clay

Frequently, the raw materials of modern ceramics do not include clays. Those that do are classified as follows:

- Earthenware, fired at lower temperatures than other types
- Stoneware, vitreous or semi-vitreous
- Porcelain, which contains a high content of kaolin
- Bone china

Classification of technical ceramics

Technical ceramics can also be classified into three distinct material categories:

- Oxides: alumina, beryllia, ceria, zirconia
- Nonoxides: carbide, boride, nitride, silicide
- Composite materials: particulate reinforced, fiber reinforced, combinations of oxides and nonoxides.

Each one of these classes can develop unique material properties because ceramics tend to be crystalline.

Applications

- Knife blades: the blade of a ceramic knife will stay sharp for much longer than that of a steel knife, although it is more brittle and can snap from a fall onto a hard surface.
- Carbon-ceramic brake disks for vehicles are resistant to brake fade at high temperatures.
- Advanced composite ceramic and metal matrices have been designed for most modern armoured fighting vehicles because they offer superior penetrating resistance against shaped charges (such as HEAT rounds) and kinetic energy penetrators.
- Ceramics such as alumina and boron carbide have been used in ballistic armored vests to repel large-caliber rifle fire. Such plates are known commonly as small arms protective inserts, or SAPIs. Similar material is used to protect the cockpits of some military airplanes, because of the low weight of the material.
- Ceramics can be used in place of steel for ball bearings. Their higher hardness means they are much less susceptible to wear and typically last for triple the lifetime of a steel part. They also deform less under load, meaning they have less contact with the bearing retainer walls and can roll faster. In very high speed applications, heat from friction during rolling can cause problems for metal bearings, which are reduced by the use of ceramics. Ceramics are also more chemically resistant and can be used in wet environments where steel bearings would rust. In some cases, their electricity-insulating properties may also be valuable in bearings. Two drawbacks to ceramic bearings are a significantly higher cost and susceptibility to damage under shock loads.
- In the early 1980s, Toyota researched production of an adiabatic engine using ceramic components in the hot gas area. The ceramics would have allowed temperatures of over 3000 °F (1650 °C). The expected advantages would have been lighter materials and a smaller cooling system (or no need for one at all), leading to a major weight reduction. The expected increase of fuel efficiency of the engine (caused by the higher temperature, as shown by Carnot's theorem) could not be verified experimentally; it was found that the heat transfer on the hot ceramic cylinder walls was higher than the transfer to a cooler metal wall as the cooler gas film on the metal surface works as a thermal insulator. Thus, despite all of these desirable properties, such engines have not succeeded in production because of costs for the ceramic components and the limited advantages. (Small imperfections in the ceramic material with its low fracture toughness lead to cracks, which can lead to potentially dangerous equipment failure.) Such engines are possible in laboratory settings, but mass production is not feasible with current technology.
- Work is being done in developing ceramic parts for gas turbine engines. Currently, even blades made of advanced metal alloys used in the engines' hot section require cooling and careful limiting of operating temperatures. Turbine engines made with ceramics could operate more efficiently, giving aircraft greater range and payload for a set amount of fuel.

- Recent advances have been made in ceramics which include bioceramics, such as dental implants and synthetic bones. Hydroxyapatite, the natural mineral component of bone, has been made synthetically from a number of biological and chemical sources and can be formed into ceramic materials. Orthopedic implants coated with these materials bond readily to bone and other tissues in the body without rejection or inflammatory reactions so are of great interest for gene delivery and tissue engineering scaffolds. Most hydroxyapatite ceramics are very porous and lack mechanical strength, and are used to coat metal orthopedic devices to aid in forming a bond to bone or as bone fillers. They are also used as fillers for orthopedic plastic screws to aid in reducing the inflammation and increase absorption of these plastic materials. Work is being done to make strong, fully dense nanocrystalline hydroxyapatite ceramic materials for orthopedic weight bearing devices, replacing foreign metal and plastic orthopedic materials with a synthetic, but naturally occurring, bone mineral. Ultimately, these ceramic materials may be used as bone replacements or with the incorporation of protein collagens, synthetic bones.
- High-tech ceramic is used in watchmaking for producing watch cases. The material is valued by watchmakers for its light weight, scratch resistance, durability and smooth touch. IWC is one of the brands that initiated the use of ceramic in watchmaking.

Using the breakage data as a function of temperature, a lumped parameter, representing hardness, H, and fracture toughness and having the form H/Kc2 according to the model of Ghadiri and Zhang , was evaluated as a function of temperature. The value of this parameter also showed an increase with temperature, indicating that the fracture toughness of Aspirin should decrease with an increase in temperature, considering the functional form of the parameter. In addition, its breakage propensity as a function of temperature was found to be well described by the Arrhenius equation from which the activation energy, −19.04 J/mol can be explained as equivalent to the energy required to overcome plastic deformation and initiate fracture.

Spinel-type ceramics based on mixed transition-metal manganites and/or magnesium aluminates are known to be widely used for temperature measurement, in-rush current limiting, liquid and gas sensing, flow rate monitoring and indication, etc. But their sensing functionality is sufficiently restricted because of bulk performance allowing, as a rule, no more than one kind of application. The aim of this work is to develop the high-reliable multifunctional sensors based on the above spinel-type compounds, allowing integrated temperature-humidity sensitivity for effective environment monitoring and control. At the present time, a number of important problems connected with hybrid microelectronic circuits, multilayer ceramic circuits, temperature sensors, thermal stabilizers, etc. requires such resolution, when not bulk (e.g. sintered as typical bulk ceramics), but only thick-film performance of electrical components (possessing the possibility to group-technology route) is needed . The well-known advantages of screen printing technology revealed in high reproducibility, flexibility, attainment of high reliability by glass coating as well as excellent accuracy, yield and interchangeability by functional trimming are expected to be very attractive now, for new-generation sensing electronics . No less important is the factor of miniaturization for developed thick-film elements and systems, realized in a variety of their possible geometrical configurations. Thus, the development of high-reliable nanostructured thick films and their multilayers based on spinel-type compounds for multifunctional environment sensors operating as simultaneous negative temperature coefficient thermistors and integrated temperature-humidity sensors are very important task [6-8]. To fabricate the integrated temperature-humidity thick-film sensors, only two principal approaches have been utilized, they being grounded on temperature dependence of electrical resistance for humiditysensitive thick films and/or on humidity dependence of electrical resistance for temperature-sensitive thick films. The first approach was typically applied to perovsite-type thick films like to BaTiO3 . Within second approach grounded on spinel-type ceramics of mixed Mn-Co-Ni system with RuO2 additives, it was shown that temperature-sensitive elements in thick-film performance attain additionally good humidity sensitivity . Despite improved long-term stability and temperature-sensitive properties with character material B constant value at the level of 3000 K, such thick-film elements possess only small humidity sensitivity. This disadvantage occurred because of relatively poor intrinsic pore topology proper to semiconducting mixed transition-metal manganited in contrast to dielectric aluminates with the same spinel-type structure. Thick-film performance of mixed spinel-type manganites restricted by NiMn2O4-CuMn2O4-MnCo2O4 concentration triangle has a number of essential advantages, non-available for other ceramic composites. Within the above system, can be prepare the fine-grained semiconductor materials possessing p+-type (Cu0.1Ni0.1Co1.6Mn1.2O4) and p-type of electrical conductivity (Cu0.1Ni0.8Co0.2Mn1.9O4). So, a real possibility to prepare multilayer thick-film spinel-type structures for principally new device application, such as temperature-sensitive p+-p junctions seems to be a quite realistic one. In addition, the prepared multilayer thick-film structures involving semiconductor NiMn2O4-CuMn2O4-MnCo2O4 and dielectric MgAl2O4 spinels can be used as simultaneous thermistors and integrated temperature-humidity sensors with extremely rich range of exploitation properties. The aim of this work is development and selection the high-reliable separate temperature and humidity sensitive thick-film elements based on spinel-type ceramics for multifunctional application in integrated temperature/humidity sensors.

The separate temperature and humidity sensitive thick-film elements based on spinel-type NiMn2O4- CuMn2O4-MnCo2O4 manganites with p- and p+-types of electrical conductivity and dielectric magnesium aluminate MgAl2O4 were prepared using ecological glass constituents. These thick-film elements can be used as starting components to produce multifunctional integrated temperature/humidity sensors for effective environment monitoring and control.

Conclusions

Ceramic (Ferrite) magnets are susceptible to demagnetization when exposed to temperature extremes. There are grades which have better resistance to high and low temperatures, but several factors will dictate the performance of the Ceramic magnet. One of the most pertinent variables is the geometry of the magnet or magnetic circuit. Magnets which are thin relative to their pole cross-section (Magnetic Length / Pole Area) will demagnetize easier than magnets which are thick. Magnetic geometries utilizing backing plates, yokes, or return path structures will respond better to temperature changes. The maximum recommended operating temperatures listed on the Ceramic magnetic characteristics page does not take into account all geometry conditions. Unlike Neodymium, Samarium Cobalt, and Alnico, Ceramic magnets have a Positive Temperature Coefficient for the Intrinsic Coercive Force (Hci) (β). This means that as the temperature increases the magnet may exhibit an increase in net field. This is up to a certain point and the degree of increase is dependent upon the geometry of the magnet. The converse is also true and this is where some designs may have issues. As a Ceramic Magnet experiences a temperature decrease, the net field decreases. This is unlike all other commercial magnet alloys which experience a net field increase when the temperature decreases. Applications where failures may occur could be sensor trigger when the field is not sufficient to trigger a sensor in colder climates.

References

[1] Vakiv M, Hadzaman I, Klym H, Shpotyuk O, Brunner M. Multifunctional thick-film structures based on spinel ceramics for environment sensors. InJournal of Physics: Conference Series 2011 (Vol. 289, No. 1, p. 012011). IOP Publishing.
[2] Sheftel I.T., Thermoresistors, Nauka, Moscow, 1973, p. 415.
[3] Zaharov V.I., Olesk A.O., Elektronnaja Tehnika, Ser. Radiodetali i Komponenty 63 (1989) 30.
[4] Zaharov V.I., Olesk A.O., Film thermistors, Zarubeznaja Elektronnaja Tehnika 5 (1983) 43.
[5] Zhong J., Bau H.H., Am. Ceram. Soc. Bull. 80 (2001) 39.
[6] Feingold A.H., Wahlers R. L., Amstutz P., Huang C., Stein S.J., Mazzochette J., Microwave Journal 1 (2000) 90.
[7] Qu W. et al., Meas. Sci. Technol. 11 (2000) 1111.
[8] White N.W., Turner J.D., Meas. Sci. Technol. 8 (1997) 1.
[9] Dziedzic A. et al., Meas. Sci. Technol. 8 (1997) 78.
[10] Holc J., Sensors and Actuators B 26/27 (1995) 99.
[11] Huang J., Mat. Sci. Eng. B 99 (2003) 523.
[12] Brunets I., Shpotyuk O., Mrooz O., Altenburg H., Proc. of 24th Intern. Conf. on Microelectronics. Nis, Serbia and Montenegro (2004) 503.

[13] Vynnyk I., Hadzaman I., Klym H., Mrooz O., Shpotyuk O., Technology and Design in Electronics 2 (2006) 60.
[14] Shpotyuk O., Ingram A., Klym H., Vakiv M., Filipecki J., J. Europ. Ceram. Soc. 25 2005 2981.
[15] Klym H.I., Balitska V.O., Vakiv M.M., Brunets I.M., Shpotyuk O.I., Bull. Lviv Polytechnic National University: Solid-state electronics: theory, devices and application 510 (2004) 98.
[16]