# Newsletter

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中国计量科学研究院
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# Contents



# NIM's Activities in Response to Evolving Needs in Metrology

The 27th meeting of the General Conference on Weights and Measures (CGPM) adopted Resolution 1 "on the report prepared by the International Committee for Weights and Measures on the 'Evolving Needs in Metrology'" on November 18th, 2022 in Versailles, France. This Resolution is aimed at encouraging the International Committee for Weights and Measures (CIPM) to take forward-looking actions and inviting Member States and National Metrology Institutes (NMIs) to work together to address the evolving needs for metrology and to develop a new vision for the BIPM.

The report of the CIPM identifies seven grand challenges in metrology, which are climate change and environment, health and life sciences, food safety, energy, advanced manufacturing, digital transformation, and "new" metrology. "These seven metrology challenges are of multidisciplinary nature. Each challenge covers a wide array of research topics and poses unprecedented difficulties in solving them", says Dr. Yuning DUAN, NIM Vice Director and CIPM member. "The response to each challenge calls for collaborations not only among metrologists from different NMIs and different disciplines but also between metrologists and stakeholders from outside."

This issue presents some activities carried out by NIM in response to these new challenges. NIM is always willing to cooperate with its international counterparts and stakeholders to address these new metrological challenges.

# Climate Change and Environment

## Assessment of the Impact of Humidity on the Measurement of Atmospheric Volatile Organic Compounds



Trace volatile organic compounds (VOCs) play essential roles in the physic-chemical processes of the troposphere. Photochemical reactive VOCs contribute significantly to the formation of ozone and haze precursors. They also pose a severe threat to human health due to the well-known toxicity of several compounds. Therefore, precision measurement of various atmospheric VOCs is essential. The concentration of atmospheric VOCs is usually as low as ppb or sub-ppb, which is well below the detection limit of GC-FID/MS instruments. Thus, enrichment, as well as other pretreatment measures, is needed for VOCs analysis. Removing the water in ambient air without the loss of the target VOCs is difficult since the atmospheric water content is usually higher than VOCs by million orders of magnitude. However, the impact of humidity on atmospheric VOC measurement is largely unknown.

The NIM,China developed a dynamic standard dilution and humidifying system to determine if humidity is causing a deviation in atmospheric VOC measurement. The schematic diagram of the dynamic standard dilution and the humidifying system is shown in figure 1. The purified carrier gas was saturated by a bubbling humidifier and mixed with dry carrier gas to generate humidifying carrier gas. Then the humidifying carrier gas was combined with the dry VOC gas standard to obtain the VOC gas standard of a specific concentration. The mass flow controller and needle valve controlled the dilution ratio and humidity. The humidified gas standard was measured against the diluted dry gas standard to examine the potential bias caused by humidity. This system examined as many as 117 different compounds. The result showed that the deviation of aldehydes and ketones was much larger than that of the BTEX compounds (refers to the chemicals benzene, toluene, ethylbenzene and xylene). Furthermore, the $C_{10}$-$C_{12}$ compounds were more susceptible to air humidity than the $C_2$-$C_9$ compounds, which showed that the hydrophilic compounds and compounds with higher carbon numbers were more susceptible to air humidity compared with hydrophobic compounds and compounds with lower carbon numbers.

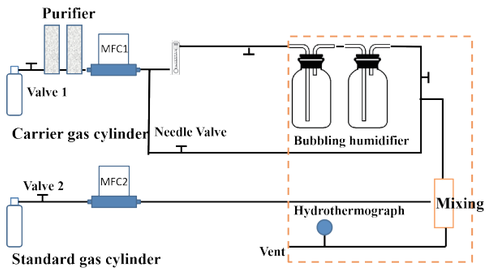


Fig. 1 The dynamic dilution and humidifying system

This standard device is not only promising for a precision evaluation of the VOC measurement in metrology institutes, but also is very likely to become a commercial device to benefit science and industry applications, while water is universally present in ambient air and has a significant impact on our measurement result. Increasing the precision of trace VOC measurements could ensure the comparability of results across countries in different climatic conditions and fundamentally improve our scientific understanding of global trace gases transmission and transformation.

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**Reference:**

BI, Zhe, et al 2021 IOP Conf. Ser.: Earth Environ. Sci. 621 012139



## Development of Filter-based Reference Materials (RMs) for Carbonaceous Aerosol



Carbonaceous aerosol, including organic carbon (OC) and elemental carbon (EC), significantly influence human health, air quality, and climate change. Carbonaceous aerosol is typically measured by the thermal/optical analysis (TOA) method by separating OC and EC. However, the accurate separation of OC and EC is complex and can be influenced by multiple conditions, such as the charring of OC, the different temperature protocols, and optical techniques. Therefore, the development and application of reference materials (RM) for carbonaceous aerosol measurement, especially for validating OC/EC separation, is essential for further study of carbonaceous aerosol.

NIM applied an improved aerosol generation and mixing technique to develop traceable RMs with known OC/EC contents, which could provide uniform deposition of OC and EC on quartz filters. The traceability of the RMs was realized by the gravimetric method. Moreover, different potential candidates for EC have been tested, and the best type was identified as amorphous carbon. After generation, the filters were tested using other instruments and protocols. The comparison of total carbon (TC), OC, and EC results showed good correlations, with relative standard deviations within 10%. The homogeneity within the 47mm filter was validated below 2%. The results indicated that the newly developed RMs were acceptable for calibrating and validating OC and EC.

The development of filter-based RMs could improve the accuracy of carbonaceous aerosol measurement. The OC/EC RMs can be widely used in instrument calibration, measurement data evaluation, and many other industrial fields. It has provided reliable technical support for reducing the uncertainty of radiative forcing estimation, which could benefit national and global control of air pollution and the greenhouse effect.

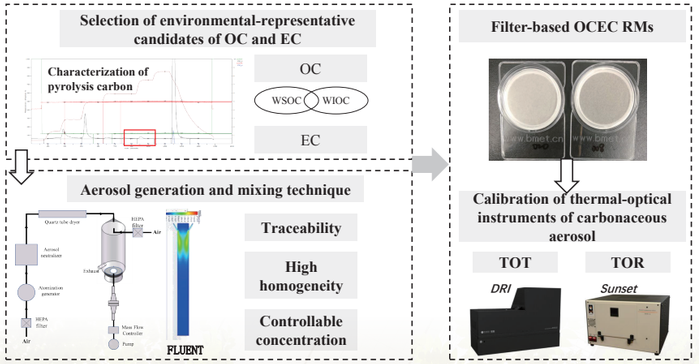


Fig. 2 Development process of filter-based reference materials for carbonaceous aerosol

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# Health and Life Sciences

## Release of CRM of Chinese Quartet Family 1 (Monozygotic Twin Family) Human Whole Genome DNA Sequence and Transcriptome RNA

With the rapid development of molecular biology, gene sequencing plays an increasingly important role in scientific research and medical diagnoses. It has become an important economic and technological fulcrum of the life and health industry. Various international projects based on sequencing technology, such as the Human Genome Project, the Human Genome Haplotype Map Project and the Rice Genome Project, have greatly promoted the rapid transformation of gene sequencing from science to industry, with a compound growth rate of 30% or more. In particular, it plays a vital part in prenatal diagnoses, tumor screening and disease prevention.

However, there are still challenges with clinical applications of gene sequencing, mainly in that there is no standardized quality control in sequencing platforms and later data processing. For the same sample, different platforms have different test results. In addition to the difference in sequencing platforms, different teams have different results based on the same data by using different pipelines. Lack of standard reference materials and benchmarking dataset seriously affect the promotion of gene sequencing on human life and health.

The Gold Standard of China Genome (GSCG) was launched by NIM, aimed to develop Chinese own genomic reference materials, establish national genetic science benchmarks and authoritative standards for genome research, etc. Among them, the research team composed of NIM and Fudan University has successfully developed the Chinese Quartet Family 1 (Monozygotic Twin Family) human whole genome DNA and transcriptome RNA reference material from B-lymphoblastoid Cell Lines by overcoming the problems related to the whole genome sequence reference material.

The reference materials can be used as the "standard ruler" for biological analyses. With them, we have:

1. created a new development mode of nominal property and quantitative omics reference materials in the field of life sciences;
2. established a benchmark for genomics and transcriptomics measurement to improve its accuracy, traceability and consistency; and
3. established standards, specifications and a quality control system for the whole process from generation to analyses of omics data

At present, Chinese Quartet Family 1 (Monozygotic Twin Family) series of reference materials have been used by the National Center for Clinical Laboratory of China to carry out inter-laboratory quality evaluation of exon sequencing and RNA-seq among clinical and scientific research laboratories across the country. It provides strong metrological support for the reliability of genome sequencing data quality and high-quality development of the sequencing industry. With further promotion and application, we believe that the series of reference materials will play a more significant role in improving the quality of gene sequencing, ensuring the reliability of gene sequencing data, and increasing the accuracy of gene diagnoses.

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**Reference:**
DNA: https://www.biorxiv.org/content/10.1101/2022.09.28.509844v1
RNA: https://www.biorxiv.org/content/10.1101/2022.09.26.507265v1





## SAR Measurement Capability for MRI Scanning

Magnetic resonance imaging (MRI) systems have been widely used in clinical research and diagnoses of vital human organs such as the brain because of their advantages including the high resolution in soft tissue. However, strong radio frequency pulses can be delivered during MRI scanning. The energy of such pulses can excessively accumulate in the target area, which is characterized as high specific absorption rate (SAR) and may lead to burns. Hence, it is of great importance to monitor and measure SAR accurately in clinical use of MRI systems. SARs are classified into whole-body SAR and local SAR. Consensus on the limitations of both types has been achieved worldwide according to standard IEC 60601-2-33. The traceability chain of SAR measurements in MRI scanning was once missing in China. As such, SAR measurements were often evaluated against predictive values given by MRI systems or empirical values provided by manufactures.

NIM developed a whole-body SAR measurement system based on the calorimetry method in standards IEC 60601-2-33 and NEMA MS 8-2016 in 2021. The system adopted an improved trunk phantom and an optical fiber thermometer. The trunk phantom modifies the recommended structure in the NEMA standard and simplifies the calculation of equivalent mass. The optical fiber thermometer can be used for MRI systems with B0 fields higher than 1.5 T with temperature measurement precision of better than ± 0.1 ℃ . Experiments showed that whole-body SAR measurement results of NIM's system had a relative deviation of ±10% from those of a measuring system built in accordance with the NEMA standard for the same MRI systems. Moreover, NIM's system does not require a severe ambient environment, and experiments showed that it is suitable for SAR measurement with various MRI systems. It can provide reliable whole-body SAR measurements in registration tests and clinical quality control.

Fig. 3 Whole body SAR measurement using NIM's system

As for local SAR measurement, there is still no agreed method. However, NIM realized SAR measurement at specific locations with a self-developed head phantom and the equipment Easy4MRI. The measurement range of this method is 10 μW/g to 100 W/kg. It can also be used for safety evaluation of special MRI sequences in clinical research.

In the future, NIM will study in-vivo SAR measurement techniques and the conversion between SAR measurements at specific locations and local SAR measurements. NIM is willing to cooperate with other NMIs on those topics. Through these efforts, NIM will try to provide metrological support to increase the safety of MRI scanning and reduce the unnecessary electromagnetic exposure for patients.

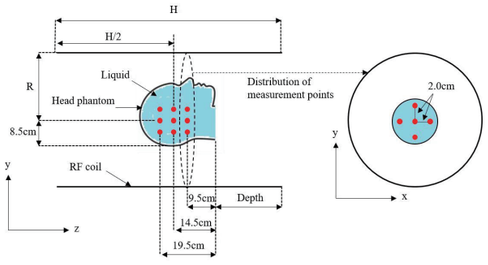


Fig. 4 SAR measurement at specific locations inside the self-developed head phantom

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**Reference:**
Liu, W., et al. (2019). "Statistical Evaluation of Radiofrequency Exposure during Magnetic Resonant Imaging: Application of Whole-Body Individual Human Model and Body Motion in the Coil." International Journal of Environmental Research and Public Health 16(6): 1069.

# Structure Characterization and Quick Detection of Carbohydrates in Aesthetical Field

The market of cosmetics and biomedical materials has extensively expanded in the last decade due to the rocketing development of the aesthetic field. The quality of aesthetic products needs to be strictly regulated to ensure their safety and effectiveness. Measurement techniques are thus urgently needed for guiding the establishment of national or industrial standards. In this regard, NIM has developed analytical approaches for structural characterization and quick detection of carbohydrates in aesthetic products.

## a. In-depth characterization of BDDE substituted hyaluronic acid hydrogels

Hyaluronic acid (HA) is a linear polysaccharide ubiquitously expressed in mammalian tissues as the main constituent of the extracellular matrix. Despite its biological significance, HA-based hydrogels have been extensively applied for medical, aesthetic, and biotechnological purposes. 1,4-butanediol diglycidyl ether (BDDE) substituted hyaluronic acid (HA) hydrogel is the most commonly used HA product in the biomedical field due to the extended in vivo half-life. The degree of modification (MoD) and substitution position/pattern can affect the physical and biochemical properties of the products. Efforts have been made to characterize the molecular structure of BDDE substituted HA hydrogels through enzymatic depolymerization and LC-MS analysis of resultant oligosaccharides. However, none of the existing methods is capable of elucidating the cross-linked fragments (ie, 2-B-2 and 4-B-2), which are the 'signatures' of the BDDE substituted HA hydrogels.

A LC-MS based approach was first established for mapping and accurately quantifying the oligosaccharides obtained through HAase-B degradation of BDPE modified HA. The most abundant BDPE linked species, particularly the cross-linked fragments 2-B-2 and 4-B-2, were reduced and separated by a porous graphitic carbon (PGC) column. Tandem MS was applied to resolve the structure of each isomer. From the proportion of each peak, we can depict the linkage network in BDDE modified HA hydrogels. Particularly, two types of previously unknown structures were detected in the 2-B-2 and 4-B-2 fragments. Based on the feature of resistance to NaBH4 reduction, they were modified at GlcNAc (-OH1). This special sugar unit may represent the reducing end of the native polysaccharide chain and could be a signature to discriminate subtle batch-to-batch variations.

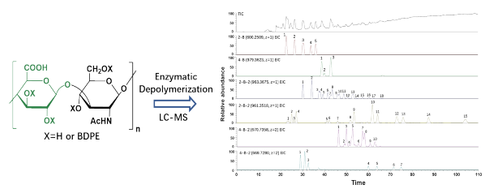


Fig. 5 LC-MS analysis for the characterization of BDDE-substituted HA hydrogels

This robust method enables finger-printing analysis of chemically modified HA structures, which will facilitate the investigation of structure-function correlation. Elucidating the fine structures may also assist in guiding designed-production of HA-based biomedical products. Identification of the rare sugar moiety can contribute to the establishment of quality control standards for HA-products.

## b. Evaluation of glycosylated stress markers AGEs in anti-aging effect of aesthetic products

The accumulation of advanced glycation end products (AGEs) in the skin is considered to be one of the indications of skin aging, such as the reduction of skin compactness and elasticity. There are some raw materials in aesthetic products that play a role in combating saccharification. Their mechanisms include inhibiting the formation of AGEs, accelerating the catabolism of existing AGEs or AGEs crosslinks, and blocking the biological effects of AGEs. The detection of AGEs in the skin can effectively reflect the anti-sugar and anti-aging effects of aesthetic products. However, the method commonly used for AGEs detection is based on biochemical experiments, characterized by cumbersome detection procedures, high cost, and long time. So far, there is still a lack of effective, convenient and fast detection methods.

A method for detecting the accumulation of AGEs in the skin was established based on spectrum. This method employed a safe LED light source of 375 nm to stimulate the fluorescent AGEs in human skin, and the signal was received at the emission wavelength of 450 nm. The accumulation of AGEs was indicated by the intensity of the optical signal obtained. The participants can evaluate their own skin based on the test data. Clinical experiments have shown that the specificity and the sensitivity of fluorescence spectroscopy for detection of AGEs in the skin reached 77.4% and 74.7%, respectively. The method can quickly evaluate the anti-aging effect of aesthetic products in the medical beauty industry.

Detection of AGEs with the autofluorescence method has the advantages of high sensitivity, fast speed, non-invasive, and more acceptability to testers. This method can potentially monitor skin health and may be used to detect diabetes and chronic complications. However, human skin is a strong absorption and scattering medium with many chromophores and fluorescent groups. Thus, the following research will focus on solving and removing other fluorescent interferences.

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Structure Characterization and Quick Detection of Carbohydrates in Aesthetical Field

# Food Safety

## NIM's Contribution to BIPM CBKT Program for Mycotoxin Metrology

Mycotoxins have a variety of negative effects on health in both humans and animals. Many countries have established regulations on mycotoxins in food and feed over the past few decades to safeguard human health, as well as the economic interests of producers and traders. The BIPM NIM have worked together to launch an international project "Mycotoxin Metrology Capacity Building and Knowledge Transfer (MMCBKT)" to strengthen mycotoxin metrology infrastructure.

This project is designed to provide knowledge transfer on mycotoxin measurement and improve developing NMIs' capabilities to provide mycotoxin calibrants and matrix certified reference materials (CRMs) and proficiency testing materials for mycotoxin testing laboratories within their countries, thus enhancing the measurement infrastructure in the Asia-Pacific region. As a main partner and sponsor of the project, NIM carried out a series of actions, including international comparisons, proficiency testing and CRMs, joint research and technical training. More importantly, NIM cooperated with the BIPM in the development and release of international purity evaluation guidelines and calibrant assessment guidelines for mycotoxins.

To meet the goals of the MMCBKT project, a series of key comparisons (KCs), CCQM-K154.a/b/c/d, entitled "Organic solvent calibration solution: Gravimetric preparation and value assignment of Zearalenone (aflatoxin B1, Deoxynivalenol, Patulin) in acetonitrile", were coordinated by the BIPM and NIM to support NMIs or Designated Institutes (DIs) to demonstrate their capabilities in the preparation and value assignment of mycotoxin calibration solutions.

What's more, NIM piloted a key comparison, CCQM-K168, entitled "Non-polar analyte in high carbohydrate food matrix: trans-Zearalenone (trans-ZEN) in maize powder", to align with the OAWG strategy. Participating NMIs in CCQM-K168 demonstrated their measurement capabilities in determining mass fraction of organic compounds, with molecular mass of 100 g/mol to 500 g/mol, having low polarity pKow < -2, in mass fraction ranging from 1 µg/kg to 1000 µg/kg in a high carbohydrate food matrix. Paralleled with CCQM-K168, NIM has coordinated a proficiency testing (PT) program (APMP-APAC PT T112) that improved APMP member economies' measurement capability for trans-zearalenone (Tran-ZEN) in maize powder. A total of 15 laboratories nominated by 7 accreditation bodies from China, Hong Kong China, Canada, Russia, India, and Belgium participated in the PT.

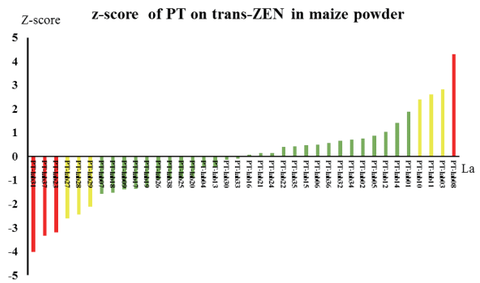


Fig. 6 CCQM-K168 piloted by NIM

Besides, NIM has organized interregional proficiency testing (PT) programme cooperated with NMIs from South Africa, Thailand and Singapore, with more than 75 participating laboratories in Asia, Africa and South America. NIM has developed 21 CRMs on mycotoxins, including calibrant CRMs and matrix CRMs, such as zearalenone, aflatoxin B1, deoxynivalenol and patulin etc.

Five researchers from NIM joined BIPM MMCBKT program who have launched CRM development and training activities in BIPM. NIM also accepted nine visiting scholars for long-term training on calibrant and matrix CRM development on mycotoxin. Through training, knowledge transfer, international proficiency testing and joint research and workshops, the measurement capabilities of over 20 participating economies have been improved.

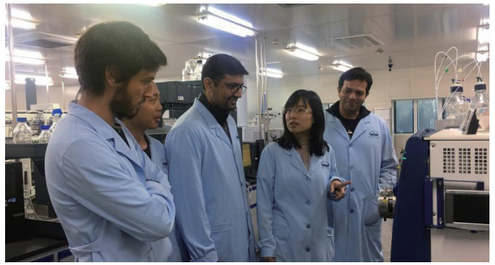

Fig. 7 NIM scholar coaches metrologists from Tunis, Uruguay, Columbia at BIPM laboratory

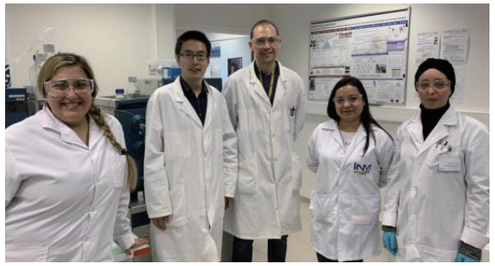

Fig. 8 Metrologists from Brazil, Argentina, Pakistan and Singapore in NIM's lab for training

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# Energy

## Solar Cell Measurement Capabilities Underpin Photovoltaic Industry in China

The photovoltaic (PV) industry is constantly innovating in solar cell materials and the manufacturing process to achieve higher power generation efficiency. New-type high-efficiency crystalline silicon PV modules (such as PERC/Topcon) have been developed and used in mainstream PV applications. The solar cells based on perovskite or other new materials have also been intensively studied. New techniques and materials bring new characteristics of solar cells, such as excitation state, response time, capacitance effect and spectral response characteristics, which are greatly different from those of conventional crystalline silicon solar cells. As a result, the measurement uncertainty of the photoelectric performance parameters of new-type solar cells, such as power and photoelectric conversion efficiency, is generally too large to meet the industrial needs for product performance evaluation, research and development (R&D).

NIM has established the traceability of measurement results in the PV field to ensure the accuracy of key quantities such as solar irradiance. Light sources with different flash characteristics, such as short pulses, long pulses and steady state types, have been established for various types of solar cells. With spectral modulation, the spectral matching consistency was achieved for various scenarios including terrestrial and space applications. By means of piecewise superposition and smart approximation, the electronic load scanning mode was optimized to suppress the influence of capacitance effects to a minimal level for new-type solar cells. Technical difficulties arising from the spectral response and instability of new materials were addressed to achieve more reliable measurements of the photoelectric performance parameters of non-silicon new-type solar cells. Further, NIM has formulated calibration specifications for reference solar cells, photoelectric performance of solar cells/PV modules, and new-type perovskite cells to guide and support the PV testing industry in China.

Since 2016, the PV instrument calibration services provided by NIM have reached an annual average of 1,000 units, covering about 150 customers, and supported the breakthrough in new-type crystalline silicon solar cell efficiency of up to 26% for leading PV enterprises in China. More than 600 tests were conducted for R&D of non-silicon new-type solar cells. Related services were provided to other countries and economies including the United States, South Korea, Saudi Arabia, and Hong Kong. Measurement results were adopted as third-party testing and verifications for R&D of solar cells and national scientific and technological projects in China, and quoted in international academic journals, including Science and Nature photonics, providing solid metrological support for R&D of high-efficiency PV devices based on new materials.

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**Reference:**

Zhang Junchao, et al. "Study on photoelectric parameter measurement method of high capacitance solar cell", Proc. SPIE 10621 (2017): 1062121;
Meng Haifeng, et al. "Accurate Measurement of New Type Non-silicon Solar Cells' Photoelectric Conversion Efficiency", IOP Conf. Series: Journal of Physics: Conf. Series 972 (2018): 012017.





# Advanced Manufacturing

## Atomic Scale Nano Metrology Based on Silicon Lattice Constant

Advanced nanomanufacturing techniques are increasingly miniaturized, integrated, and digitalized, which requires extremely high manufacturing accuracy for device structures. For instance, the critical dimension (CD) of integrated circuits has reached below 14 nm, and a 10% error in the value will lead to device failure. The International Semiconductor Technology Blueprint (ITRS) also clearly states that the measurement uncertainty of 14 nm and 10 nm CD should be respectively reduced to 1.5 nm and 1.0 nm, which means that the atomic level accuracy is essential to the CD measurement of integrated circuits in the post-Moore law period. However, the traditional method, which is traceable to the SI metre definition by laser wavelength, is limited by fringe subdivision and periodic non-linearities in the interferometry at atomic scale. So it is necessary to establish an alternative route of traceability at the nanometre and sub-nanometre level.

It was recommended that the Si {220} lattice parameter ($d_{220}$ = 192.0155714 × $10^{-12}$ m, $u_C$ = 0.0000032 × $10^{-12}$ m) be one of the secondary methods of realizing the metre for dimensional nanometrology according to the Consultative Committee for Length (CCL) meeting in 2018. Following this recommendation, NIM has been carrying out research on silicon lattice constant to underpin the accurate CD control for integrated circuits.

- **Source:** NIM has established a lattice comparator to make comparisons between silicon with unknown impurity concentration and a piece of silicon with known lattice spacing. Its relative standard uncertainty reaches $u_{rel}$=3.8×$10^{-7}$.

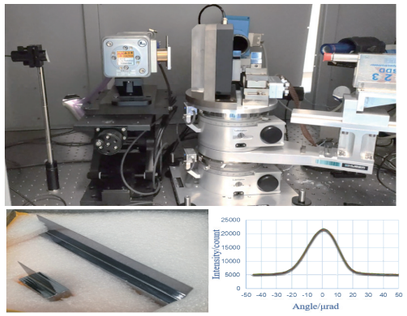


Fig. 9 Lattice comparator

- **Transfer:** With the 2D discrete Fourier transform and the centre of gravity method, NIM scientists have realized the automatic measurement of silicon lattice spacings in high-resolution transmission electron microscopy (HRTEM) images. Also, they have proposed the line width calibration method based on the fusion of silicon lattice constant and laser wavelength, significantly reducing the line width edge effect and the uncertainty of nano line width measurements. With this method, NIM scientists have further developed line width structures with the nominal CD of 14 nm, 22 nm and 45 nm. The measurement uncertainties are all below 10%.

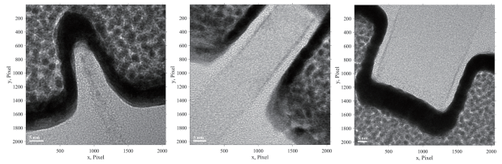

Fig. 10 HRTEM images of the CD structures: (a) 14 nm, (b) 22 nm, (c) 45 nm

NIM has successfully promoted the research findings on silicon lattice constant to State Grid Corporation of China by guaranteeing the value accuracy of industrial chips, conducting analyses on chip failure and establishing a preliminary measurement system. Moreover, this research is promising to ensure atomic-level accuracy for CD measurement necessary to advanced nanomanufacturing technologies and establish the domestic traceability of the CD value of integrated circuits. And it will realize the accurate control of nano structures during the manufacturing process, ultimately contributing to the rise in product yield.

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## Remote Calibration for Angle Measurement Devices

Industry 4.0, the digital transformation of industrial processes, is based on a set of digital enablers or specific technologies integrated into manufacturing processes, which allow the linking of the physical world to the virtual world. To support the manufacture of advanced products and advance automation in manufacturing, increased reliance will be placed on metrology, the key to control. Against such a backdrop, on-line and real-time error prediction and compensation as well as error inversion are critical to the sound performance of instruments and devices widely used in advanced manufacturing, which can be realized with the flourishing development of digital twins.

Based on the closure measurement principle, NIM developed an angle transducer embedded with a self-calibration unit, and the transducer was further built into angle measurement devices for remote calibrations. Within the closure system of angle measurement, both rotary error and measurement error were simultaneously analyzed, and the underlying mathematical model was correspondingly established. The model describes the error influence distributer as the input and the measurement error as the output of the closure measurement system. Then through a series of tests, the relation between the angle transducer and the mathematical model was accordingly acquired. Hence, a digital twin of the embedded transducer was created.

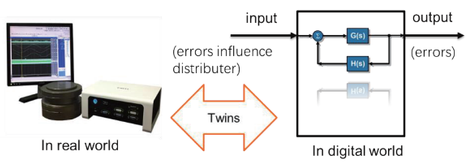


Fig. 11 Digital twin of measurement devices

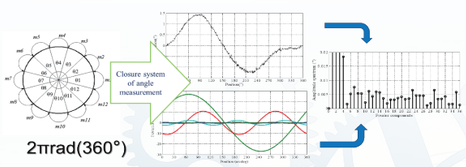


Fig. 12 Closure system of angle measurement

For practical remote calibrations, the self-calibration unit collects error data from the angle transducer and returns it to NIM's data server in real time. Upon receipt of data, NIM's data server remotely conducts real-time processing via the transducer's digital twin. In this way, the angle measurement devices successfully receive on-line, in-process and on-machine calibrations, with their measurement errors being forecasted and compensated for. Moreover, remote calibrations enable manufacturers to monitor their angle positioning systems through the detection of rotary errors inverted from angle measurement errors.

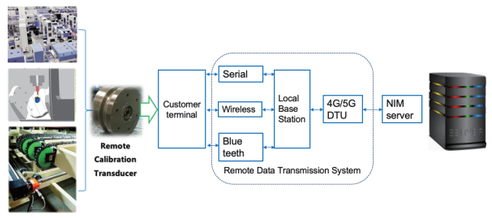


Fig. 13 Remote calibration for angle meaurement devices

Up to now, over 10 companies in China have received this kind of remote calibration service, with their angle transducers upgraded with compact self-calibration units and installed in multi-axles machines. The service has delivered tangible results to manufacturers by ensuring on-line accuracy maintenance and self-diagnoses in an effective way, further promoting the digitalization of production lines in the advanced manufacturing sector. With more and more remote calibrations under development at NIM, metrology will play an increasingly indispensable role in advanced manufacturing processes in the era of digital transformation.

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# Digital Transformation

## Trusted and Accurate Timestamp Service System and Certificate Authority System at NIM

### Trusted and Accurate Timestamp Service System

Under the trend of global informatization, electronic documents, such as E-certificates, E-reports, and electronic data generated by computers and the Internet, are fragile and changeable, which can be easily copied, deleted, and hard to be identified by the authorities.

The National Metrology Data Center (NMDC) of NIM, China, developed a trusted and accurate timestamp service system to solve the problem of changeability. This system is mainly used for certificate verification and proof of non-tampering to give the exact time for the generation of electronic records, and this time can be traced back to UTC (NIM). It helps prove that electronic documents existed at a point in time and have not changed since then. It also provides the legal effect of documents without disclosing their content.

The trusted and accurate timestamp service system is an useful element in the digital transformation of metrology services. It also significantly supports digital calibration certificates (DCC) for metrology institutes and calibration laboratories. So far, the time stamp has been applied to 170,000 copies of electronic calibration certificates of Hunan Institute of Metrology and Test and 1,200 copies of electronic test reports of Laboratory Information Management System (LIMS) , with a technical service fee of about 150,000 yuan and 100,000 yuan, respectively. NIM-Zhengzhou Institute of Advanced Measurement Technology adopts this timestamp system to the environmental monitoring big data platform. This system combines encryption technology and new digital anti-counterfeiting technology to build a reliable monitoring system for environmental data.

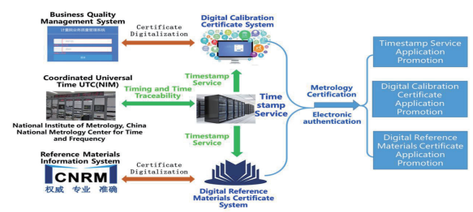


Fig. 14 Application flow chart of the Trusted and Accurate Timestamp Service System

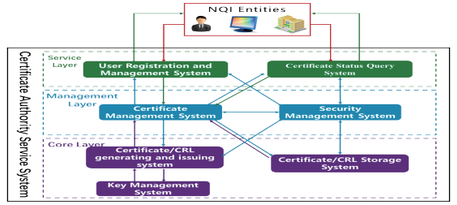


Fig. 15 Certificate Authority System architecture diagram

### Certificate Authority System (CA)

In the process of digital transformation, National Quality Infrastructure (NQI) entities, such as personnel, institutions, and devices, generally need more trusted digital identities that authoritative institutions can recognize. Establishing a certificate authority system is urgently needed by NQI entities in this digital era. Relying on the *Electronic Signature Law* in China, the National Metrology Data Center (NMDC) of NIM has developed the Certificate Authority System for NQI entities to meet the anti-counterfeiting security requirements in the NQI digitalization. This system solves many security issues, including identity authentication, data confidentiality, integrity, and etc. NMDC is now applying for cryptography testing validation.

*The National Metrology Data Center (NMDC) is one of the 20 National Scientific Data Centers, and the Center for Metrology Scientific Data (CMSD) of NIM is responsible for its operation.

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# "NEW" Metrology

## Chip-scale Quantum Metrology at NIM

After the SI redefinition was adopted at the 26th meeting of the CGPM in 2018, all SI units are defined in terms of physical constants that describe the natural world. This historic milestone assures the future stability of the SI and opens the opportunity for the use of new technologies, such as quantum, MEMS, silicon photonics etc., to implement the quantity realization and measurement. It means that a number of impending technological advances could have an important step-change impact on the way metrological traceability can be realized in the future.

In response to the quantum revolution and the trend towards flattened traceability, NIM established a laboratory centered on chip-scale quantum metrology in 2019. The laboratory is committed to developing quantum measurement standards and precision instruments, to researching quantum sensing methods based on atomic and molecular spectroscopy, microcavity photonics, and electrical macroscopic quantum effects, and to studying fabrication technologies for such key quantum devices as MEMS atomic vapor cells, optical microcavity devices, planar gratings etc. as well as integration techniques for size-, weight-, and power- (SWaP) constrained systems. Now the laboratory is on the way of developing several miniaturized and portable quantum measurement standards and in-situ calibration instruments which are exemplified below.

- **Time and frequency:** chip-scale atomic clock, microcavity optical frequency comb;
- **Electromagnetic field**: portable AC quantum voltage standard, Rydberg atom-based microwave E-field strength meter, optically pumped magnetometer;
- **Temperature**: photonic thermometer, noise thermometer.

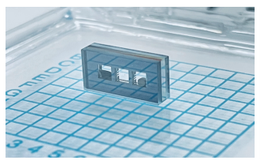

Fig. 16 MEMS Atomic Vapor Cell

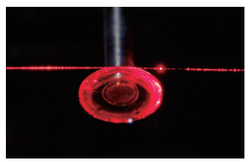

Fig. 17 Crystalline Optical Microcavity

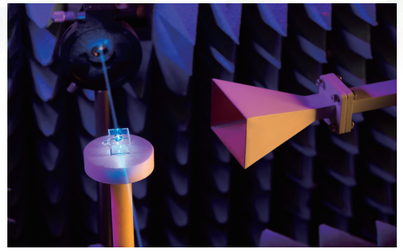

Fig. 18 Rydberg atom-based microwave E-field strength measurement system

The laboratory has made some progress on chip-scale quantum metrology since its establishment and is believed to render a profound influence on the metrology community and the scientific and industrial sectors at large in the future. For example, the Johnson noise thermometer, based on the sensor head of the traditional platinum resistance thermometer, is intended for high-temperature applications. At present, NIM scientists have accomplished a 0.3% accuracy in the measurement time frame of 30 seconds within the 0℃ - 600℃ temperature range. This sensor will not only realize in-situ calibrations of the twin platinum resistance thermometer, but also will enable thermodynamic temperature measurement, such as for the reactor core of nuclear power plants. For another example, in regards with photonic thermometry, we have designed and implemented a milli-Kelvin, high-resolution and low self-heating temperature measurement method grounded in silicon nitride photonic microcavity.

It's expected that NIM's research will contribute to building a more time-, labor- and cost-saving national quality infrastructure by fundamentally transforming its traditional hierarchy traceability chain. It will also enhance industrial measurement capabilities and ultimately facilitate industrial upgrading by greatly reducing the uncertainty of on-site instruments. In addition, the research will provide reliable self-calibration or even free-of-calibration sensing solutions in harsh environments featured by high temperature, high pressure, high radiation and high electromagnetic field.

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# Chinese Delegation Attends the 27th Meeting of the CGPM in Versailles

The 27th meeting of the CGPM was successfully held in Versailles, France from 15 to 18 November 2022. A seven-member Chinese delegation, led by Mr. Yizhi QIN, Vice Minister of the State Administration for Market Regulation of China (SAMR), participated in this event together with representatives from about 58 countries and economies as well as 14 international organizations and institutes.

The Chinese delegation is very honored to witness the successful organization of the meeting and to contribute to the adoption of 7 important Resolutions. China as one part of the global metrology community is also so proud for those notable achievements made by Member States under the effective framework of the BIPM in responding to the COVID-19 pandemic, in promoting the digital transformation of metrology, and in developing a new CIPM strategy of far reaching significance, among others, under the especially difficult circumstances in the past few years.

On 18 November 2022, an election was conducted for all 18 seats of the CIPM. Dr. Yuning DUAN, NIM Vice Director and an incumbent CIPM member, was re-elected as a CIPM member. As President of the Consultative Committee for Thermometry (CCT), Dr. DUAN also presented the work report of the CCT on the first day of the meeting.

A few work related to NIM was also mentioned in reports presented during the meeting, for instance, NIM has made active efforts to co-pilot the international comparisons of 2019-nCoV


Fig. 19 Group photo of Chinese delegation

RNA measurement and McAb measurement, NIM has made continued voluntary support to the mycotoxin measurement Capacity Building and Knowledge Transfer (CBKT) programme of the BIPM, and Dr. Ping YANG, NIM Vice Director, was appointed as Vice Chair of the Digitalisation Task Group (DTG) of the International Organization of Legal Metrology (OIML) in May 2022.

APMP poster by NMIJ

# NIM's Delegation Participates in the 38th APMP General Assembly and Related Activities

The 38th APMP General Assembly and Related Activities (APMP 2022) were held in a hybrid style in Odaiba Tokyo from 28 November to 2 December, with some 200 participants from over 30 APMP economies and 8 stakeholder organizations. NIM sent out a delegation of 9 members led by Mr Xiang FANG, the outgoing APMP Chairperson, to attend the annual event in Tokyo. It has been the first time for APMP to finally witness an annual face-to-face gathering since the outbreak of the COVID-19 pandemic.

The APMP 2022 witnessed the smooth transfer of the Chairmanship of APMP from Mr Xiang FANG to Dr Hyun Min PARK of KRISS (Republic of Korea), with the Secretariat transferred from NIM to KRISS as well.

The meeting marked the last lap of NIM's term as APMP Chairperson and Secretariat. A summary of APMP's achievements from GA 2019 to GA 2022 was presented, which included

· the well-developed and fulfillment of APMP Strategic Plan (2021-2023) that identified six strategic working priorities for APMP with four topping Chair's agenda,

· launching of the COVID-19 Response Programme to facilitate cooperation on research, knowledge transfer to APMP DENs and engagement with stakeholders, with USD 100,000 budgeted annually and five projects supported to benefit APMP member institutes with multiple outcomes,

· the establishment of Focus Group on Digital Transformation (DXFG) to prepare APMP for digital transformation in metrology and lay out a strategy for this major topic,

· the consistent improvement of APMP's operation and governance by optimizing guidelines and website renovation, and

· increasing the international engagement of APMP by joining the BIPM E-learning initiative and signing the first MOU with IMEKO and VAMAS that will benefit APMP for metrological research and development.

Fig. 20 38th APMP GA

Fig. 21 Mr Xiang FANG and NIM Secretariat

For all the mentioned developments, Mr FANG expressed deepest appreciation to all the EC members, Committee Chairs and Secretariat for their consistent dedication, contribution and support despite the difficulties. On behalf of APMP, he also thanked the NMIJ, NICT, CERI and JEMIC for their elaborate preparation and arrangement for making a physical GA possible in such challenging context.

The NIM Chairperson and Secretariat were congratulated by delegates and stakeholders for finishing a productive term during the very challenging period of the pandemic, from "sleek but very informative newsletters, improving the documentation and governance of APMP activities aka web site, to growing the collaborative programs particularly those related to Covid response, introducing DXFG..." cited from the congratulatory message of Dr Thomas LIEW, a CIPM member in the region.

Ms Wei GAO, a former APMP EC member and Treasurer, was conferred the APMP Award 2022 as one of the two winners for her contributions to APMP, especially as a key person in DEC activities. Besides, Dr Chunhui LI , the TCFF Chair, was elected as the Lead TC Chair-elect. Dr Hong LIN was elected as the Chair-elect of Focus Group on Climate Change and Clean Air. At this GA NIM was also approved to host the 39th APMP General Assembly and Related Activities in 2023.


Fig. 22 Mr Xiang FANG presents acknowledgement gift to Dr Takashi USUDA, Director of NMIJ

*Onsite EC-CC meeting

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