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# Quality Infrastructure for the New Material Industry

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**Abstract:** Quality infrastructure, with evaluation, characterization, and standards as its basic elements, plays an important role in supporting industrial transformation, promoting technological innovation, improving production efficiency, ensuring product quality, and enhancing industrial competitiveness worldwide. The acceleration of new material innovations has expanded the scale of the industry and has increased the variety and supply of new materials. This has led to new requirements for industrial quality infrastructure. In this study, we analyze the importance of evaluation, characterization, and standards for the development of the new material industry and summarize the development status of quality infrastructure in China. A technical system has been created for the new material industry in China, and this system has considerably facilitated industrial innovation. China has also achieved progress in internationalization in terms of assessment, characterization, and standardization of the new material industry. However, China's quality infrastructure for new materials is still underdeveloped in terms of overall level and technological innovation ability in key areas; moreover, the progress of internationalization in China is insufficient to comply with industrial requirements. Therefore, an assessment–characterization–standards platform is proposed and subsequently analyzed for the new material industry in China. Based on our findings, the top-level design of the quality infrastructure should be strengthened; an evaluation–characterization–standards one-stop service mode be promoted; independent brands be developed for certification, testing, and standards; and administrative agencies be encouraged to adopt the evaluation results.

**Keywords:** new material; industry; quality infrastructure; evaluation; characterization; standards

## 1 Introduction

National quality infrastructure (NQI) is the cornerstone of national development and public well-being and embodiment of comprehensive national strength and international competitiveness [1]. The foundation of quality infrastructure includes three elements, assessment, characterization, and standards, which correspond to the three core elements of NQI. Mutual integration of these elements can produce a comprehensive effect on economic development, reflecting the fundamental and supporting role of industrial development [2,3]. Advanced basic materials, cutting-edge new materials, and key strategic materials play an important supporting role in the development of emerging industries, while the development of the material industry requires NQI foundations such as standards, characterization, and assessment. With the accelerated integration of new materials and advanced technologies related to information, energy, and biology, new technologies and models such as Internet Plus, Materials Genome Initiative, and additive manufacturing are flourishing. The increase in the variety and supply of materials has led to new requirements for quality infrastructure.

Quality infrastructure is the general term that refers to the quality management framework for establishing and

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implementing standards, inspection and testing, certification, and accreditation based on the requirements of industrial quality development. The application of NQI in the industrial field provides standards, inspections, and certifications for the industrial value chain service [4]. Quality infrastructure plays a key role in supporting industrial development. Countries worldwide have improved their management structure for industrial quality infrastructure [5]; increased investment in scientific research; and improved laws and regulations to support the development of quality infrastructure [6], optimize the technical support role of the NQI on which the business environment relies [7], and promote synergy among various factors [8]. The quality infrastructure in China has yield positive initial results [9]. However, with regard to the development trend of the new material industry in China, the quality infrastructure remains underdeveloped in terms of overall construction level and core technology innovation capabilities in key areas and internationalization. Problems such as incompatibility of the industrial demand with the quality infrastructure also exist [10].

In China, the economy is moving toward a new stage of high-quality development. Innovation in the new material industry has accelerated, the scale of production has expanded, and the variety of products has increased. Accordingly, new development requirements in terms of industrial quality and technical foundations have emerged. Thus, it is imperative to strengthen the related quality and technical infrastructure. This article presents an assessment, characterization, standard development status review, condensed problems, and demonstration of a construction plan to provide a theoretical reference for the quality infrastructure of the new material industry in China.

## 2 Significance of assessment, characterization, and standards for the development of the new material industry

### 2.1 Supporting the new material industry to improve quality and efficiency

Quality infrastructure includes the development of key basic materials, core basic components, and advanced basic processes (referred to as the “three bases”), which serve as the foundation of quality improvement of the new material industry and produce a synergistic effect. Quality infrastructure involves machinery, aerospace, aviation, rail transportation, ships, automobiles, energy equipment, metallurgy, petrochemicals, electronics, the light industry, textiles, instrumentation, and other manufacturing industries, promoting economic growth, efficiency enhancement, and industrial transformation [11].

Standards represent the foundation of product quality, the premise of production efficiency, and an embodiment of industrial upgrading [12]. The guarantee of product quality is dependent on a set of standards for both materials—such as raw materials, parts, and final products—as well as the full lifecycle, i.e., design, manufacturing, distribution, utilization, and maintenance. A more complete product quality standard system is currently required, wherein product quality and safety indicators fully comply with the mandatory national standards and comprehensive standardization of product quality, service quality, and engineering quality is achieved.

Inspection and testing technologies and experimental data constitute important foundations for industrial structure adjustment, optimization, and upgrading, which ensure improvement in industrial quality by feeding back quality information to producers, consumers, and managers [13]. Independent construction of inspection and testing laboratories and a public service platform for public welfare inspection and testing can effectively promote industrial agglomeration and development, attract talent for the development of emerging industries, and encourage enterprises in emerging industries to enhance their innovation capabilities. Strengthening, reliability testing, and endurance testing of basic components and materials, along with quality inspection and testing technologies, are important for improving the quality of the “three bases” for upgrading the industrial structure.

To clear the conformity evaluation, an enterprise must comply with certification standards, thereby completing the transformation of industrial structure and technology [14]. Production companies will introduce requirements to be followed by the part supplier after improving their product quality and production management level. This will ensure that suppliers strictly control raw materials in accordance with the relevant product certification requirements, thereby improving the quality of the industrial chain. Products will thus become more reliable through certification and accreditation, which will enable Chinese products to be sold in international markets.

### 2.2 Promoting innovation of new material industrial technologies

Standards, measurement, inspection and testing, and certification and accreditation promote industrial

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technological innovation [15].

Establishment of standards is based on comprehensive results obtained through science, technology, and experience. Advanced technology can be implemented on a larger scale with the aid of standards, which will accelerate the industrialization of innovations. In addition, technological innovation and standardization become further integrated with the shortening of the technological innovation cycle. Standards are required from product formation, product scaling, serialization, and marketization. The process of formulating, implementing, and revising standards corresponds to the process of innovation, application, and re-innovation of science and technology. Standards promote the transformation of scientific and technological achievements and lead to scientific and technological innovations.

Characterization can provide important test verification environments and conditions for innovative research and development (R&D). Accurate experimental data can be provided through testing for R&D, designing, pilot testing, and other activities associated with the "three bases," which can effectively promote industrial technological innovation. To achieve industrialization of innovation, more precise and sensitive inspection and detection techniques are required. Reasonable inspection and testing technologies can help measure the quality of innovative products, their impact on the environment, and their compliance with relevant regulations and standards, thereby promoting the marketization and internationalization of innovation.

Assessment can improve the technological added value of products, strengthen the market competitiveness of enterprises and products, and effectively stimulate industrial technology innovation by creating an environment that promotes fair market competition. Information asymmetry in transactions may lead to unreasonable quality and price positioning, which can affect the order of transactions and the efficiency of resource allocation and thus inhibit industrial technological innovation. As a third-party evaluation technique, certification can solve the problems of asymmetry in market information and lack of credit, create a level playing field, regulate the market order, and promote transformations of enterprises.

### 2.3 Enhancing international competitiveness of the new material industry

Quality infrastructure can effectively enhance the industry's international competitiveness. Standards, inspection and testing, and certification together intensify international industrial competition.

The chain of international trade is extremely long and includes numerous links, such as ordering, transportation, customs clearance, and settlement; each link involves numerous procedures and systems. As trade facilitation and standardization have become major trends in international trade, standards can create a unified, coordinated, and transparent environment for international trade activities. In a globalized environment, the amount and quality of standards have gradually become important factors indicating the level of industrial technology development, which reflects a country's ability to participate and dominate in international standards formulation.

Inspection and testing are key technical means of achieving industrial quality. These processes involve raw materials, components, semi-finished products, final products, processing, assembly, installation, maintenance, working conditions, structure, performance, safety, resource development, production emissions, energy consumption, and environmental impact. With the development of global manufacturing, the international competition involving industries in various fields has become increasingly fierce. The level of inspection and testing technologies represents a comprehensive manifestation of the level of industrial development. Only when the industrial development has a solid foundation based on inspection and testing technologies, a reliable technical guarantee can be achieved for participation in the international industrial competition.

Assessment is an important approach for industries to participate in international competition. The *Agreement on Technical Barriers to Trade* stipulates that World Trade Organization members must abide by the principle of mutual recognition in the formulation, adoption, and implementation of technical regulations, standards, and conformity assessments. If the conformity assessment procedures of other members can fully achieve the same legal objectives, the members will accept the results of the conformity procedure to avoid unnecessary trade barriers caused by multiple tests, inspections, and certifications of the same product. It is necessary to establish a certification and accreditation system that is in line with international standards, connects relevant industries, and ensures international cooperation.

## 3 Status of the quality infrastructure development in the new material industry

### 3.1 Formation of a technology system for industrial development

Continuous improvements in the standard-formulation system has provided a solid foundation for the development of the new material industry in China. In terms of standardization institutions and personnel, as of the end of 2018, there were 36 949 national standards and 1 439 national standard samples; among them, there were 2 111 mandatory national standards, 34 464 recommended national standards, and 374 guiding technical documents. We noted the establishment of 67 types of industry standards and recorded 61 854 industrial standards and 37 066 local standards. A total of 2079 social organizations have registered on the group standardization management platform, and 5 968 group standards have been announced. Moreover, 212 459 companies are registered on the corporate standard self-declaration platform. Through platform self-declaration, 899 200 standards covering 1 532 101 products have been published.

The technology system of characterization is improved and has become the basis for improving the new material industry [16]. As the state loosened the restriction on inspection, testing, and certification agencies in 2014, several private institutions have emerged, which initially satisfied the development needs of the new material industry. In 2018, 39 472 inspection and testing institutions of various types were identified through a statistical direct reporting system. A total of $4.28 \times 10^8$ inspection and testing reports were issued that year, with an industry output value of 281.05 billion.

In China, a certification and accreditation technology system has been established to cater to the development needs of the new material industry. This system has created a cross-industry, cross-departmental, and cross-professional collaborative innovation development model that has enabled internationalization and localization. The service area of the certification body has been further expanded. The certification and accreditation technologies guarantee effective quality improvement measures. For example, the new version of the ISO9000 quality system certification has improved quality certification. Moreover, certification based on a quality management system has been initiated in nine industries, including aviation, automobile, railway, and information technologies, for the establishment of upgraded standards and rules.

### 3.2 Remarkable effect of the support of industrial technological innovation

Quality infrastructure is important for supporting technological innovation in the new material industry. The use of standards to promote technological innovation and industrial upgrading has gradually become an important part of government regulations [4]. For example, in terms of energy conservation and emission reduction, 44 mandatory performance efficiency standards and 27 mandatory energy consumption limits were issued; this raised the barrier for market entry and encouraged a large number of companies, including those in the new material industry, to accelerate technological research and development and product innovation. This can lead to a significant improvement in the level of industrial technology. Inspection, testing, and certification agencies can start to assess the entire lifecycle of products, covering product design and development, process management, finished product testing, and marketing, and can enable the development of new material companies and industrial technology innovation.

### 3.3 Continuous expansion of the internationalization of assessment, characterization, and standards

In the field of standardization, China has become a permanent member of the International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) Moreover, Chinese experts have been elected as the ISO Chairman, IEC Vice-Chairman, and Secretary General of the International Telecommunication Union. In addition, 310 international standard proposals have been submitted, and 147 have been officially released. Through previous efforts, breakthroughs have been achieved in the development of international standards in the fields of high-end equipment manufacturing, fourth-generation mobile communications, and digital television, which has helped Chinese equipment to be exported worldwide.

In the field of inspection and testing, the establishment and application of methods and standards, such as special equipment material testing, structural analysis, inspection and evaluation methods, instruments and equipment, and regulations and standards, have ensured continuous improvement in inspection and testing capabilities. The product provided a good foundation for the recognition of international users.

In the field of certification and accreditation, numerous internationally leading certification and accreditation systems have been created. A part of the testing proficiency testing plan of the Asia-Pacific Laboratory Accreditation Cooperation Organization (32%) has been undertaken, which reflects the basic status of the proficiency testing field, conducive to the globalization of the new material industry and products.

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## 4 Problems with quality infrastructure development in the new material industry

### 4.1 Insufficient overall construction level

In terms of standards, a single material category lacks a unified material standard. The coexistence of multiple standards at different levels makes multiple versions and standards parallel in practical applications. In addition, there are overlaps and contradictions in the technical elements between different versions and different levels of material standards. This jeopardizes the production and management of materials. Moreover, research and test verification are insufficient for international and foreign standards; this leads to passive adoption and inhibits independent formulation of standards.

In terms of characterization, with the insufficient matching between institutional and industrial layouts, unbalanced spatial layouts, and lack of interinstitutional linkage and cooperation mechanisms, it is difficult to create synergy among diverse technologies and disciplines. The core testing technologies with independent intellectual property rights are weak and high-quality brands are lacking for external services. For some emerging industries related to new materials, there is a severe lack of comprehensive inspection and testing institutions. In addition, state-owned inspection and testing institutions have insufficient motivation, a weak foundation, and inadequate ability to participate in market competition.

In terms of evaluation, material standards are still mainly based on product standards and test method standards. The lack of relevant product evaluation standards, process evaluation standards, and evaluation implementation standards has led to insufficient material evaluation systems. In addition, the evaluation and certification of materials primarily follow existing certification systems and evaluation standards outside China.

### 4.2 Insufficient core technology innovation capabilities in key areas

The rate of technological innovation considerably exceeds the rate at which traditional organizations can formulate standards. In addition, the transformation of the new material industry is resulting in increasingly stringent requirements for the adaptability and timeliness of standards. However, the ability of China to formulate new standards in the field of materials is insufficient. The development of standards lags behind the development of materials, and standard updates cannot be synchronized with the development of new materials. Most of the published standards are basic and depend on chemical analysis, which leads to the lack of preresearch momentum for new material standards; the speed of standard formulation and revision of most new materials cannot follow the speed of product development.

In China, existing inspection and testing service capabilities cannot satisfy the overall requirements of the new material industry. For example, the shipbuilding industry has not yet established a complete data resource-sharing platform and lacks effective statistical methods and virtual simulation capabilities; this has led to a lack of ballast tanks, special functional coatings, nonmetallic materials, fouling protection materials, and other online monitoring and testing technologies and evaluation methods. In the field of aviation materials, although the existing characterization technology are adequate, efforts for exploring cutting-edge material detection and characterization technology remain insufficient.

### 4.3 Incompatible internationalization process considering industry needs

Outside China, general assessment, characterization, and standards promotes as well as restricts each other. Income is generated from assessment and characterization. The income from certification and testing is then invested to improve the level of standards. In China, standards, certification, and testing institutions are independent, which hinders the acquisition of funds for standard research; this considerably restricts research on standards. The division of administrative departments has also hindered smooth information exchange. Thus, it is not possible to combine the respective advantages of assessment, characterization, and standards.

The standards, certification, and testing of the new material industry suffer from the same problem, i.e., the “three-in-one” model is difficult to implement. The standards system in China is not recognized in several countries worldwide; this increases the cost of international trade and is not conducive to international competition for new material products. The level of inspection and testing technologies and service capabilities cannot satisfy the requirements of internationalization. In addition, the certification and accreditation agencies do not support the globalization of Chinese products, which affects the international competitiveness of these products.

## 5 New material evaluation, characterization, standard platform construction plan

## 5.1 Target of platform construction

We should improve its quality of evaluation, characterization, and standards, enable coordination and interaction between different elements, and build an advanced, coordinated, and linked platform for new material evaluation, test characterization, and standards. It should also focus on building an independent evaluation–characterization–standard interaction mechanism that is organically related to the quality infrastructure. Such a system should adapt to the development and production of new materials and should enable "one material for multiple uses, one use for multiple selection" applications to support the development of the China's new material industry.

### 5.1.1 Assessment platform

China should establish a unified evaluation platform to summarize various evaluation and certification resources, particularly professional material resources, such as implementation areas, agencies, agency capabilities, systems, projects, and laboratory capabilities for evaluation and certification. We should verify comparison data and collect, organize, and structure data resources to provide users with value-added services, such as agency recommendation and consulting. Through capacity comparison, historical evaluation, and implementation analysis for certification projects, we can identify the shortcomings of evaluation institutions and promote improvements in evaluation capabilities. We should also determine evaluation and certification requirements, undertake new evaluation and certification projects in a timely manner, improve evaluation capabilities, and match the platform with new material evaluation and certification requirements.

### 5.1.2 Characterization platform

We should establish a unified test characterization platform, collect scattered and unbalanced test characterization resources, and focus on unified coordination to realize efficient and optimized use of test characterization resources to ensure the development of the new material industry. We should collect information about the testing capabilities, service areas, equipment capabilities, and personnel skills of inspection and testing institutions to support the unified coordination and efficient use of national inspection and testing resources. We should establish a certain minimum threshold for technical ability, improve the technical certification ability of warehousing inspection and testing agencies, promote standardized operation of such agencies, improve the reliability of test results, and provide reliable data for evaluation and certification.

### 5.1.3 Standard platform

We should collect information on international standards, national standards, industry standards, group standards, corporate standards, measurement procedures, and general methods in the field of and build a multi-party, efficient, and integrated resource database for material standards. For fragmentation classification of the material standard database, the corresponding dimensions include materials and test expertise, material types, test methods, chemical composition, mechanical properties, and service performance. In response to the different reasons for database use, a material database sharing the service ecosystem should be created to provide industry users with professional standard data services such as standard information query, standard comparison, material performance query, and material selection. We should devote attention to the missing elements in the standard system, perform targeted formulation of new standards, continue to improve the standard system, and satisfy the dynamic development needs of the new material industry.

## 5.2 Key tasks in platform construction

### 5.2.1 Construction and improvement of basic platform elements

We should optimize the standard system and supply structure of the new material industry for future material technologies and to adapt to the rapid changes in the industry. Considering the different characteristics of advanced basic materials, key strategic materials, and cutting-edge new materials, we should accelerate the establishment of a standard system that supports the upgrading of advanced basic materials, provides a guarantee for key strategic materials, and presents the layout for cutting-edge new material standards. We should optimize the standard supply structure and actively develop group standards in accordance with new material technology.

We should also establish a maturity classification system and quality evaluation system for new material technology. In view of the construction goal of China's material and test evaluation standard system, starting from the application dimension, the standardization of material performance indicators, characterization methods, and evaluation will be conducted. Focusing on the requirements for the quality control of the entire production process

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and the full lifecycle of materials, a new material quality evaluation standard system has been established to ensure product quality compliance, production process stability, and service performance applicability. We should promote performance compliance, production stability, service applicability, and reliability evaluation of test results for the new material industry.

5.2.2 Mechanism construction and improvement

We should establish a mechanism to coordinate the formulation of new material standards with technological innovation and industrial development and promote the development of technology, standards, and industries in an integrated manner. List standardization is one of the assessment and acceptance indicators for key projects in the new material industry. For key research and development materials, pilot and innovative technical standards should be developed to promote the transformation and application of innovative results in pilot demonstrations. Relying on key enterprises, colleges, universities, and industrial clusters, we should build a base for national technological standard innovation for the new material industry.

We should also establish a coordination and interaction mechanism to provide a solid quality technology infrastructure for the development of the new material industry. We should promote research on the transmission mechanism between the elements of the quality technology infrastructure and provide a one-stop service for "Measurement–Standard–Inspection and Testing–Certification and Accreditation." We should ensure in-depth integration of standards, metrology, certification and accreditation, and inspection and testing to enhance quality, improve services, and establish trustable quality. Thus, high-standard and high-quality production and services will ensure market recognition and competitiveness.

We should also innovate the standard formulation mechanism for new materials. We should use platform big data to establish a standard library of new materials and build a new material index database suitable for Chinese conditions. We should formulate new standards, such as technical documents and database standards, while focusing on the technical adaptability of the standards. Material genome engineering methods are used to promote the standardization of high-throughput material calculation and design as well as high-throughput material preparation and characterization. We should build a new standard demonstration platform for material genome technology, explore and formulate theoretical standards in the gene map, and guide the creation of new materials.

## 6 Suggestions

### 6.1 Strengthening top-level design of quality infrastructure

We should formulate a development strategy for quality infrastructure, strengthen the top-level design, and exert a synergistic effect of government agencies, enterprises, and scientific research institutions. By combining the country's major strategic deployments and industrial development needs, the layout of quality infrastructure should be optimized to provide collaborative, efficient, and systematic integrated support for quality infrastructure. We should strengthen the supervision and evaluation of quality and technology and establish a linking mechanism between standardization, scientific research, and industrialization. We should encourage standardization agencies to provide consultations and support services for national scientific research and industrialization projects, covering the project establishment, implementation, promotion and application, and pilot demonstration stages. The reliance on standardization will promote rapid industrialization and synergy between scientific research, standardization, and industrialization.

### 6.2 Consolidating quality infrastructure and implementing one-stop service

We should enhance public awareness regarding quality infrastructure and create a social environment that supports the implementation of quality infrastructure. We should conduct special training through higher education to provide a standardized education system for the entire society. We should improve the training of quality professionals and explore the establishment of a joint education system for institutions of higher learning, vocational schools, scientific research institutions, and enterprises to provide high-quality intellectual resources for measurement, standards, certification, and inspection. We should accelerate the research on key and frontier technologies related to quality, improve the quality of technical support systems, and implement key special projects on the basis of quality. In line with the development needs of the new material industry, we will implement an assessment–characterization–standard one-stop service model and ensure comprehensive service for the entire chain of standards–measurement–testing–certification as soon as possible.

### 6.3 Developing certification, testing, and standard brands

In the field of professional certification of new materials, the focus is on the construction of a quality certification evaluation system. Pilot demonstration work should be conducted to construct a quality certification and evaluation system for key new materials and establish an international and professional quality certification and evaluation agency. The national new material testing and evaluation platform, in view of the development needs and particularities of the new material industry, can enable organization of existing testing resources, research on testing methods, optimization of testing capabilities, availability of credible data support, and establishment of an internationally renowned testing brand. We should focus on promoting the construction of group standards and fostering the establishment of group standardization organizations that satisfy the development needs of the new material industry. We should use methods such as group standard good practice evaluation and training programs to accelerate the internationalization of the group standardization organizations.

### 6.4 Encourage government agencies to adopt platform certification evaluation and inspection results

We should strengthen the coordination and overall planning, fully utilize existing resources and incremental investment in the new material industry, accelerate the construction of a new material evaluation–characterization–standards platform, and incorporate it into the government information platform. The evaluation–characterization–standards platform will provide comprehensive and accurate data retrieval and consultation services, evaluation and testing services for relevant scientific research institutions, production enterprises, and user units, and will encourage government agencies to adopt the platform's evaluation and test results. We should promote the branding of the evaluation–characterization–standard platform, guide evaluation and test results of the market recognition and approving platform, focus social attention on the platform, increase the business traffic in the platform, and accelerate the growth of the platform.

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