Publishable Summary for 16NRM05 Ion gauge
Towards a documentary standard for an ionisation vacuum gauge

Overview

The ionisation gauge is the only vacuum gauge type for high and ultrahigh vacuum. The pertinent standardisation committee for vacuum technology ISO TC 112 has indicated that important applications need better accuracy, reproducibility and the sensitivity for many gas species, properties which all present types of ionisation gauges lack. This project will provide the relevant parameters for an ISO standard of an ionisation gauge so that this gauge is accurate (total relative uncertainty: 1 %), robust and long-term stable, with known relative gas sensitivity factors, and can be built by any experienced manufacturer.

Need

High and ultrahigh vacuum is an indispensable tool for science and industry. Fields of application for science include high-energy accelerators, plasma and fusion science, surface science, and thin film studies, which have a great impact on industry, e.g. optics, optoelectronics, and solar cells. Additional areas of application for industry include the semiconductor industry, the coating industry, and extreme ultraviolet (EUV) lithography, in which the Dutch company ASML, in cooperation with Zeiss, is the only instrument manufacturer worldwide.

The ionisation gauge is the only vacuum gauge type for high and ultrahigh vacuum but is lacking in robustness, as well as long-term and transport stability.

The pertinent technical committees ISO/TC 112 "Vacuum Technology" and of the DIN NA 060-07 “Vacuum Technology” section have made clear that the reliability and usefulness of ionisation gauges can be greatly improved by standardisation and have encouraged research towards a standardised ionisation gauge. The need in detail:

- For pumping speed measurements, ISO 21360-1 requires a standard uncertainty of 3 % of pressure measurement with an ionisation gauge. This is possible for nitrogen, but at present not for any other gas. A standardised ionisation gauge could provide this accuracy for many kinds of gases. Also the measurement of compression ratios according to ISO 5302 and ISO 21360-1 requires an ionisation gauge with well-known relative gas sensitivity factors which are not available at present.
- Support is needed for the two projects ISO NP TS 20175 and ISO NP TS 20177 by means of a standardised ionisation gauge. This was one of the major needs identified in the EMRP JRP IND12 and its follow-up Support for Impact project 14SIP01, which will benefit from the standardisation developed in this JRP.

Calibration laboratories for vacuum gauges in the HV and UHV ranges do not have reliable reference standards below 1 mPa. An ionisation gauge that is stable over a long-term (relative uncertainty of 1 % over 1 year) will provide this in order to apply ISO 3567 and ISO 27893.

Objectives

The overall objective is to determine and specify all relevant parameters to enable an ISO standard for an ionisation gauge so that this gauge is accurate, robust and long-term stable. This standard will also strengthen the metrological and technological basis of the ISO NP TS 20175 and 20177 which require a reliable ionisation gauge.

The specific objectives are:

1. To provide a substantial contribution to the resolution 2015-09 of ISO TC 112. This means in detail to determine and specify all relevant parameters that are needed to elaborate an ISO standard of an ionisation gauge (total uncertainty: 1 %) in the measurement range from 10^{-6} Pa to 10^{-2} Pa.

2. To make a substantial contribution to the two standards projects ISO NP 20175 and 20177 by providing new data material for a stable ionisation gauge and by providing 10 relative gas sensitivity factors of this ionisation vacuum gauge. This is needed for the calibration of quadrupole mass spectrometers and outgassing rate measurement systems as outlined in the aforementioned two standards.
3. To work closely with ionisation gauge manufacturers in order to consider their experiences and to make sure that the standard for the ionisation gauge will result in an instrument that is easy to use and economical to produce.
4. To work closely with ISO TC 112 and national standards developing organisations, as well as the future users of the standard, to ensure that the output of the project will cover their need for a reliable ionisation gauge. This includes close communication with their respective working groups to consider their input and to make the output of the project easily available to them in order to make the results applicable to a standard at the earliest possible opportunity.

Progress beyond the state of the art

All manufacturers of ionisation gauges develop different products even if belonging to the same type of gauge. They differ in the selection of materials, potentials and, most important, geometry. For this reason, they also significantly differ in their relative sensitivity factors. In addition, all available types are lacking long-term and transport stability, the instability being presently about 5 % over one year. Important reasons are that the electrodes are not rigid enough, the spatial emission from the cathode is not stable and the materials show a too high and unstable secondary electron yield.
This project will improve this situation by providing the design of an ionisation gauge that exceeds present performance and can be standardised. The new gauge shall improve the relative standard uncertainty due to long-term and transport instability from about 5% to below 1 % for nitrogen gas and make it unnecessary to calibrate relative gas sensitivity factors for each individual gauge and gas species, because the spread of the sensitivity factors will be reduced from about 10 % to 2 %-3 % depending on gas species. This gauge will then be able to be produced by any experienced manufacturer so that reliably known sensitivity factors can be provided together with the gauge. The aimed-for transport and long-term stability will ensure that the gauge can be used by calibration laboratories applying ISO 3567 and by users applying ISO TS 20175 and ISO TS 20177, which are presently under development.

Results

The final technical outputs will be:

1. Reports will summarise the literature review, results of simulations and materials testing and the validation of the finally preferred gauge design type. The reports will be made available to ISO TC 112. A report of published papers will show which designs were pursued in the past, which were successful and which not. It will also address the technical issues that were solved in the past and provide material for the simulations. Simulations of several different designs of ionisation gauges will be performed and a report will assess the designs in terms of sensitivity, stability, robustness, and their risks in realisation. Materials will be tested in terms of SEY, ESD and sputter rate by ion bombardment.
2. A data set of relative sensitivities of at least 10 different gas species summarised in a report as well as a validation report will contribute to the success of the two projects ISO NP 20175 and 20177. Ten model gauges will be produced in the project as a result of the investigations and these will be tested in terms of stability and in their spread of relative sensitivities.
3. The ionisation gauges will be designed with the industrial partners. This will ensure that the experience of ionisation gauge manufacturers is included, taking into account that at the end the instrument has to be economical for production. In a first step, laboratory gauges, where the geometry and materials can be exchanged for testing, will be produced. In a second step, model gauges will be produced by two different manufacturers that shall serve as a model for a standardised ionisation gauge.

The project partners will seek input from the WG 2 “Vacuum Instrumentation” of ISO TC 112 and their participating standards organisations and will provide and explain all relevant reports to the WG 2. Finally, the project will produce a Technical Specification of an ionisation gauge to be circulated to ISO TC 112 that can be used to start a ballot of a new project within ISO TC 112.

Impact

Impact on relevant standards

By carrying out this research it will be possible to develop an ISO standard for an ionisation gauge which is in the business plan [1] of ISO TC 112. With such a standardised ionisation gauge, ISO TS 20175 and 20177, presently under development, will be able to be effectively implemented. ISO 3567, 5302 and 21360-4 will also greatly benefit.

Impact on industrial and other user communities

For pumping speed measurements, ISO 21360-1 requires an accuracy of 3 % of pressure measurement with an ionisation gauge. The results of this project will enable pump manufacturers to fulfil this requirement not only for nitrogen, but also other gas species important for buyers of high vacuum pumps.

The project will have a significant impact on the semiconductor and coating industry, EUV lithography, high energy and fusion physics research facilities in Europe (CERN, DESY, ESRF, ITER) and the aerospace industry by ensuring traceability and comparability of outgassing measurement results. The exchangeability of a standardised gauge will lead to great impact in the vacuum market by reduced costs for maintenance.

Impact on the metrological and scientific communities

The impact in the scientific area will be that there is a reliable measurement of many different gas species in the high and ultrahigh vacuum. Examples of use are determinations of collision cross sections, ionisation probabilities, absorption transitions and gas exposure measurements in surface adsorption experiments.
The impact in the metrology area will be twofold: (i) The function of ionisation gauges as reference and transfer standards for calibration services will be greatly improved and widened to relevant gases other than nitrogen. National Metrology Institutes will have a reliable transfer gauge for high and ultrahigh vacuum to compare their primary standards. (ii) The use of ionisation gauges to calibrate quadrupole mass spectrometers in situ will be much more accurate with a standardised ionisation gauge, because the relative gas sensitivity factors will be reliably known.

List of publications

Project start date and duration: 01 June 2017, 3 years		
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