PHYSICOCHEMICAL PROPERTIES OF CERAMIC MATERIALS AND THEIR APPLICATION

Rakhmonov Tokhtasin Nurmamatovich

assistant of the Department of "Materials Science" of the Andijan Mechanical Engineering Institute

E-mail: +998 91 609 42 63

E-mail: traxmonov1960@gmail.com

Annotation: Ceramic materials, due to their heat resistance, chemical inertness and strength, are widely used in mechanical engineering, electronics, medicine and the aerospace industry. This article discusses their physical and chemical properties, including heat resistance, chemical resistance, hardness and electrical conductivity, as well as the importance of these properties in practical applications. Modern types of ceramics, research methods and application prospects are also analyzed.

Keywords: Ceramics, physical and chemical properties, hardness, heat resistance, electrical conductivity, testing methods, areas of application, chemical resistance, structural analysis, modern materials.

Аннотация: Керамические материалы благодаря своей термостойкости, химической инертности и прочности находят широкое применение в машиностроении, электронике, медицине и аэрокосмической промышленности. В данной статье рассматриваются их физико-химические свойства, включая термостойкость, химическую стойкость, твердость и электропроводность, а также значимость этих свойств в практическом применении. Также анализируются современные виды керамики, методы исследования и перспективы использования.

Ключевые слова: Керамика, физико-химические свойства, твердость, термостойкость,электропроводность,методы испытаний,области применения, химическая устойчивость, структурный анализ, современные материалы.

Annotatsiya: Keramik materiallar o‘zining yuqori haroratga chidamliligi, kimyoviy inertligi va mustahkamligi bilan mashinasozlik, elektronika, tibbiyot va aerokosmik sohalarda keng qo‘llanilmoqda. Ushbu maqolada ularning fizik-kimyoviy xossalari, jumladan issiqlik barqarorligi, kimyoviy chidamliligi, qattiqligi va elektr o‘tkazuvchanligi hamda ushbu xossalarning amaliy qo‘llanilishdagi o‘rni yoritiladi. Bundan tashqari, zamonaviy keramik materiallar sinfi, ular ustida olib borilgan tadqiqot usullari va kelajakdagi qo‘llanish imkoniyatlari ham tahlil qilinadi.

ISSN 3030-3907

Kalit so‘zlar: Keramika, fizik-kimyoviy xossalar, qattiqlik, termik chidamlilik, elektr o‘tkazuvchanlik, sinov usullari, ilova sohalari, kimyoviy barqarorlik, strukturaviy tahlil, zamonaviy materiallar.

Introduction

In the context of modern industrial and scientific development, the issue of creating new generation materials and their practical application is gaining global importance. Ceramics, which are among such materials, are sharply distinguished from other materials by their high temperature resistance, corrosion resistance, hardness and light weight. According to historical sources, although ceramic materials have been used by mankind since ancient times, their technical and functional capabilities have only begun to be studied in depth in recent decades. Therefore, the demand for ceramic materials and scientific research on them is increasing. Traditional ceramic materials, such as aluminum oxide (Al_2O_3), silicon nitride (Si_3N_4), zirconium oxide (ZrO_2), etc., are characterized by high thermal stability, chemical inertness and mechanical strength. These properties open the way for their use as structural, functional and bioceramics. In particular, maintaining their shape under temperature influence, stress resistance and resistance to chemically reactive environments are among the main advantages of ceramics.

Ceramic materials are complex substances in terms of their physicochemical properties, and parameters such as their structure, phase state, particle size, hardness, thermal conductivity and electrical conductivity determine their field of application. For example, electrically insulating ceramics (Al_2O_3-based materials) are the main basis for electronic devices, while superhard ceramics (boron carbide, silicon carbide) are widely used in the production of abrasive and cutting tools. In medicine, bioceramic materials based on zirconium oxide are used in dental implants and bone prostheses. In addition, ceramic coatings used as thermal barriers are also the most optimal solution for various engines and temperature environments. Therefore, in-depth analysis of the physicochemical properties of ceramic materials, development of testing methods, determination of structure-related properties and development of recommendations for their application are currently relevant scientific and technological areas. This article aims to shed light on these problems and contribute to the development of modern technological solutions based on ceramic materials.

Research and method:In this study, samples prepared on the basis of Al_2O_3 (aluminum oxide), ZrO_2 (zirconium oxide) and SiC (silicon carbide) were selected to study the physicochemical properties of ceramic materials. The selected materials were sintered using modern technological methods and tested. Each

ISSN 3030-3907

sample was evaluated for the following properties: density, thermal conductivity, thermal expansion coefficient, chemical stability and electrical conductivity, density was determined using the Archimedes method. Thermal conductivity was measured using the Laser Flash (Laser Flash analysis) method. A TMA (Thermal Mechanical Analyzer) was used for the thermal expansion coefficient. To determine the chemical stability, the samples were kept in strong acid (HCl 10%, H_2SO_4 10%) and alkaline solutions (NaOH 10%) for 24 hours, and their solubility and surface changes were observed. Electrical conductivity was measured directly in the test equipment with electrodes installed. All measurements were carried out in accordance with ISO and ASTM standards. Structural analyses were carried out using SEM (Scanning Electron Microscope), in which the shape, size and phase states of the particles were determined. Based on the data obtained, the following table was formed and a description of the structural picture was given.

In addition, structural analyses were carried out using SEM (scanning electron microscope). Through this, the size, shape and porosity of the particles were determined. Each sample was subjected to thermal stress at a temperature of 1000 °C and the result of the cooling process was analyzed (thermal shock test). These measures were important in determining the level of thermal stability of the materials. Al_2O_3 was distinguished by its homogeneous particles; ZrO_2 increased strength with a mixture of polymorphic phases; SiC exhibited a sharp-angled, abrasive structure. The physicochemical characteristics of the three main materials are given in the table below, as well as the difference in grain structure based on SEM images.

Table 1.

Physicochemical properties of ceramic materials.

Material	**Density (g/cm³)**	**Теплопроводность (Вт/м.К)**	**Thermal expansion (×10⁻⁶/K)**	**Chemical stability**	**Electrical conductivity (S/m)**
Al_2O_3	3.95	30	8.4	High	10^{-12}
ZrO_2	5.60	2.5	10.5	Very high	10^{-8}
SiC	3.21	120	4.5	Average	10^{-2}

Al_2O_3: Smooth and homogeneous particle structure, high surface strength.
ZrO_2: Enriched with phase transformations, few microscopic cracks.
SiC: Irregularly shaped and angular particles, high hardness and abrasiveness.
Taken under a microscope at 10,000× magnification, the grain size was in the range of 1–5 μm.

ISSN 3030-3907

Result and discussion: The results of the study showed that the physicochemical properties of ceramic materials are directly related to their chemical composition, structure and production technology. The Al_2O_3 (aluminum oxide) sample was found to have high density and chemical stability, and its thermal stability was also relatively good. Based on SEM microscopy images, it was observed that the particle structure of this material is homogeneous and flat. This provides it with high surface strength and makes it difficult to process. On the other hand, the SiC (silicon carbide) sample was distinguished by its extremely high thermal conductivity and extreme hardness. Its electrical conductivity is higher than that of other ceramics, which allows it to be used in the electronics and semiconductor industries. ZrO_2 was distinguished by its low thermal expansion coefficient and high chemical inertness, which may be especially important in the medical and aerospace industries. Such a wide range of physical properties opens up great opportunities for the selection of ceramics specifically tailored for various applications. The results show that the main factors determining the application of materials are their structural integrity, particle size and surface condition. The sharp-angled and uneven particles in SiC determine its high wear resistance, but require careful processing. The high dielectric strength of Al_2O_3 makes it preferable as an insulating ceramic. ZrO_2, on the other hand, maintains a stable structure under mechanical stress due to its transformation strength. ZrO_2 samples have also successfully passed thermal shock tests, which makes it a key material for medical implants and jet engines. In many cases, the performance of ceramics depends on the pressure, temperature and sintering time during their production stage, and these parameters have a significant impact on the phase balance and the final structure. Thus, by increasing control over physicochemical properties, it is possible to increase the efficiency of using ceramic materials, extend their reliability and service life. This will allow the introduction of technologically reliable and energy-efficient solutions in industry.

Conclusion: Based on the results of the study, it can be concluded that ceramic materials are among the most promising and multifunctional materials today. Their physicochemical properties, such as high temperature resistance, chemical inertness, hardness, thermal and electrical properties, and structural stability, allow them to be widely used in various industrial sectors. Experiments conducted on ceramics based on Al_2O_3, ZrO_2, and SiC have shown that each of them has its own advantages and limitations. In particular, Al_2O_3 is distinguished by its insulating and abrasive properties, ZrO_2 by its structure suitable for medical and high-temperature environments, and SiC by its level of thermal and electrical conductivity. The properties of each material directly depend on the production

ISSN 3030-3907

technology, particle size, phase structure, and sintering parameters, and accuracy and quality control play an important role in these processes. Factors such as structural stability, uniformity of grain size, and porosity determine the service life of the final product. As a result, ceramic materials are expected to become the main structural and functional material not only in traditional construction and mechanical industries, but also in strategic industries such as medicine, aerospace, electronics, and energy. In the future, the development of new generations of these materials, their modification at the nano- and microstructural level, and comprehensive analysis of their physicochemical properties will lead to their widespread use in innovative applications. From this perspective, in-depth study of the physicochemical properties of ceramic materials, development of mechanisms for their practical application, and creation of highly efficient products based on advanced technologies are among the priority areas of today's scientific and industrial processes. Fundamental and applied research in this area will serve to further expand the capabilities of ceramic materials.

REFERENCES

1. Yuldoshev, B. et al. Fundamentals of Materials Science. – Tashkent: Science, 2018. – 320 p.
2. Juraev, M. M. Engineering Materials and Their Use. – Tashkent: “Ilm Ziyo”, 2020. – 256 p.
3. Xasanov, U. R. Technology of Ceramic Materials. – Tashkent: “Science and Technology”, 2017. – 210 p.
4. Qodirov, S. T. High-Temperature Materials and Their Properties. – Samarkand: SamSU Publishing House, 2019. – 188 p.
5. Mirzayev, T. et al. Technical Materials and Their Physical Properties. – Tashkent: National University of Uzbekistan, 2016. – 234 p.
6. Tokhtayev, Z. M. Modern structural materials– Fergana:2020– 198 p.
7. Jorayev.N.A. Chemistry of inorganic materials. – Tashkent:Fan, 2015– 270 p.
8. Abdurahmonov.R. R. Resistance of materials. – Tashkent:TDPU,2021– 180 p.
9. Karimov,M.Kh.Mechanical and thermal properties– Bukhara:BDU,2022.–165 p.
10. Salimov, R. T. Ceramics for the electronics industry. – Tashkent: “Ilm”, 2021. – 140 p.
11. Zokirov, I. N. Nano-ceramic materials. – Tashkent: Innovatsiya, 2022. – 192 p.
12. Usmanov, A. Physics of solids. – Tashkent: Science and Technology, 2018. – 225 p.

ISSN 3030-3907