European Metrology Programme for Innovation and Research

Delivering Impact

Assessing ultra-high vacuum quality

Ultra-high vacuums are essential in many manufacturing processes, including the complex electronics and coatings that are increasingly used in micro- and nano-technologies. Achieving the extremely low operating pressures these processes require, relies on removing damaging contamination traces produced by system component outgassing. Reliable measurements of both the ultimate pressures reached and the outgassing rates of ultra-high vacuum components are needed to ensure system efficiency and reliability.

Europe's National Measurement Institutes working together

The European Metrology Programme for Innovation and Research (EMPIR) has been developed as part of Horizon 2020, the EU Framework Programme for Research and Innovation. EMPIR funding is drawn from 28 participating EURAMET member states to support collaborative research between Measurement Institutes, academia and industry both within and outside Europe to address key metrology challenges and ensure that measurement science meets the future.

Challenge

Manufacturing micro-electronics, complex coatings and operating the high energy accelerators important in producing cancer therapies or used in advanced research relies on the ability to remove all gases from evacuated systems. To achieve the low operating pressures needed, it is vital that only extremely clean materials and components are used inside these systems. Outgassed water vapour and hydrocarbon traces remaining from component handling during manufacture and the packaging used for their storage can cause lingering contamination that damages products or reduces system performance.

Assembling ultra-high vacuum systems involves combining many components from different suppliers who are required to provide accurate component specifications that include the material's outgassing rate. This is essential as these rates influence the ultimate pressure and trace gas composition the vacuum system will achieve. It also effects the selection of vacuum pump size and hence the system's operational energy requirements. Quadrupole mass spectrometers (QMS) are often used to determine material and system outgassing rates. However, these complex instruments require improved characterisation and standardised methods for their use, underpinned by international documentary standards, to enable the vacuum component supply chain to have confidence in the performance of new ultra-high vacuum systems.

Solution

During the EMRP project *Vacuum metrology for production environments* the research team realised that QMS used in high and ultra-high vacuum systems suffer performance changes during transportation between calibration labs and end user vacuum system installation, as well as over time and usage. To overcome this issue, reference outgassing materials suitable for characterising QMS performance in-situ were developed and a specification for calibrating these instruments proposed. These have now been thoroughly discussed by the user community and adopted by the International Standard Organisation (ISO) as Technical Specifications 20175 and 20177. The EMPIR project *Technical Specifications for quadrupole mass spectrometers and outgassing rates for assessing the quality of vacuum environments* provided the additional NMI support needed to make this happen. Extensive field testing will now follow, providing a route for the technical specification on QMS calibration and outgassing rate determination to be rapidly accepted and upgraded to ISO standard status.

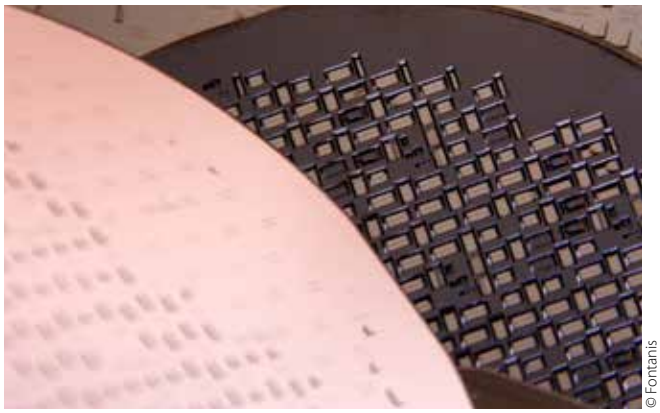
Impact

Suppliers of high and ultra-high vacuum systems to the global semiconductor industry have previously had to rely on their own in-house procedures and instrument calibration methods to provide the rigorous quality standards to which their suppliers must adhere. Assembling systems using components from over one hundred different manufacturers and requiring each to be quantified before use has created problems due to the absence of a recognised international measurement standard for outgassing rate determination. The introduction of ISO Technical Specifications for the QMS and material outgassing rates now enables ultra- and high-vacuum suppliers to apply the same robust measurement criteria for component acceptance testing, creating smoother incorporation into assembled systems. The harmonised measurement approach being introduced will also help reduce development costs for new high vacuum system and novel materials important for the ongoing miniaturization of all kinds of sensors used in the communication, semiconductor and biomedical sectors. This will help ensure the ongoing competitiveness of Europe in these important commercial markets.

Quadrupole mass spectrometers

Residual gas analysis is routinely used to monitor the quality of vacuum systems – including those used in industrial processes – as it can easily detect minute traces of impurities in low-pressure environments. The pressure inside, and contents of these systems can be determined by identifying the ion and molecular fragments present using quadrupole mass spectrometers, QMS. At their core is a filter consisting of four parallel rods to which a DC voltage and a radio frequency voltage are applied. Only ions with a specific mass to charge ratio can pass through this quadrupole filter. Ensuring QMS performance remains stable over time and that results from different instruments are comparable relies on having a standardised measurement procedure accepted by the user community.

The EMRP project *Vacuum metrology for production environments* developed outgassing reference materials and procedures for the in-situ calibration of QMS installed in industrial vacuum systems – a first step towards the introduction of measurement standardisation for QMS used in ultra-high vacuum systems.



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