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Strategic Thinking on the Development of Electronic Ceramic Technology in China

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Abstract: Electronic ceramics are a novel material with industrially strategic significance. They are core materials in passive electronic components and an important technological frontier in the field of electronic information technology. As electronic technology develops in the direction of integration, intelligence, and miniaturization, passive electronic components have become a bottleneck constraining the development of electronic component technology. Therefore, electronic ceramic materials and their processing technologies have become increasingly important. The electronic ceramic materials and components industry in China has established a good foundation. However, it has been out-competed by other countries who control advanced materials and components and some key material, process, and equipment technologies. Thus, a nation-wide strategic plan is urgently required to increase overall R&D investment, translate research into industry applications, and strengthen independence and innovation in the industrial chain.
Keywords: electronic ceramics; passive electronic components; advanced materials

1 Introduction

Electronic ceramics are core materials of passive electronic components used in electronic technology. In recent years, developments in electronic systems have placed increasing emphases on integration, intelligence, and miniaturization. Thus, active devices and integrated circuits based on semiconductor technology have developed rapidly, while passive electronic components have become a bottleneck in the development of electronic component technology. As a result, electronic ceramic materials and their processing technologies have become increasingly important in electronic technology [1–3].

The passive electronic component industry in China accounts for more than 40 % of global output; however, this industry is not sufficiently strong as its output value is less than a quarter of the global output value and advanced components rely heavily on imports [4–5]. Electronic ceramic materials and associated technologies are important factors in determining the development rate of advanced components. Therefore, the study and assessment of the current status of domestic and foreign electronic ceramic technology is of great significance from a strategic perspective for enhancing the development of China's advanced electronic components industry and to problem-solve issues in associated industries.

2 The developmental levels and trends in the international electronic ceramic industry

Japan and the United States lead in the global electronic ceramic industry. Japan is the leading manufacturer in the electronic ceramic market, accounting for more than 50% of worldwide production, determined by its

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ultra-large-scale production and advanced processing technologies [2]. The United States is superior in both basic research and novel material development, focusing on cutting-edge skills for innovation and applications in the military field, such as underwater acoustics, electro-optics, optoelectronics, infrared technology, and semiconductor packaging. In addition, South Korea is experiencing rapid development in the electronic ceramic field.

2.1 Multilayer ceramic capacitors (MLCC)

The main applications of electronic ceramics are in passive electronic components, with MLCC being one of the most widely used passive components. Their main use is in oscillation, coupling, and filter bypass circuits in various electronic circuits, including applications in automatic meters, digital home appliances, automotive electrical appliances, communications, computers, and other industries.

With growing end user demand in consumer electronics, communications, computers, networks, automobiles, industry, and national defense, the global market for these products is valued at tens of billions of dollars and increases at a rate of 10%–15% annually. Since 2017, MLCC products have experienced several price hikes due to the relationship between supply and demand. Murata, Kyocera, Taiyo Yuden, and TDK-EPC of Japan, Semco of South Korea, and PSA and Yageo of the Taiwan Province of China are world-renowned MLCC manufacturers. The mainstream development of MLCC trends towards miniaturization, high capacitance, thin film, base metal electrode (BME), and high reliability.

Among these, the use of base metals as the inner electrode has gradually become more common in recent years. It is the most effective way to reduce the cost of production and the key to this technology is in high-performance anti-reduction barium titanate ceramics. Japan mastered this technology in the early 21st century, securing its leading position in the industry. Thus far, all its large-capacity MLCC products have adopted BME.

Miniaturization has always been a central trend in this industry, and with increasing miniaturization and portability of electronic equipment, the market share of these smaller products has increased, as shown in Fig. 1. The thin ceramic dielectric layer is the basis for the miniaturization of components. At present, Japanese companies take the lead, with the thickness of their MLCC monolayer commonly 1 μm thin, and the top-ranking R&D departments of Murata and Taiyo Yuden have developed monolayers as thin as 0.3 μm. In theory, thin film dielectric is dependent on micronized dielectric materials. Barium titanate is mainly used as the ceramic medium in MLCCs, and its grain size needs to be decreased from to 200–300 nm to 80–150 nm to ensure reliability as the thickness of the single layer is gradually reduced in large-capacity thin-layer MLCC components. Thus, future developments trend towards obtaining barium titanate with a grain size of ≤150 nm for the MLCC dielectric layer.

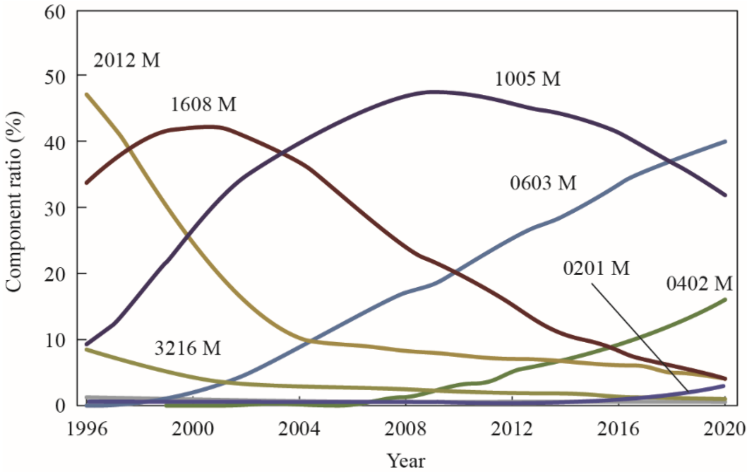

Fig.1. Changes in the market share of MLCC of various sizes over the last two and a half decades [6].

2.2 Chip inductors

The chip inductor is another type of passive electronic component that is widely used. Its core material is magnetic ceramics (ferrite) and requires the most complicated technology, compared to other passive chip components. At present, total worldwide demand for chip inductors is approximately 1000 billion pieces per annum, with an annual growth rate of more than 10%, with Japan’s output accounting for approximately 70% of

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total worldwide demand. TDK-EPC, Taiyo Yuden, and Murata have mastered the cutting-edge technologies in this field. According to the statistics from IEK, a website providing industrial intelligence reports, the total output from TDK-EPC, Taiyo Yuden, and Murata account for about 60% of the global inductor market. The main trends in the development of chip inductors include small size, high inductance, high power, high frequency, high stability, and high precision. The technical core is soft ferrites, and dielectric materials are sintered at low temperatures.

2.3 High-performance piezoelectric ceramics

Piezoelectric ceramics are an important energy conversion material with excellent electromechanical coupling performance. They find wide utilization in electronic information, electromechanical transduction, automatic control, micro-electromechanical systems (MEMS), and biomedical instruments. To adapt to novel application requirements, piezoelectric devices develop in the direction of multilayering, chips, and miniaturization. In recent years, novel piezoelectric devices such as multilayer piezoelectric transformers, multilayer piezoelectric actuators, and chip piezoelectric frequency devices have been under continuous development, being widely used in electrical, electromechanical, and electronic fields. Moreover, great breakthroughs have been made in the development of lead-free piezoelectric ceramics that incorporate novel materials, making it possible to replace lead zirconate titanate (PZT)-based systems in many fields, promoting the uptake of green electronic products. Additionally, applications for piezoelectric materials have begun to emerge as part of the next generation of energy technology. With the rise of wireless and low-power electronic devices in the last decade, the R&D of miniaturized energy harvesting technology using piezoelectric ceramics has been highly valued by governments, institutions, and enterprises in many countries.

2.4 Microwave dielectric ceramics

Microwave dielectric ceramics are the cornerstone of wireless communication devices, and extensively used in mobile communications, navigation, global positioning systems, satellite communication, radar, telemetry, Bluetooth technology, and wireless local area networks [7]. Components such as filters, resonators, and oscillators composed of microwave dielectric ceramics are widely utilized in fifth-generation mobile communication (5G) networks. Their quality largely determines the final performance, size limit, and cost of microwave communication products. Hence, microwave dielectric materials with low loss, high stability, and modulation capability are in high demand. During the early developmental phases of microwave dielectric ceramics, there was fierce competition among the United States, Japan, and Europe, but Japan gradually gained dominance. Currently, with the rapid development of third-generation mobile communications and data microwave communications, the United States, Japan, and Europe are adjusting their strategies. Recent trends indicate that the United States has strategically prioritized nonlinear microwave dielectric ceramics and ceramics with a high dielectric constant, while Europe is focusing on ceramics for fixed frequency resonators; and Japan, relying on its industrial advantages, is vigorously promoting the standardization and high quality of microwave dielectric ceramics [7]. Currently, Japan's Murata, Kyocera, TDK-EPC, and American Trans-Tech have the most advanced levels of production of microwave dielectric materials and devices.

2.5 Semiconductor ceramics

As a functional ceramic material, semiconductor ceramics can convert physical quantities such as moisture, gas, force, heat, sound, light, and electricity into electrical signals. They are used as an essential base material in Internet of Things technologies such as positive temperature coefficient thermistors, negative temperature coefficient thermistors, varistors, and gas-and moisture-sensitive sensors. The yield and output value of thermistor ceramics and varistor ceramics are the highest among semiconductor ceramic materials. Japan's Murata, Shibaura Electronics Co., Ltd., Mitsubishi, TDK-EPC, Ishizuka, Vishay (US), and TDK Electronics (formerly Epcos Germany), among others, possess the most advanced technology and produce the largest volume of these components internationally. Their products are generally of good quality and command high prices, with a combined annual output accounting for approximately 60%–80% of the total worldwide volume. Recently, the development of foreign ceramic semiconductor devices has trended in the direction of high performance, high reliability, high precision, multi-layer chips, at large-scale. To date, some foreign enterprises have successively launched advanced chip semiconductor ceramic devices based on multilayer ceramic technology.

3 The developmental status of electronic ceramic materials and components in China

China is a large producer of electronic components, and the world leader in the output of various electronic ceramic products. At present, it has formed a large number of competitive manufacturing bases, which also has the highest market contribution. However, as a whole, the current high-end market of electronic ceramic materials is monopolized by Japanese companies, and most domestically produced components are used in mid- to low-end products. The advancement of high-level domestic research has encountered bottlenecks stemming from raw materials, production equipment, stability, and other aspects during the production process, resulting in a relatively low market share.

In the context of industrial technology, with a production level considered advanced by international standards, the production base of electronic ceramics in China has reached a considerable scale. For instance, Fenghua Advanced Technology Co., Ltd., one of the few comprehensive enterprises in the world, has an industrial system integrating electronic components, electronic materials, and electronic special equipment. Sunlord Electronics Co., Ltd. has internationally competitive advantages in producing chip inductors and low-temperature co-fired ceramics (LTCC). Additionally, Chaozhou Sanhuan (group) Co., Ltd., Shenzhen Eyang Science and Technology Development Co., Ltd., and other leading backbone enterprises also influence the global industry, and have been supported by a series of national R&D programs. In addition, the electronic technology innovation strategy alliance is jointly established by 20 large and medium-sized enterprises, research institutions, and universities. Led by Tsinghua University and Fenghua Advanced Technology Co., Ltd, it has played an important role in promoting both the R&D and enterprise of functional ceramic chip components and ceramic materials in passive integration.

3.1 MLCC

Currently, the MLCC industry in China functions at a large scale, and has established a group of enterprises with international competitiveness, such as Fenghua Advanced Technology Co., Ltd. and Shenzhen Eyang Science and Technology Development Co., Ltd., occupying notable positions in the global industry. However, as the preeminent MLCC manufacturers, such as Japan’s Taiyo Yuden, Murata, Kyocera, TDK-EPC, and South Korea’s Samsung Electrics Co., Ltd. have established their own production bases in mainland China and attained significant production capacity, more than half of China’s domestic MLCC production now stems from foreign capital or joint ventures. Concurrently, advanced MLCC products in the domestic market are mostly dependent on imports. Owing to the lack of independent intellectual property rights and advanced processing equipment, foreign manufacturers are able to tightly restrict the production volumes of high-quality ceramic powders, electrode slurries, and advanced production equipment. Accounting for 75% of global consumption, MLCC consumption is greatest in Asia, with China’s intake accounting for more than half of the total consumption. As the manufacturing industry for mobile communication products continuous to expand, the demand for MLCC products in China is still growing rapidly.

3.2 Chip inductors

The development and production of chip inductors and related materials in China can be traced back to the early 1990s. The now established inductor industry, dealing in both traditional and novel products, operates at considerable economic scale, maintaining a position in the international market, supplying about 20% of global consumption. In particular, Shenzhen Sunlord Electronics Co., Ltd. has secured an internationally competitive position, by virtue of its technological advantages in materials and processes. Nevertheless, there are still some obstacles for domestic chip inductor manufacturers to overcome.

First, most of the products are destined for ordinary consumer electronics, with production of key communications and automotive electronics components monopolized by companies in Japan, South Korea, and the Taiwan Province of China. Moreover, the price war in the low-end market has caused a reduction of profit margins for domestic chip inductor manufacturers.

Currently, global market demand for chip inductors is continually increasing, and the market structure is also continuously changing, especially in the field of mobile/wireless communications. At the moment, while the large majority mobile communication products are mobile phones that are manufactured in China, the chip inductors used across the afore-mentioned mobile communications products are mainly supplied from abroad. Computers and automotive electronics are other areas where domestic demand for advanced chip inductor products is growing rapidly. However, the market gap between foreign and domestic supply of advanced chip inductors in China will

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be quite large for an extended period of time.

3.3 High-performance piezoelectric ceramics

There are many enterprises in China dealing with high-performance piezoelectric ceramics and their components, but most of them are small-scaled, producing low-end products. In recent decades, R&D into piezoelectric ceramics in China has made many technological achievements, along with associated independent intellectual property rights. With the rapid development of information technology, novel energy technology, biomedicine, and aerospace technology, demand for novel devices based on piezoelectric ceramics is expected to rise sharply and become the dominant sector of the applications market. Based on the current state of the industry, market competitiveness, industrial technology level, and product structure require urgent improvement if these enterprises are to secure good market positions.

3.4 Microwave dielectric ceramics

Research on microwave dielectric ceramic materials and related fields started early in China, and was synchronous with developed countries. Initially, R&D and production were focused on the demands of key microwave device components in the defense industry. During the past decades, several enterprises at a reasonable scale have been formed, such as Wuhan Fangu Electronics Co., Ltd., Jiali Electronics Co., Ltd., Dafu Electronics Co., Ltd., Shenzhen Sunlord Electronics Co., Ltd., and Jiangsu Canqin Technology Co., Ltd. Nonetheless, compared with large international manufacturers, there are still large gaps in technology, product variety, and production scale. At present, wireless information technology is rapidly advancing, represented by 5G, wireless broadband, wireless sensor networks, satellite communication, and positioning systems. These have brought higher requirements for microwave devices with them, in which there is great room for further development.

3.5 Semiconductor ceramics

The bulk of domestic manufacturers of semiconductor ceramics and related sensitive devices established in the 1990s comprised foreign-funded enterprises and private enterprises. These foreign-funded enterprises have rapidly established production bases in the domestic market through sole proprietorship or joint ventures, and they dominate the domestic high-end market, with significant technical advantages, excellent performance, and large-scale exports. Contrastingly, the production technology of private enterprises is backward, and hampered by major deficiencies in raw materials, production equipment, testing equipment, quality control, among other aspects, resulting in a simple domestic product line and a basic product structure, making it difficult for these enterprises to meet the demands of the high-end market. In future, advanced Internet of Things and sensor networks will bring about explosive growth in the demand for semiconductor ceramic sensors in China, and a large space for future development.

4 Analysis of major technical requirements for electronic ceramic materials

With further development of electronic products in the direction of broadband, miniaturization, integration, wireless/mobility, and clean manufacturing, electronic ceramic components with multiple functions and multilayers have become mainstream. Additionally, chips in multi-layer components and the integration of chip components are also in high demand. These new trends have brought with them a series of novel requirements for electronic ceramic materials, such as grain refinement in material microstructures, diversification of material functions, excellent electromagnetic properties at high frequency, and low loss. Thus, slower development of materials technology in these and related fields has increasingly bottlenecked the development of information technology. In the coming years, the key technical problems that require urgent solving include the following aspects:

(1) Novel electronic ceramic materials and key technologies conducive to the miniaturization/micromation of electronic components in a variety of systems. For example, nanocrystalline material preparation technology, ultra-thin ceramic film molding techniques, and ultra-low-loss dielectric ceramic materials that are suitable as the key microwave components in low-power wireless/mobile systems.

(2) Novel electronic ceramic materials adapted to the characteristic frequencies of the next generation of mobile communications technology. With the development of 5G/6G technology, communication frequencies have gradually extended from micrometer to millimeter wavelengths; thus, novel electronic ceramic materials should

suit these higher frequencies. This is especially necessary for dielectric ceramic materials, which will be critical in the upcoming development of next generation components and devices.

(3) Novel electronic ceramic materials for passive component integration and passive–active integration with modularization. Passive integration technology based on LTCC technology will become increasingly promising. Additionally, compatibility with various functional ceramic materials and co-firing technology are technical bottlenecks that must be overcome.

(4) Novel functional electronic ceramic materials for multifunctional electronic systems. Novel multifunctional ceramic materials with electrical, magnetic, optical, thermal coupling, and exotic electromagnetic properties, as well as novel information functional ceramic materials with high stability and excellent performance in complex external fields or extreme environments.

(5) Other technical fields also place novel demands on electronic ceramic materials. Materials for energy applications, such as the development of solid fuel cells, solar cells, and semiconductor lighting technologies depends on breakthroughs in electronic ceramic materials and their preparation technologies. Moreover, with the rise of the Internet of Things and sensor networks, a wide range of sensors with different functions require novel sensitive ceramic materials with higher performance.

5 Major hurdles in the domestic electronic ceramic industry

The main hurdles in the development of electronic ceramics and their components industry in China are discussed below.

5.1 The degree of social investment is critically lacking

Currently, the significance of electronic ceramic materials is only inferior to that of semiconductors in electronic technology and compared with their semiconductor counterparts, focus on them is significantly deficient. As Maruyama Hideki, president of Murata (China) pointed out, China's national policy has great support for chips and semiconductors but not for components, so the manufacturers in related fields are forced to be more self-reliant. Due to inadequate social investment, most companies lack effective mechanisms for attracting high-level professionals, hence suffer from weak R&D funding and potential, which makes it challenging for them to adapt to ever-changing R&D requirements.

5.2 The translation pathway from research breakthroughs to industrial applications needs improving

The domestic R&D of electronic ceramic materials is distributed over a few research institutes, universities, and large enterprises. As university and research institute effort is spread out and often greatly disjointed from each other and among diverse fields of materials and components studies, systematic research on the integration of materials, processes, and components is lacking. The transition from R&D developments to industrialization is inadequate and untimely. Because universities, research institutes and enterprises are independent of each other, communication and cooperation between them is poor, with no timely and effective mechanism for the combination of "production, study and research," which would quickly and efficiently translate research breakthroughs into industry implementation. Ultimately, without product testing or verification of effectiveness via mass production, the research results from universities and research institutes often remain in the laboratory stage. On the other hand, R&D at the enterprise level is often limited by the lack of relevant equipment.

5.3 The domestic industrial chain's support for independent innovation can be improved

Electronic ceramic materials are part of the upstream industrial chain, with the front- and back-end being raw materials and components, respectively. As equipment and technical standards are mainly determined by foreign organizations, a large gap remains between domestic and foreign raw material products, and the standardized application of domestic electronic ceramic materials in component products is restricted in terms of stability and consistency. In particular, owing to a compatibility mismatch with existing technologies, some original materials cannot be applied. This makes it challenging for domestic electronic ceramic materials and component products to retain prominence in the industry.

5.4 The standard of large-scale production technology and equipment needs improving

Thus far, advanced domestic electronic ceramic materials and processing equipment for components are mostly

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imported. Due to the rapid pace of technological upgrades, advanced technology takes time to enter China, making it difficult for large-scale domestic productions to secure leading roles at the global scale. For example, although Fenghua Advanced Technology Co., Ltd., Sunlord Electronics Co., Ltd, and Eyang Science and Technology Development Co., Ltd. are core enterprises that form the backbone of domestic chip component production, their advanced products are still significantly inferior to that of international renowned enterprises such as TDK-EPC and Taiyo Yuden.

6 Strategic goals and pathways for the advancement of the electronic ceramic industry

6.1 General concepts

Further increase R&D investment into electronic ceramic materials and related components, and focus on breakthroughs in advanced electronic ceramic materials, advanced processing technology, and key equipment technology. Follow up by accelerating the localization and independent innovation of the entire industry chain of electronic ceramic materials and components, and forming independent intellectual property systems and advantages on related technologies. Improve the industrialization processes of electronic ceramic materials, and establish advanced international R&D systems and production bases for electronic ceramic materials and components. Bring the Chinese industry up to leading international levels in several fields, including the following: ultra-thin layer MLCCs based on metal internal electrode and ferroelectric ceramic material industrialization technology, high-performance low-temperature sintered chip inductors, ferrite material industrialization technology, high-performance piezoelectric ceramics and industrialization technology of novel components, dielectric ceramic materials with high energy storage density and preparation technology, microwave dielectric ceramic industrialization technology, semiconductor ceramics, and sensitive components for industrial technology.

6.2 Strategic objectives

Target the urgent demand for information technology, further reinforce the R&D work of electronic ceramic technology and support industrial upgrades, overcome the key technological hurdles restricting the technological progress of the domestic industry, and push China to the international lead in these fields. Strive to be competitive with the United States and Japan in most aspects by 2025, and then become the main global source of advanced electronic ceramic materials and components by 2035 (Fig. 2).

6.3 Key development directions

6.3.1 Next-generation electronic ceramic components and materials

Focus on breakthroughs in the widely used passive electronic components, such as the advanced electronic ceramic materials required for MLCCs, chip inductors, and ceramic filters. Develop material formulas with independent intellectual property rights and establish stable production at scale. Focus on breakthroughs in the key technology and equipment for precision molding and processing of materials in advanced electronic ceramic components, secure an independent and stable supply of key nano-ceramic materials required for thin multilayer ceramic technology, and then establish independent R&D and production capabilities of core equipment for passive integration.

(1) High-performance, low-cost MLCC materials and components: Strengthen the R&D of high-performance anti-reduction ceramic dielectric materials and their large-scale production. Focus on the R&D of thin functional ceramic molding technology and equipment, sintering technology of nanocrystalline ceramics, and internal electrodes of ultra-thin multilayer ceramic structures.

(2) Novel chip inductive components and key materials: Strengthen the R&D of high-performance low-temperature sintered ferrite and low-loss ceramic dielectric powder materials with low permittivity and large-scale production. Development of high precision multilayer ceramic technologies and equipment, advanced circuit design in miniaturized microwave chip inductors, etc.

(3) High-performance multilayer chip-sensitive components and materials: Focus research on large-scale production technology for high performance chips, thermal-, gas-, humidity-, pressure-, and photo-sensitive ceramics, preparation and characterization technologies for micro-nano-scale multilayer chip ceramic sensors.

(4) High-performance piezoelectric ceramic materials: Focusing on the net shape forming, processing, and industrialization technology of piezoelectric ceramic materials, the preparation and industrialization technology of high-performance multilayer piezoelectric materials for micro power, advanced preparation technology for

high-performance multilayer lead-free piezoelectric materials, and novel components that can be engineered and industrialized.

(5) Next generation of electromagnetic dielectric ceramic materials for 5G/6G technology: Focus on research on high-frequency low-loss chips for microwave dielectric ceramics and their large-scale production, high-performance low-cost chips utilizing composite dielectric ceramics, and large-scale production with equipment for base materials, design, preparation, and large-scale production of artificial chip electromagnetic media.

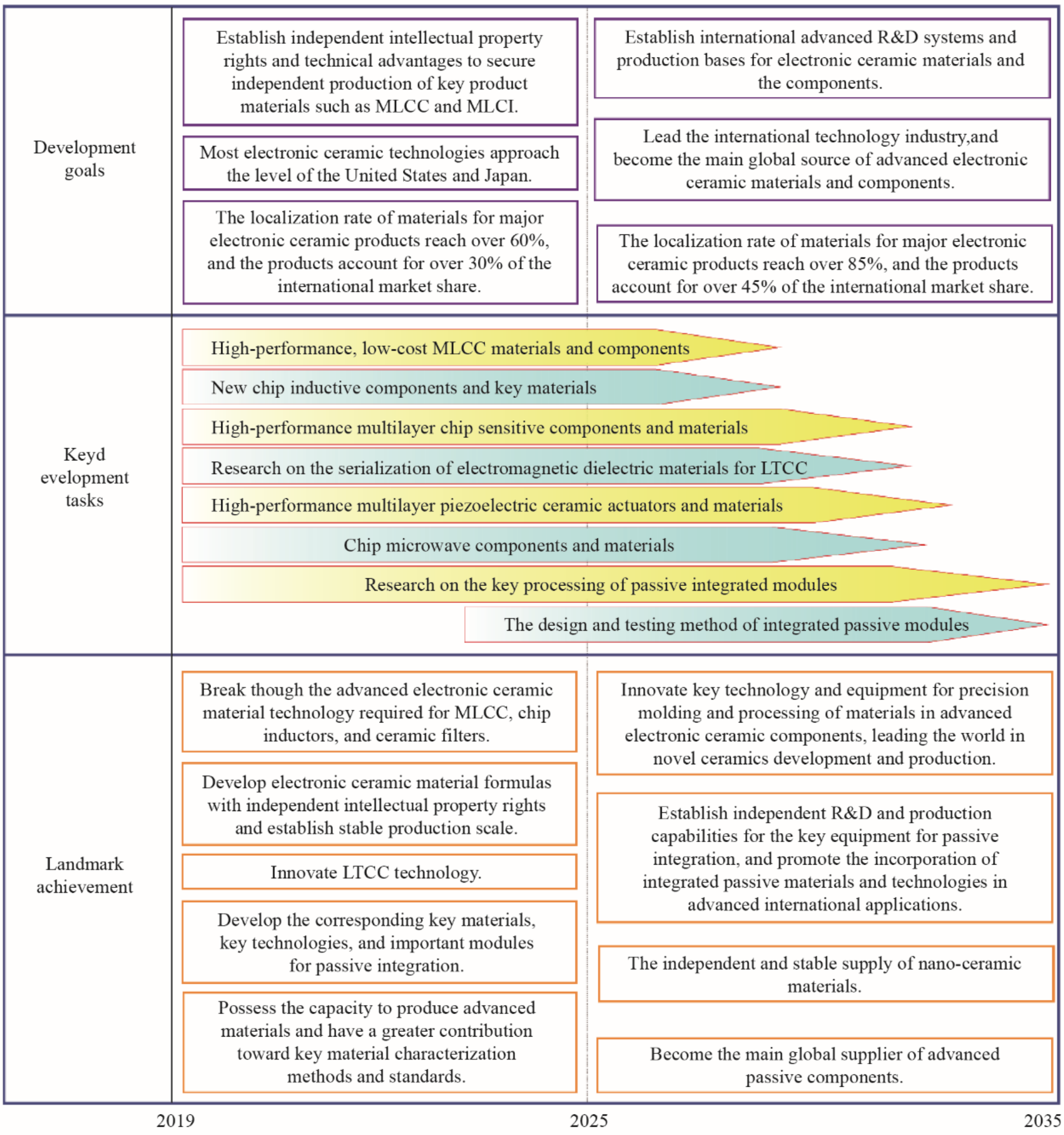

Fig. 2. Roadmap of electronic ceramic development.

6.3.2 Integrated passive devices and associated core materials and technologies

Dependent on the breakthrough of LTCC technology, integrated passive technology has reached industrial applications. Currently, although some passive integration technologies carry various advantages, mainstream technology is still dominated by LTCC. While the properties and preparation methods of LTCC need to be optimized to improve their integration into advanced international applications. Other passive integration technologies also need to be considered for development of corresponding key materials, technologies, and modules.

(1) Research on the serialization of electromagnetic dielectric materials for LTCC: Focus on the research of ceramic powders and green tapes with serialized permittivity and permeability, which can meet the requirements of LTCC. Then, Chinese enterprises can obtain independent intellectual property rights in the field of LTCC

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materials.

(2) Research on the key manufacturing process of integrated passive modules: Focus on several key processes for the preparation of integrated passive modules, such as thick film and thin film preparation processes, micropore formation and grouting processes, precision printing processes of conductive paste, ceramic co-firing processes, etc.

(3) Integrated passive module design and testing methods: Research topics will include the development of software for design, simulation of novel integrated passive structural characteristics, design of highly integrated passive modules, and testing technology of integrated passive modules.

7 Policy suggestions

Electronic ceramic materials and components in China have established a robust technological industrial foundation. However, to achieve leading global roles in the advanced electronic ceramic industry, high-level planning is urgently needed across China, as important novel strategic materials and significant advancements in the field of electronic ceramics are currently restricted by limitations in key material, processing, and equipment technologies. The following suggestions are recommended:

(1) Consider incorporating passive components, key electronic ceramic materials, and passive electronic components into the national strategy for semiconductor industry development. Set up a special project on passive components in major national R&D plans that support the microelectronics industry. Implement preferential policies that support the development and extension of the chip industry into the electronic ceramics and passive electronic components industry.

(2) Increase the volume of researchers and capital investment, strengthen overall R&D capabilities, and reinforce the direct contact and collaborations between research institutes and the industry. Simultaneously create strong and comprehensive R&D systems based on novel materials research with industry support and facilities for device integration and production. Establish effective pathways to translate research advancements into industry applications in a timely manner, and realize the potential of the combined “production, study, and research” trinity approach.

(3) Coordinate both upstream and downstream enterprises in the industry chain for electronic ceramic materials and components. Ensure sufficient electronic ceramic precursors with high stability and strengthen the supply chain of raw materials. In addition, vigorously improve the R&D of advanced processes and equipment, while encouraging independent innovation in passive component development and system design, and strengthen the implementation of relevant standards.

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