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Research Progress of Five Great Kilns Materials in Terahertz Biochemical Sensing Detection Technology

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Abstract: *This paper summarizes the research progress of Five Great Kilns materials in terahertz (THz) biochemical sensing detection technology. Terahertz technology has shown great potential in the fields of biomolecule detection, disease diagnosis and environmental monitoring because of its unique non-ionization, strong penetration and molecular fingerprint spectrum characteristics. Five Great Kilnss, including Ru kiln, Guan kiln, Ge kiln, Ding kiln and Jun kiln, are considered to have potential applications in THz sensing technology because of their unique electromagnetic and optical characteristics. These traditional ceramic materials not only play an important role in the fields of art and materials science, but also show new application prospects in the fields of modern science and technology, especially in THz biochemical sensing detection technology. The research shows that the unique glaze color, texture and firing process of Five Great Kilns materials may have a special influence on the propagation of THz wave, thus improving the sensitivity and specificity of sensing. This paper discusses the application potential and advantages of Five Great Kilns materials in THz biochemical sensing detection technology, and provides useful reference and enlightenment for researchers in related fields. With the cross-integration of materials science, chemistry, physics and other disciplines, the research of Five Great Kilns materials will be more in-depth, and its application prospects in the new era will be broader.*

Keywords: *kiln materials; research progress; terahertz; biochemical sensing detection technology*

1. Introduction

In today's rapidly changing era of science and technology, biochemical sensing detection technology, as a bridge connecting life science and information science, is developing at an unprecedented speed. Among them, terahertz (THz) biochemical sensing technology, with its unique non-ionization, strong penetration and fingerprint spectrum characteristics, has shown great application potential in many fields such as biomolecule detection, disease diagnosis and environmental monitoring [1-2]. However, with the deepening of application requirements, the performance requirements of sensing materials are also increasing, and finding new and efficient THz sensing materials has become the focus of current research.

The Five Great Kilnss, namely Ru kiln, Guan kiln, Ge kiln, Ding kiln and Jun kiln, as treasures in the history of China ceramics, are not only famous for their exquisite artistic attainments, but also rich in material science and technological wisdom. Porcelain produced by these famous kilns, with its unique glaze color, texture and firing process, shows the precise control and innovative utilization of material properties by ancient craftsmen. In recent years, with the progress of materials science, people began to explore the application of traditional ceramic materials in the field of modern science and technology, and the Five Great Kilns materials have gradually entered the field of vision of scientific researchers because of their unique electromagnetic and optical characteristics.

The introduction of Five Great Kilns materials into THz biochemical sensing technology is expected to not only provide new ideas for the selection of sensing materials, but also reveal more microscopic information of biomolecules through the interaction between materials and THz waves, thus improving the sensitivity and specificity of sensing. This research is not only of great significance to promote the development of THz sensing technology, but also opens up a new direction for the application of Five Great Kilns materials in the new era. In this paper, the latest research progress of Five Great Kilns materials in THz biochemical sensing detection technology is summarized and analyzed, and its application potential and advantages are discussed, which can provide useful reference and enlightenment for researchers in related fields.

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2. THz biochemical sensing detection technology

2.1. Characteristics of THz wave

THz wave, as a special electromagnetic wave, has a frequency range between microwave and infrared light, and has the characteristics of non-ionization, strong penetration and unique molecular fingerprint spectrum [3]. These characteristics make THz wave show great application potential in the field of biochemical sensing detection [4]. Fig. 1 shows the spectrum of THz wave, in which different peaks and valleys represent the absorption characteristics of THz wave in different molecules or materials. This spectrogram is often used to analyze the composition and structure of substances in practical applications.

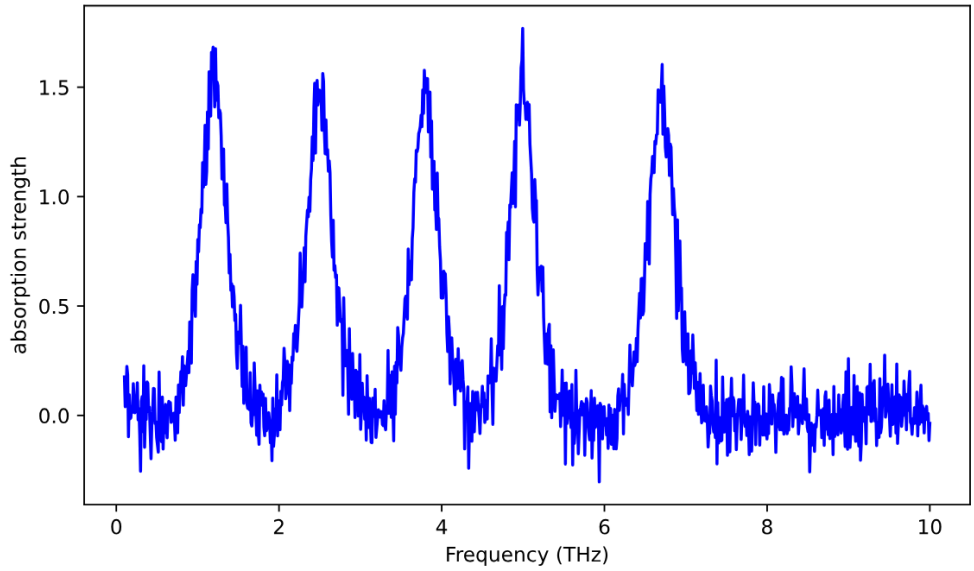

Figure 1: THz wave spectrogram

THz wave has attracted much attention because of its unique physical characteristics, including its non-ionization, strong penetration and molecular fingerprint spectrum. Because THz wave has low energy, it does not have the ability to ionize substances, which means that it will not harm human or biological samples in the application process, ensuring the safety of use. THz wave has strong penetrating ability, which can penetrate many materials such as nonmetallic solids, plastics and textiles, which makes it an ideal tool in nondestructive testing technology [5]. The frequency range of THz wave coincides with the vibration and rotation frequencies of a large number of biomolecules, so the structure and properties of various biomolecules can be accurately identified and studied by THz spectroscopy, which is of great significance to the fields of biological research and medical diagnosis.

2.2. Application status of THz biochemical sensing detection technology

THz biochemical sensing detection technology has shown a wide application prospect in many fields, especially in biomedical detection, food safety detection and environmental monitoring. In the biomedical field, this technology can be used for early detection of cancer, tissue imaging and drug composition analysis; In terms of food safety, THz wave can effectively detect possible harmful substances in food, such as pesticide residues, illegal additives and microbial contamination; In environmental monitoring, it can realize efficient analysis of air pollutants and water quality, such as detecting harmful gases such as sulfur dioxide and nitrogen oxides in the air. These applications not only improve the accuracy and efficiency of detection, but also provide strong support for scientific research and technical development in related fields.

THz wave shows remarkable advantages in sensing detection, including high sensitivity and selectivity, nondestructive detection and real-time monitoring ability. THz wave can detect specific biomolecules with high sensitivity and selectivity by virtue of its unique molecular fingerprint spectrum characteristics. At the same time, its non-ionization and strong penetration ensure that the integrity and biological activity of biological samples are not affected during the detection process; In addition, the rapid response characteristics of THz waves also support the real-time monitoring of

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biochemical reactions, which provides an effective means for exploring biomolecular dynamics.

3. Application of metamaterials in THz sensing

3.1. Basic concepts of metamaterials

Metamaterials are a kind of man-made periodic structures, which can produce special control effects on electromagnetic waves, including negative refraction, superlens, electromagnetic induction transparency and other strange phenomena. In THz band, metamaterials show unique application potential, especially in the field of biochemical sensing.

3.2. Application of metamaterials in THz sensing

THz metamaterial sensing technology uses metamaterials to enhance the localization of THz waves to achieve high sensitivity detection of trace biochemical substances. THz wave has important application value in biomedical field because of its non-ionization, sensitivity to weak resonance and strong penetration ability to nonpolar substances.

Metamaterials can enhance the field of THz wave by enhancing the local electromagnetic resonance response, thus improving the resolution and sensitivity of the sensor. For example, by optimizing the design of the fully enclosed metamaterial structure, the electric field of electromagnetically induced transparent resonance is tightly confined inside the structure, which significantly enhances the interaction with the liquid to be measured, and improves the sensitivity to 0.312 THz/RIU, which is 9.8 times of that without etching [6].

The strategies to improve the sensing sensitivity mainly include the selection and design of materials. The sensitivity is improved by selecting materials such as metal, silicon and carbon nanotubes and designing metamaterial structures with specific resonance characteristics. Combined with microfluidic technology, the liquid to be measured is confined in nano-space to enhance the interaction between THz wave and target substance; Specific antibody modification involves adding specific antibodies to the surface of metamaterials to achieve highly sensitive detection of specific biomolecules. Additionally, chiral metamaterials are used to distinguish different chiral molecules by adjusting the polarization response of THz waves, thereby further enhancing detection sensitivity.

The application of metamaterials in THz sensing shows great potential. By enhancing the interaction between THz wave and the object to be measured, the sensing sensitivity is significantly improved. Future research will continue to explore new metamaterial structures, new materials and the combination with microfluidic technology, so as to further expand the application scope of THz sensing technology and improve its practicability.

4. Research status of Five Great Kilns materials

The Five Great Kilnss, namely Ru kiln, Guan kiln, Ge kiln, Ding kiln and Jun kiln, as the pinnacle of China's ceramic art in the Song Dynasty, not only left a rich legacy in history, but also aroused extensive research interest in many fields such as material science and art. The following will summarize the research progress of Five Great Kilns materials from the perspectives of ceramics and art, and discuss their potential applications in electromagnetism and optics.

4.1. Research progress of Five Great Kilns materials in ceramic field

The Five Great Kilns have become important subjects of ceramic research due to their unique glaze colors, textures, and craftsmanship [7-8]. The Ru kiln is renowned for its sky-blue glaze, crab-claw patterns, and incense ash-colored bodies, with its distinctive glaze color formation and firing techniques being hot topics in ceramic research. The Guan kiln is characterized by its purple rims and iron feet, with a heavy and lustrous glaze surface, reflecting the superb skills of the Song Dynasty's official kilns due to the high iron content in the clay and precise control of firing temperatures. The Ge kiln is famous for its gold silk and iron lines, with unique crackle patterns, variable glaze colors, and coarse and loose body, showcasing a unique artistic style. The Ding kiln is mainly known for its white porcelain, with pure glaze colors and a glaze surface as white as jade, and the fineness of its production techniques is simply amazing. The Jun kiln is renowned for its magical kiln changes and variegated

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glaze colors, with the unique glaze materials and firing methods producing kiln change effects that have become an important symbol in the history of ceramic art.

4.2. Research progress of Five Great Kilns materials in art field

The Five Great Kilnss not only reached a very high level in ceramic technology, but also set a good example in artistic aesthetics. The artistic features of the Five Great Kilnss are shown in Table 1 below.

Table 1: Summary of artistic characteristics of Five Great Kilnss

Names	representative works	Artistic Characteristics
Ru Kiln		Simple and generous, with elegant glaze colors primarily in sky blue, including powder green, bean green, egg green, shrimp green, etc. The glaze surface is smooth without decoration but features crab claw patterns and fish scale-like crazing. "Sesame seed nails" are also an important criterion for identifying Ru kiln ware.
Guan Kiln		Regular and symmetrical with a courtly atmosphere, the glaze color pursues a jade-like effect in green, with moonlight, powder green, and deep green being the most popular, among which powder green is representative. The glaze surface is glossy and moist, and may also feature crab claw patterns and other types of crazing.
Ge Kiln		Unique crazing patterns and glaze color variations, with irregular cracking on the glaze surface forming fish roe patterns, crab claw patterns, and a hundred pieces of debris, etc. The color tone is rich and varied, including powder green, rice yellow, milk white, etc.
Ding Kiln		White porcelain as white and delicate as jade, with a warm glaze color, thin and smooth glaze surface, and a slight yellowish tinge. Skilled in using decorative techniques such as carving, scratching, and printing.
Jun Kiln		Magical kiln changes and variegated glaze colors, with brilliant and gorgeous glaze colors that are ever-changing, blending red, blue, green, white, and purple. Due to the thick and viscous glaze layer, the glaze material naturally flows and fills cracks during firing, forming regular flowing lines after leaving the kiln.

The Ru kiln's celadon is deeply favored by the royal family for its simplicity and elegance, reflecting the Song Dynasty royal family's reverence for Taoism. The Guan kiln porcelain is renowned for its regular symmetry and courtly grandeur, showcasing the refined and majestic style of the Song Dynasty's official kilns. The Ge kiln porcelain, with its unique crazing patterns and glaze color variations, has become a collector's item for literati and refined scholars. The Ding kiln white porcelain, with its jade-white and lustrously delicate glaze surface, has become a treasure in the art of ceramics. The Jun kiln porcelain, with its magical kiln changes and variegated glaze colors, is widely loved by ceramic enthusiasts and has become an important milestone in the history of ceramic art.

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4.3. Potential application of Five Great Kilns materials in electromagnetism and optics

With the continuous development of materials science, the potential applications of the Five Great Kilns materials in electromagnetism, optics, and other fields are gradually being revealed. The glaze color of Ru kiln celadon is warm and soft, with a milky luster, which may be related to the microstructure in its glaze layer. This microstructure may have a special impact on the propagation of electromagnetic waves, offering potential applications in electromagnetism. The glaze surface of Guan kiln porcelain is heavy and lustrous, with a glaze thickness like piled fat, which may possess excellent optical properties such as high light transmittance and low reflectivity, making it suitable for the manufacture of optical devices. The crazing patterns and glaze color variations of Ge kiln porcelain may be related to the stress distribution and chemical composition in its glaze layer. This special structure may affect optical properties, offering potential optical application value. The pure glaze color and white, jade-like glaze surface of Ding kiln white porcelain may possess good optical transmittance and chemical stability, making it suitable for use in optical instruments, chemical containers, and other fields. The variegated glaze color and magical kiln changes of Jun kiln porcelain may be related to the special components in its glaze material and the chemical reactions during the firing process. This special glaze color effect may affect optical properties, offering potential optical decorative and application value.

The Five Great Kilns materials have not only made remarkable research achievements in the fields of ceramics and art, but also showed potential application value in electromagnetism and optics. In the future, with the cross-integration and continuous development of materials science, chemistry, physics and other disciplines, the research on Five Great Kilns materials will be more in-depth and extensive, and its application prospects will be broader.

5. Conclusion

The research of Five Great Kilns materials in terahertz biochemical sensing detection technology shows its unique application potential and advantages. Because of their unique electromagnetic and optical properties, these traditional ceramic materials have been explored for use in modern science and technology, especially as THz sensing materials. The research shows that the Five Great Kilns materials can not only provide new ideas for the selection of sensing materials, but also reveal more microscopic information of biomolecules through the interaction with THz waves, thus improving the sensitivity and specificity of the sensor. The research progress of Five Great Kilns materials in terahertz biochemical sensing detection technology shows that these traditional materials not only have irreplaceable value in art and technology, but also show new vitality and application prospects in modern science and technology. With the cross-integration and continuous development of materials science, chemistry, physics and other disciplines, the research of Five Great Kilns materials will be more in-depth and extensive, and its application prospects will be broader.

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