Research and Analysis of functional ceramics

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Keywords: nano functional ceramics, foam functional ceramics, intelligent functional ceramics, biological functional ceramics, application analysis

Abstract: Functional ceramics has a wide variety of uses. It is one kind of important basic materials in fields of electronic information, integrated circuit, mobile communication, energy technology, national defense and other modern high-tech. This paper mainly analyzes the research status and application of new ceramic materials with different functions such as nano, foam, intelligence and biology. The main obstacles to the application of functional ceramics are the high cost and low reliability. With the development of modern new technology, functional ceramics and its applications are developing towards the direction of high reliability, miniaturization, thin film, refinement, multifunction, intelligence, integration, high performance, high function and composite structures.

1. Introduction

Ceramics is a general term of products made from inorganic raw materials on earth treated by high temperature processing. Compared with traditional ceramics, fine ceramics is a kind of inorganic nonmetallic material that utilizes pure and super fine powder raw materials, and is treated by special processing technology to achieve the fine structure and various functions, such as excellent mechanical properties, high temperature strength, high corrosion resistance, high abrasion resistance, low density (equivalent to about half of the steel), etc. Fine ceramics can be divided into engineering ceramics and functional ceramics.

Functional ceramics refers to dielectric materials with electrical, magnetic, acoustic, optical, thermal, mechanical, chemical or biological functions. It is different from household ceramics, art ceramics, architectural ceramics, etc., but refers to ceramic materials used in the fields of electronics, microelectronics, optoelectronic information and automation technology, as well as energy, environmental protection and biomedicine. Functional ceramics plays a cruical role in corresponding engineering and technology due to its unique biological and chemical properties, outstanding physical properties such as sound, light, heat, electricity and magnetism, and good mechanical properties. It is used in fields such as capacitors in electronic circuits (dielectric porcelain) and integrated circuit substrates and shells (high-frequency insulating porcelain).[1]

2. Research status of functional ceramics

2.1 Nano functional ceramics

Nano functional ceramics is one kind of composites which is obtained by effectively dispersing and compounding in order to make the heterogeneous phase nanoparticles evenly and dispersively retain in the ceramic matrix structures. When the ceramics has particular functions, it will be named nano functional ceramics. The essence of the definition is nano functional composite materials composed of multi-functional nano materials. Solid nano material has huge surface and interface, and the external environment is sensitive to the changes in temperature, humidity, light and atmosphere, causing a rapid change of the surface or interface valence and electronic transmission, whose features are fast response and high sensitivity.The use of the solid nano material interface effect, small size effect and quantum effect can fabricate high-precision and high-performance

sensors.

Nowadays, through researches in the physics, chemistry and structures of the complex multi-oxide system on the nanometer scale, and by means of ion replacement and adulteration, adjustment and optimization are achieved, with many excellent performance or special properties of nano functional ceramics obtained.

2.2 Foam functional ceramics

Foam functional ceramics is a new type of porous ceramics materials with small volume density, high open porosity, and three dimensional network structure, thus possessing properties such as high thermal shock resistance, temperature resistance, chemical corrosion resistance, good mechanical strength and filtering performance and other characteristics, making it possible to be widely applied in the catalyst carrier, filter materials, heat transfer materials, automobile exhaust purifier, reaction tower, absorption tower of chemical packing, etc.

Japan, Germany, the United States and other industrial developed countries have started the development of foam functional ceramics as early as the 1970s, applied it in automobile exhaust, metallurgical industry molten metal inclusion filter and catalyst carrier, and achieved satisfactory results. China started this research work in the mid-1980s. Dozens of scientific research institutions have explored and studied the preparation of foam functional ceramics by using various preparation techniques. The developed foam functional ceramics has reached the practical technical level in the application fields of high-temperature molten metal, automobile exhaust purification and so on.

The common preparation methods of foam functional ceramics include organic precursor impregnation, foaming reaction and organic matter filling and firing. At present, the most ideal preparation method is the organic precursor impregnation method, which has been confirmed by many researchers. Foam functional ceramics prepared by this forming method has been applied in many fields and achieved relatively obvious results.

2.3 Intelligent functional ceramics

Intelligent functional ceramic materials includes environmentally sensitive materials, which has become the highlight of material science and engineering research. Intelligent functional ceramics contains smart material systems or structures of functional materials, drive systems and feedback systems. Because of the display of its comprehensive functionality, it has the property to timely perceive and respond to the changes of the external environment, thus achieving properties such as self-monitoring, self-diagnosis, self-protection and self-adaptation.

Nowadays some kinds of functional ceramics have intelligent functions, such as semiconductor barium titanate positive temperature coefficient of heat resistance and zinc oxide varistors, which have the function of self-diagnosis, self-repair and self-protection on voltage and temperature. In the smart ceramics system, piezoelectric ceramics is of great significance. Since piezoelectric ceramics has the coupling effect and various functions of power, electricity, sound, thermal, and light, it can be used as sensors on pressure, temperature, light, sound and other aspects. More, the piezoelectric actuator has high displacement control precision, fast response, large driving force, low drive power and wide frequency range advantages, as a result of which piezoelectric ceramic materials is often used in fields such as structural damping, vibration control, structural damage and noise reduction. It is now universal used in developed piezoelectric intelligent wipers, ceramic sonar system, pyroelectric voltage transformer, and shock absorbers for premium cars. Among intelligent functional ceramic materials, there are thermosensitive ceramics that is sensitive to temperature changes and can make a certain response, gas-sensitive ceramics that can detect toxic or flammable gases, photosensitive ceramics that can produce photoconductive electricity or volt effect under the irradiation of light, and moisture-sensitive ceramics that can detect environmental humidity.

2.4 Biological functional ceramics

Biological functional ceramics (bioceramics) refers to a kind of ceramic materials with special physiological behaviors, which can be used to form some parts of human bones and teeth, and can

even be expected to partially and completely repair or replace some tissues and organs of human body to improve their functions.

The special physiological behavior of bioceramics means that bioceramics must meet the following biological requirements: it must be compatible with the biological body, have no toxic side effects, irritations or allergic reactions to the biological body tissues, and not cause mutations, aberrations or cancer. The bioceramics should have certain mechanical requirements, such as sufficient strength and stiffness, no catastrophic brittle fracture, fatigue, creep and corrosion fracture, etc., should be both rigid and soft, and its elastic deformation should match the replaced structure. Bioceramics can be combined with other tissues of human body and have good tissue affinity. According to the biochemical reactions in the physiological environment, bioceramics can be divided into three types: one is close to biological inert bioceramics, such as alumina, zirconia and titanium oxide ceramics, another type is bioceramics with surface activity, such as dense hydroxyapatite ceramics and bioactive glass-ceramics.The last type is bioabsorbable bioceramics, such as gypsum-like ceramics, calcium phosphate ceramics and calcium aluminate ceramics.[2-3]

2.5 Problems existing in the application of functional ceramics

The main obstacles to the application of functional ceramics are the high cost and low reliability. At present, the price of ceramic parts is far more expensive than metal parts, for instance, the price of ceramic piston pin or valve production is 2.5 times that of the same metal parts. The main factor affecting the reliability of ceramic parts is the internal crack generated during manufacturing. The size, shape and direction of this crack are random, and sometimes it can cause brittle failure due to crack growth. Therefore, the strength of ceramic parts is random. According to expert analyses, it takes time to overcome high ceramic material price and low reliability.The application process of engine ceramic materials can only be from small to large, easy to difficult, friction resistance to insulation, and parts to the whole machine gradually. Since the late 1980s, the focus of developing ceramic for engine application has been shifted from the development of heat insulation engine to the development of existing ceramic components for engine. Up to now, a variety of ceramic components have been produced in large quantities.

2.6 Development prospect of functional ceramic materials

The current development trend of functional ceramics can be summarized as the following characteristics: composite, multi-functional, low-dimensional, intelligent, and integration of design, material and process. The characteristics and functions of a single material are often difficult to meet the requirements of new technology on the comprehensive performance of materials. Material composite technology can develop new functional effects that do not exist in raw materials through addition effect and coupling product effect, or obtain comprehensive functional effects far higher than that of a single material. The recently proposed gradient functional materials can also be regarded as a special kind of composite materials. Functional and structural materials, or a variety of high performance functional materials provide the foundation to improve the performance and reliability of the product and promote the product to thin, light, small development and other aspects[4].

In addition to the explaination of four new functional ceramic materials above, there are other kinds of functional ceramics such as nuclear reactor ceramics which can be in nuclear reactor standing the test of the high-energy particles and gamma rays, space cautery ceramics which can withstand more than 10000℃, functional ceramics that can be used to make high-performance engine on cars, optical ceramics that has good light penetration optical activity and resistance to high temperature corrosion.With the continuous progress of productivity and the rapid development of science and technology, more advanced products will surely appear in functional ceramic materials. In the future research and development, functional ceramic materials will have more outstanding contributions in superconducting ceramics, optical ceramics, porous ceramics, ceramic coatings, ceramic fibers and ceramic matrix composites.[5-6]

3. Conclusion

In summary, in recent years, the application and development of functional ceramic materials are very attractive. Although the current application of functional ceramic materials under the applicable environment is a tiny fraction, functional ceramics, as the third potential materials following metals and polymer materials, in all aspects of performance it is better than the metal materials and polymer materials currently in use. The fundamental reason why synthetic functional ceramic materials has not been popularized is that it must have extremely high purity, which makes the manufacturing cost and processing cost relatively high. At present, both scientific and industrial circles are working on finding new methods to synthesis and lower the cost of functional ceramic materials. There are enough reasons to believe that functional ceramic materials, as a new application material in the 21st century, will show indispensable application values.[6]

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