Partial pressure gauges

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Abstract

The determination of partial pressures in vacuum systems is usually performed by mass spectrometers. The most common type is the QMS. Quadrupole mass spectrometers were developed decades ago and have been used by vacuum specialists as a diagnostic tool since then. In the first part of the paper the principles of these mass spectrometers are briefly reviewed together with the key features of the instruments. This is necessary to operate these instruments. In the second part the boundary conditions which arise from the application as residual gas analyser in UHV/XHV plants are described. These lead to special versions of mass spectrometers. Results obtained with these instruments and typical artefacts in mass spectra obtained in the UHV are discussed.

1 Introduction

The quadrupole mass spectrometer was invented in 1958 at the University of Bonn [1, 2]. The development for industrial applications started in the early 1960s. At the beginning these instruments were mainly used by specialized vacuum-scientists and engineers solely for vacuum diagnostic purpose. Later on the instruments found their way into other applications such as gas analysis in general, surface science, plasma diagnostics, and many other applications where partial pressure measurement is one of the basic tasks.
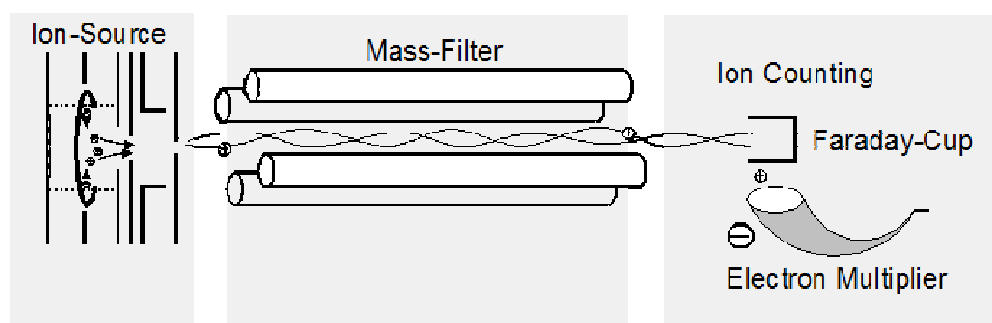
Today quadrupole mass spectrometers are also integrated into analytical systems for environmental applications and biological research and very often coupled to another analytical instrument (e.g., gas chromatograph, liquid chromatograph, ion mobility spectrometer).

A basic understanding of the principle is required to select the suitable instruments in terms of sensitivity, stability, mass range, and the like.

Ultra high vacuum applications result in high requirements on the instruments.

As the main differences compared to standard instruments, a low detection limit, extremely low outgassing of the gauge, and temperature and radiation resistivity must also be mentioned.

2 The functional units of a quadrupole mass spectrometer

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2.1 Ionization of the gas

In a quadrupole mass spectrometer the particles are separated according to their *m/e* ratio in an electrical field, so the neutral atoms or molecules have to be ionized first. The most commonly used technique is electron-impact ionization, other methods such as chemical ionization, proton transfer reaction [3], ion attachment, and laser ionization etc. are applied for special analysis methods.

For electron-impact ionization, electrons are emitted from a heated filament and accelerated towards the anode (Fig. 1). In first order approximation the electron energy is given by the voltage drop between the filament and the anode.
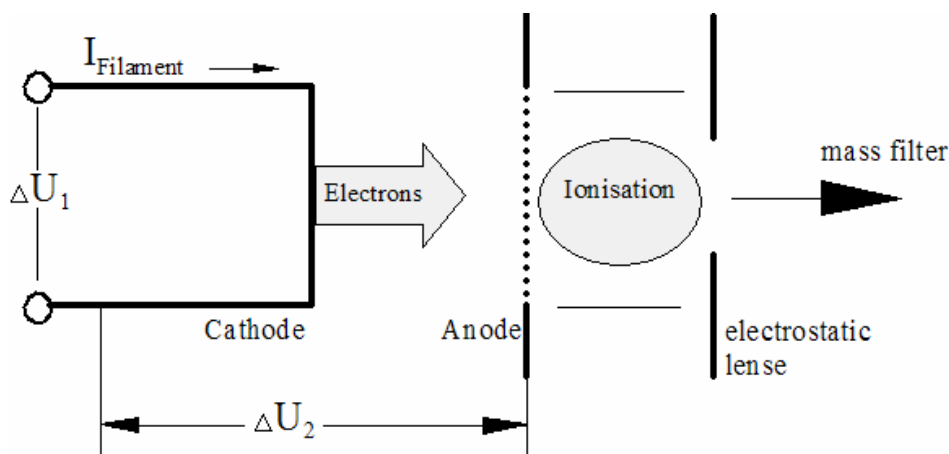

Fig.1: Electron impact ionization

Electrons which have reached the anode (here shown as a grid) have an energy of U_2 in eV.

Because they are decelerated by the electrical field of the electrostatic lens again, and ionization will occur at every space in the gas phase, this is only an approximation and spectra obtained by different instruments can not be compared totally.

As a well known fact the ionization cross-section for electron impact ionization depends on the atom or molecule to be ionized and on the electron energy as well.
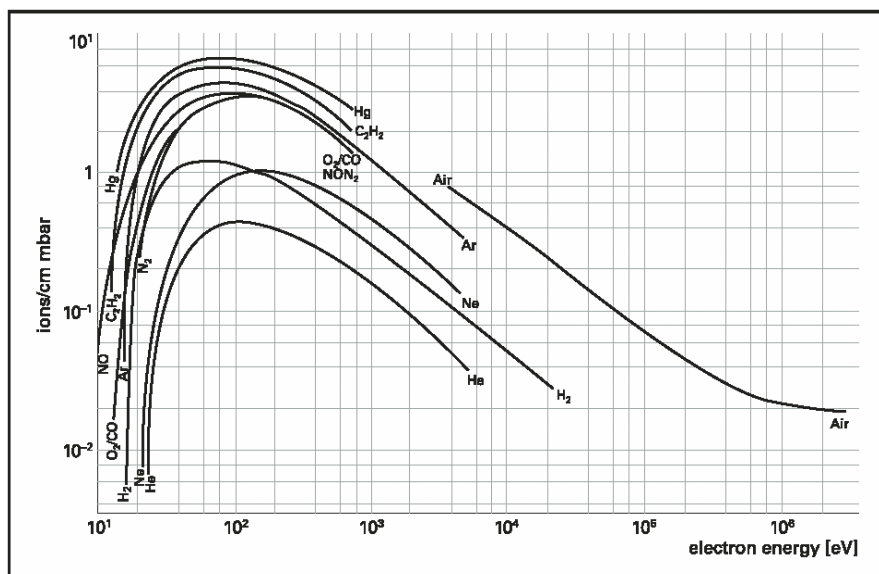
This is shown in Fig. 2.

Fig. 2: Ionization cross-section as a function of the electron energy

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From this it is evident that the sensitivity of a partial pressure gauge is gas specific and will also depend on the settings of the instrument (one essential parameter is the electron energy).

2.2   Mass separation

With the instruments described here a quadrupole mass filter is used.

Ions created in the ion source are injected with an energy of a few electronvolts into a high-frequency electrical field established among four metal rods, as shown in Fig. 3.
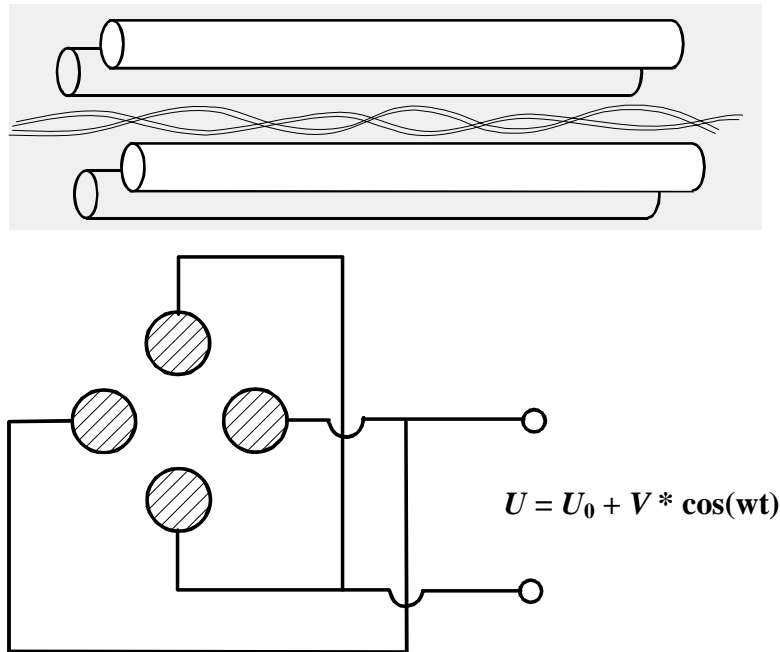

Fig. 3: The quadrupole mass filter

$$U = U_0 + V * \cos(wt)$$

Only ions with a well-defined ratio of m/e, where m is their mass and e their charge, can travel on stable trajectories in this field.

The mass resolution of the instrument is adjusted by the ratio U_0/V and a mass scan is performed by increasing the absolute value of U_0 and V.

To use such an instrument this simple description of the filter is sufficient; those interested in the equations of motion, their solution, and the stability diagram of a quadrupole filter can find an introduction in the literature [4].

Although the principle of a quadrupole is rather easy, a very high mechanical precision of the filter and a stable RF frequency are required to ensure proper operation of the instrument.

For the user of such instruments it is important to know that impurities inside the filter—coatings or small dielectric particles—may strongly influence the performance of the instrument.

2.3   Detection

The primary quantity to be measured at the exit of the filter is an ion current. Depending on the application there are different ways of measuring this current.

Two types of detectors, a Faraday cup or a secondary electron multiplier SEM (discrete or continuous) are used (Figs. 4 and 5).
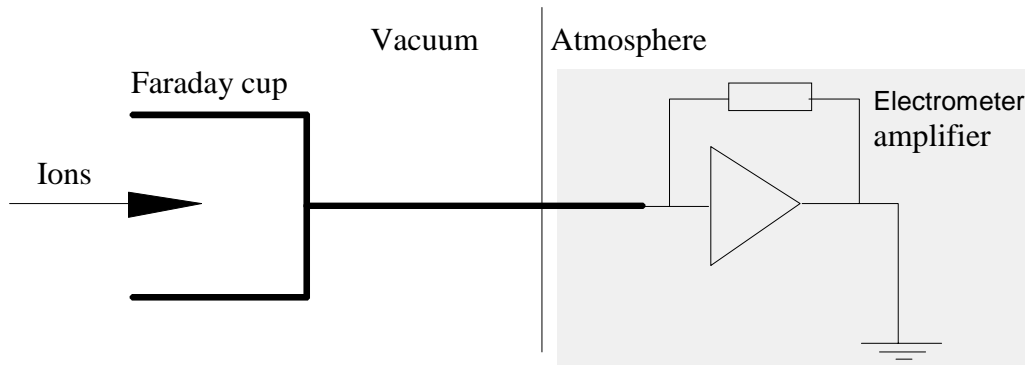
Fig. 4: Faraday cup in combination with an electrometer pre-amplifier

If a lower detection limit and a higher sensitivity are required, then the arriving ion current has to be amplified in the vacuum. Here an SEM or an C-SEM is used for an amplification up to 10^8.

Particles (ions, neutrals, electrons, photons) hitting a surface with high kinetic energy release several 'secondary electrons'. The amount of the secondary electrons released depends on the surface material. The use of several dynodes in combination with the appropriate dynode material allows for an amplification up to 10^8. One single ion impinging on the first dynode will cause an avalanche of electrons. This current can be converted to a transient in voltage and thus single-ion counting is possible with such a device too, provided the current pulse is short enough (10^{-8} s).
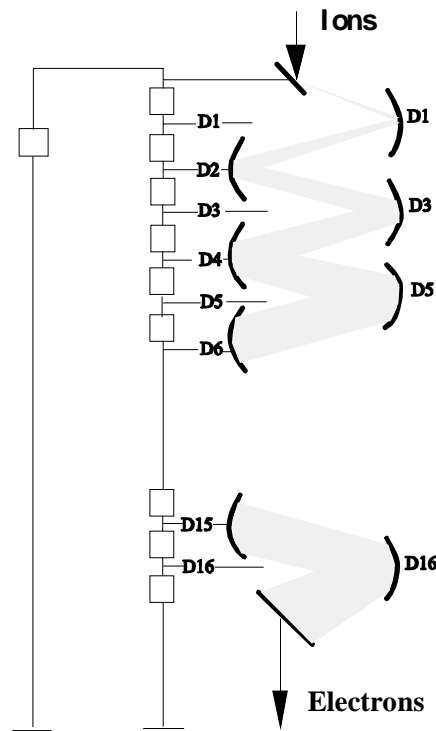

Fig. 5: The principle of a discrete SEM

A SEM can be used to amplify the initial ion current and as ion counter as well. In the latter the short voltage pulse caused by each ion arriving at the first is used to count the ions directly.

In Fig. 6 the response of the detector versus the SEM voltage at constant gas pressure is shown.

In this mode the SEM has a characteristic like a Geiger–Müller tube.

In the first region the signal increases rapidly with the increasing voltage, then it tends to saturate in a so-called plateau. (Note that Fig. 6 is a semi-logarithmic plot and the plateau achieved may be not as flat as with a Geiger–Müller tube.)

In this mode ion currents down to 0.1 CPS can be detected and a detection limit of about 10^{-16} mbar can be achieved.

The dynamic range of this method is mainly determined by the width of the pulse; for example a pulse width of 20 ns limits the upper linear range to 5×10^6 CPS.
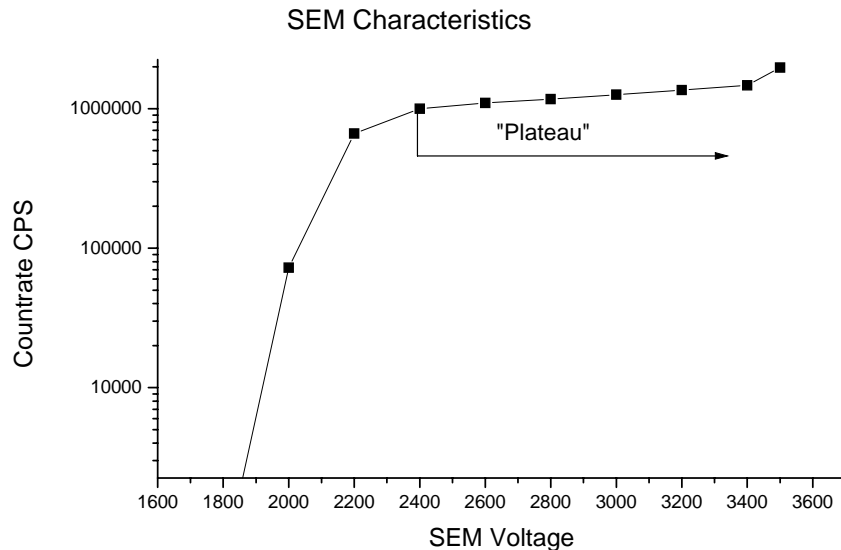
Fig. 6: Characteristics of a SEM operated in the counting mode

An SEM or a C-SEM is a passive amplifier which means that the amplifier undergoes ageing.

This effect is shown in Fig. 7. With long time-operation the characteristics will shift towards higher voltages. Therefore the characteristics have to be checked from time to time.

Because the ageing depends on many effects such as total pressure during operation, gas measured, signal height and the like, no general numbers about the lifetime of an SEM can be given.
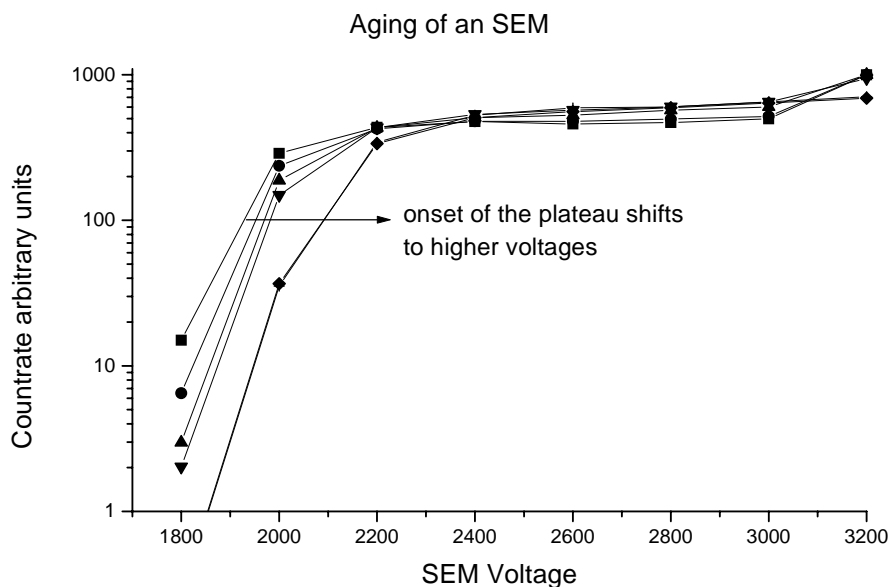
Fig. 7: Ageing of an SEM

In the ion count mode the plateau is shifted towards higher voltages during long time-operation. If the SEM is used for current amplification, the amplification decreases with time, which makes a re-adjustment of the SEM voltage necessary.

All parts of an SEM or a C-SEM are within the vacuum. Therefore the dynodes, insulators, and resistors used to build the SEM have to be UHV compatible. Other important features are the temperature resistivity during bakeout and the degas rate of the SEM under operation.

(Of course, also with an SEM used in UHV/XHV, gaps have to be avoided and threads if they are used at all have to be equipped with additional holes for easier degassing.)

2.4   Background reduction

In order to achieve a low detection limit, the background of the detector has to be as low as possible and on the other hand the sensitivity of the whole system has to be as high as possible.

One very effective method to reduce background is to use an SEM 90 degree off axis (Fig. 8). In this design photons and electrons from the ion source do not contribute to the signal and thus a very low background is achieved.
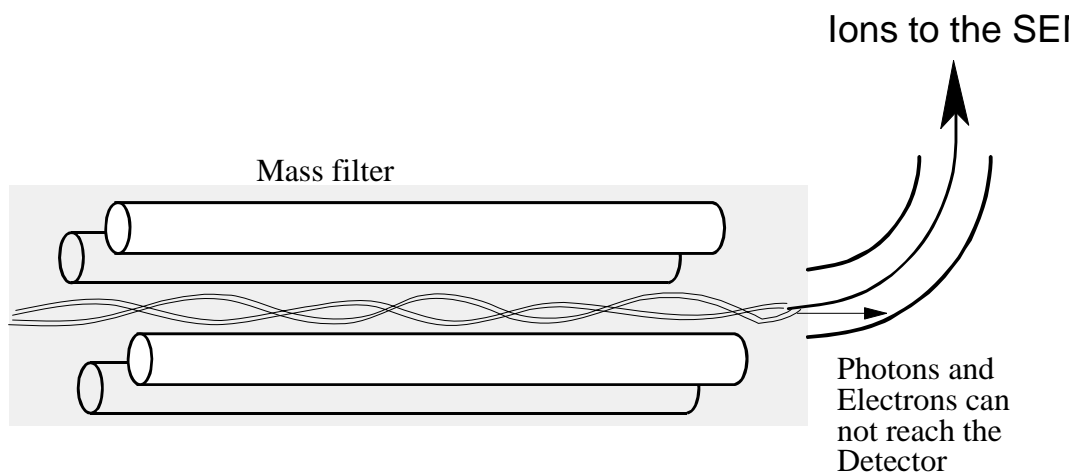

Fig. 8: SEM 90º off axis

Ions leaving the mass filter are deflected 90 degree onto the detector to suppress background.

The ions out of the mass filter have to bent 90 degree by an electric field to reach the detector in this configuration. Thus the sensitivity is lower compared to an in-line arrangement (about a factor of 2–5). However, the reduction of the background is more than one order of magnitude because photons and electrons will not reach the detector. Therefore the 90 degree off-axis geometry leads to a lower detection limit.

2.5   Interpretation of the measured spectra

With electron impact ionization not only the molecule is ionized. In most cases a fragmentation of the molecule occurs too. In addition, molecules can be multiple charged. If isotopic effects also have to be considered, the spectrum of one simple molecule can be rather complex.

For example CO_2 will show up at mass 44, 12, 16, 28, 44 and 46 amu corresponding to the ions CO_2^+, C^+, O^+, CO^+, CO_2^{++} and $^{12}C^{16}O^{18}O^+$, respectively.

As a consequence, different molecules may contribute to the signal at the same mass. For example, the water molecule will appear as H^+, H_2^+, O^+, OH^+ and H_2O^+, oxygen will appear as O^+ and O_2^+.

Thus at mass number 16 there will be an overlap of the two species. In Fig. 9 the situation for the main components of air is shown.

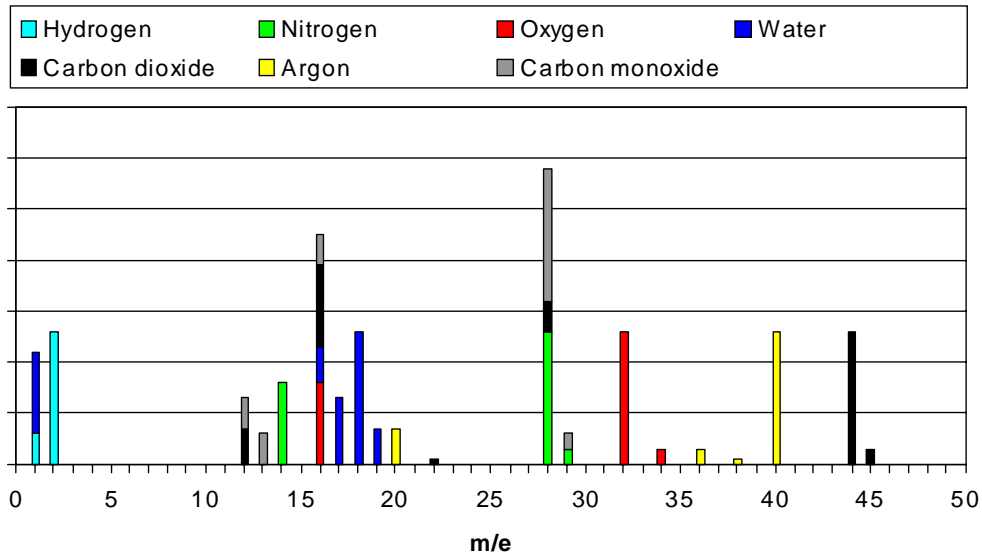## Model spectrum (Origin of peaks)

Fig. 9: Interpretation of mass spectrometric data

A quantitative analysis is possible if the cracking pattern and the sensitivity for the individual components are known. In this case the concentrations can be calculated via a set of linear equations.

For analytical purposes, spectra libraries and time-consuming calibrations by means of test gases are required.

A residual gas spectrum in the UHV or XHV region, however, can easily be interpreted; hydrogen, carbon-monoxide, carbon dioxide are the dominant gases together with water vapour (Fig. 10).
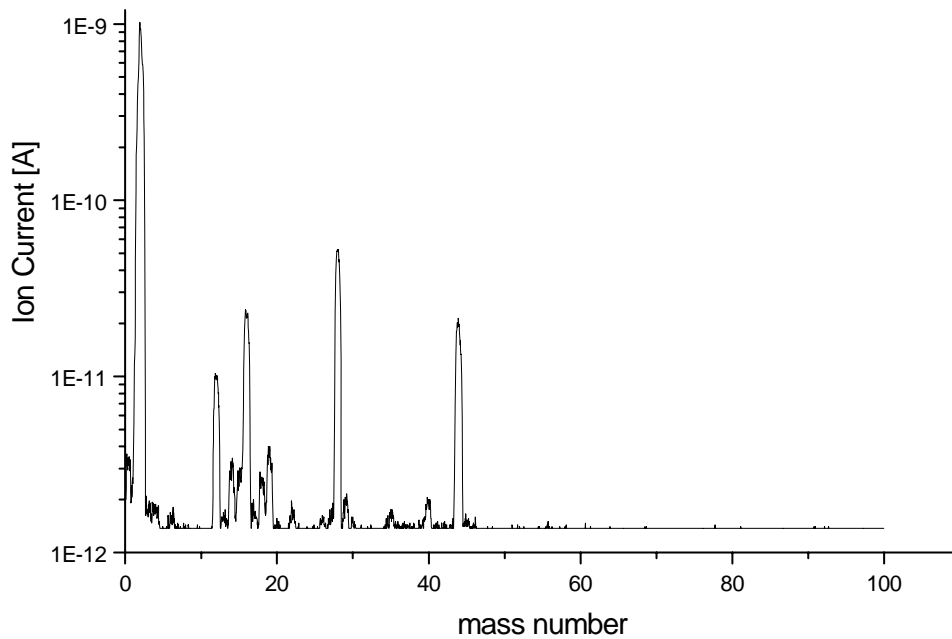

Fig. 10: Residual gas spectrum, total pressure about 10^{-10} mbar

3 Key features of quadrupole mass spectrometers

A large number of definitions and terms are used to describe these instruments.

For example, transmission, sensitivity, stability, reproducibility, and some other terms may be mentioned.

In order to get an overview, it is important to classify which of the parameters directly contribute to the measured result, which parameter just contributes to a key feature. (Of course only parameters which can be measured in common laboratory practice make sense.)

When beginning an experiment one has an idea what order of magnitude the quantity to be measured may be. Thus the basic question is the detection limit of the instrument or, more precisely, the experimental set-up. If more than one species has to be detected, as will be the case in most mass spectrometric applications, the next question is for the dynamic range of the instrument.

Of course, in many applications also the measurement speed, its influence on the accuracy and the like are essential.

3.1 Detection limit and dynamic range

However, let us stay first with the detection limit and the dynamic range and 'investigate' which of the other quantities contribute here. For this reason we describe the mass spectrometer again in brief:

- Gas is ionized in the ion source. The essential quantity is the sensitivity of the ion source in terms of ampere/mbar $= S_{\mathrm{ionsource}}$.

- The ions generated in the ion source have to be transferred towards the mass filter. The important thing here is the transfer efficiency in per cent $= T_{\mathrm{ransfer1}}$.

- Ions passing the mass filter. Here the transmission at a selected mass resolution is important $= TR_{\mathrm{ansmission}}$.

- Finally the ions have to be transferred onto the detector, see transfer efficiency $= T_{\mathrm{ransfer2}}$.

- The detector is characterized by its detection efficiency, dark noise and its dynamic range $= D_{\mathrm{eff}}$.

The resulting signal at the detector can be described in an abstract formula:

$$S_{\mathrm{ignal}} = P_{\mathrm{artialPressure}} * S_{\mathrm{ionsource\ (gas\ specific)}} * T_{\mathrm{ransfer1}} * TR_{\mathrm{ansmission}} * T_{\mathrm{ransfer2}} * D_{\mathrm{eff}} \ .$$

Looking more in detail, we see that the transmission and also the detection efficiency may depend on the mass number.

As a result of this elementary picture a high transmission of a filter, a high sensitivity of the ion source, or high detection efficiency alone do not tell us anything about the performance of such an instrument. All these quantities contribute to the sensitivity. However, the essential quantity is the total sensitivity at the output of the detector. This in detail depends on resolution settings and the gaseous component to be detected. In addition, all parameters contained in the equation above may be measured, in principle. The only quantity, however, which can be determined in normal laboratory practice is the sensitivity.

According to common practice in measurement technology a signal is accepted (species detected) if the signal is at minimum a factor of two of the background at the detector.

From the overall sensitivity S_{total} and the background b_{Detector} at the detector this detection limit can be calculated:

$$D_{\text{etection limit}} = (2 * b_{\text{Detector}})/S_{\text{total}} \quad \text{where} \quad [S_{\text{total}}] = \text{A/mbar} \quad [b_{\text{Detector}}] = \text{A} \ .$$

This is shown in Fig. 11. Here the sensitivity of the instrument (for argon) was determined to be 24.0 A/mbar. The noise band was measured with an integration time of 60 seconds ten times. This results in $b_{\text{Detector}} = 5.4 \times 10^{-14}$ ampere and a detection limit of 4.5×10^{-15} mbar.
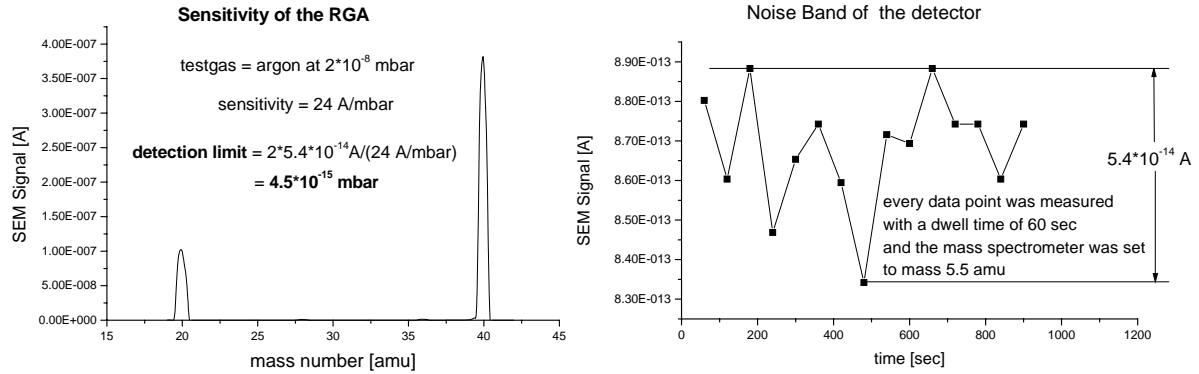
Fig. 11: Detection limit of a mass spectrometer

In some cases other gas components may interfere with the component to be detected. Then the detection limit is higher than calculated by the formula above. Because the noise band of the detector among other parameters depends on the integration time, the detection limit also depends on the desired measurement speed.

The dynamic range of the instrument is the span between the detection limit and the maximum detectable partial pressure. (If ion counting is applied, the pulse width of the SEM is an important parameter for the maximum detectable partial pressure.)

3.2 Mass resolution

The resolving power of the instrument is of vital importance especially if two gaseous components have to be detected which show up at neighbouring mass numbers.

There are some definitions which describe the mass resolution.

One according to AVS Standards is called **unit resolution**. A mass spectrometer is operated at unit resolution when the individual peaks are of equal width all over the spectrum and when there is 10% valley achieved between two neighbouring peaks at equal height.

This setting is most used for RGA applications.

Sometimes the full width at half maximum is specified. A more precise definition is the **contribution to the neighbouring mass**, because the full width at half maximum does not tell so much about the mass resolution.

This is shown in Fig. 12. Here two hypothetical peak shapes are compared and obviously the mass resolution is different. The contribution to the neighbouring mass provides more information than the full width at half maximum.

(Of course the contribution to the neighbouring mass depends on mass and mass range. And a high mass resolution always results in a lower sensitivity.)
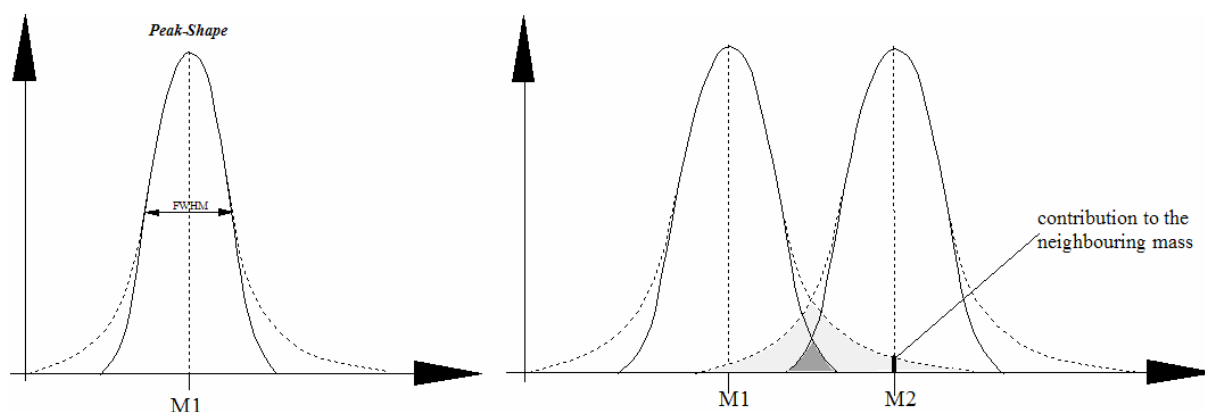
Fig. 12: Mass separation at different peak shapes with the same peak-width at half maximum

3.3 Stability, reproducibility, accuracy

Stability, reproducibility, and accuracy are well defined in measurement technology.

The latter is the band within which the measured signal stays for a given time. Reproducibility is the band in which the results are found when the measurement is repeated. The accuracy of an instrument can be specified, if a well-defined standard sample is measured.

In practice it turns out that the stability and reproducibility of the gaseous sample may have a large influence on the results too. Thus every specification of these terms should include a precise definition of the experiment.

3.4 Measurement speed

For some applications it may be important to collect data in the shortest time possible, no matter if a total mass scan or a sampling at pre-selected masses is required.

To achieve an appropriate mass resolution, the dwell time of the ions in the mass filter has to be *ad minimum* a few RF cycles. With a frequency of 3 MHz a dwell time of a few microseconds is reasonable, which results in a minimum possible response time of the same order of magnitude.

Apart from this, the electronics used to operate the mass spectrometer is the limiting factor.

One component is the RF generator used to drive the mass filter. The other component is the electrometer pre-amplifier (in combination with the SEM used which may in addition limit the measurement speed). Also the response time of an electrometer pre-amplifier depends on the type of amplifier and the range of the current to be measured. Obviously the dwell time to measure an electrical current of the order of 10^{-12} amperes differs in magnitude from the dwell time to measure a current in the order of 10^{-6} amperes provided the same accuracy is desired.

In general the electronics used determines the maximum possible measurement speed and again the maximum measurement speed depends on the accuracy and the dynamic range required.

State-of-the-art instruments offer a maximum speed of about 0.1 ms both in the sampling and the scan mode. (This may not be necessary just for residual gas analysis.)

Summary:

The key features of a quadrupole mass spectrometer are

– detection limit (depends on the setting of the instrument and in some cases on the vacuum system too)

- dynamic range of the analysis

- mass resolution, the contribution to the neighbouring mass is an appropriate definition

- the measurement speed.

All these can not be discussed as single parameters, they mutually influence each other.

For example, the specified detection limit may never be achieved at the maximum measurement speed.

4   Calibration of mass spectrometers

As already mentioned, the sensitivity and the fractionation pattern are gas-specific. Further, the sensitivity depends on the setting of the instrument, e.g., the resolution selected, the ion source parameters and the amplification by the SEM. Therefore all these parameters have to be filed together with the other calibration data, otherwise the calibration is questionable.

In general, one can use pure gas for a calibration or a gas imbedded in a carrier gas which shows no spectral overlap with the gas to be calibrated. A mixture of He, N_2, Xe in Ar as carrier gas is an example for the latter. (Such a gas mixture can also be used to check the mass scale and the resolution setting over a wide range.)

An appropriate dosing valve is required to introduce the gas mixture into the vacuum chamber (Fig. 13).

In order to discriminate against the background of the vacuum system it is recommended to introduce as much gas as the total pressure—measured by a calibrated gauge—at minimum two orders of magnitude higher than the base pressure of the system.

The measured quantity is an ion current versus mass number. Therefore the sensitivity of the instrument is specified in terms of ampere/mbar for the gas component under question.
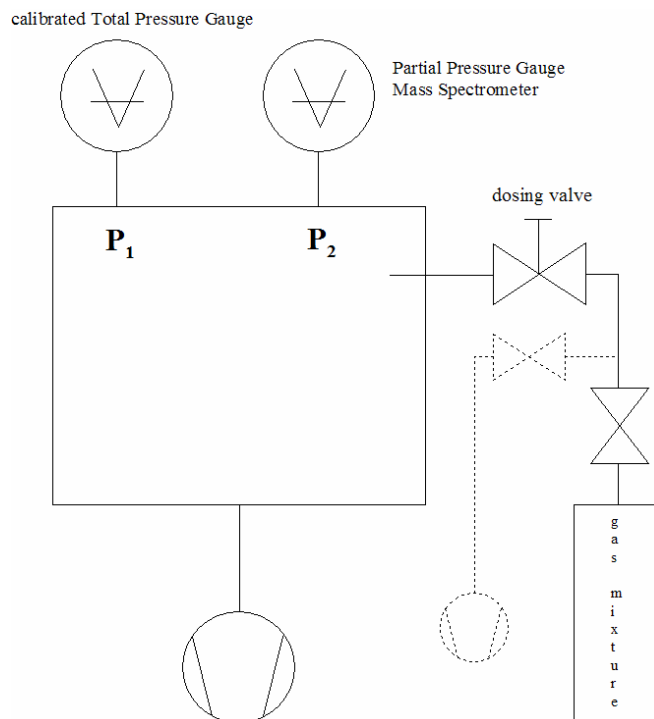

Fig. 13: Calibration of a mass spectrometer

Furthermore it is important to make sure that the pressure P_1 and P_2 at the gauge and at the mass spectrometer do not differ too much.

When a gas cylinder with calibration gas is attached to the dosing valve, it is important to avoid contamination with the air in the tubing when the gas supply is attached to the valve. A pump/purge method as indicated by the broken lines can be recommended for that.

General advice for calibration time intervals can not be given here, because the service-time of the instrument and the SEM depend strongly on the application.

In Fig. 14 the spectrum of a gas mixture is shown for different settings of the electron energy. Not only the sensitivity but also the cracking pattern changes with the electron energy.

The same is valid for changes in the settings of the resolution and electrical potential applied to the ion optical instruments.

Therefore calibration data for a RGA have to include every setting of the mass spectrometer, such as resolution, electron energy, emission current of the filament, the SEM voltage, and setting of the ion optical elements.
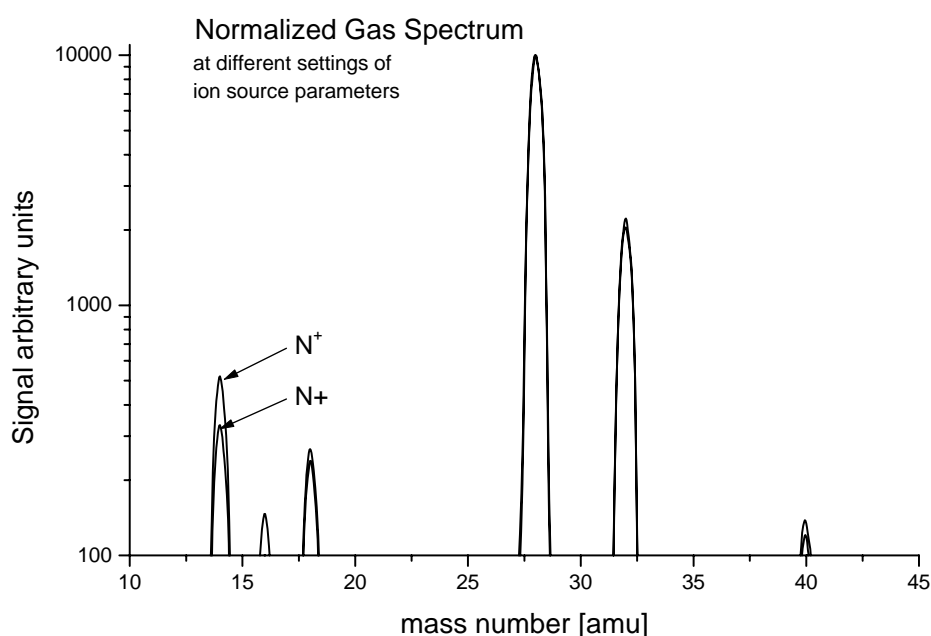

Fig. 14: Normalized gas spectra at different electron energies (70 eV and 50 eV), the sensitivity change for the nitrogen ion becomes clearly visible

5   General demands on a partial pressure gauge used in the UHV / XHV

5.1   Maximum allowed degas rate

Every material and instrument in a vacuum system will degas. Degas rates as high as 10^{-5} mbar l s^{-1} for a total plant in high vacuum technology are typical. Assuming an effective pumping speed of 1000 l s^{-1} the base pressure will be at 10^{-7} mbar which is a good number for a high vacuum system and thus indicates a low degassing rate of the whole system.

The question is how high the maximum tolerable degassing rate of a partial pressure gauge in an UHV system can be.

This can be calculated by the base pressure in the system and the effective pumping speed at the place of the total pressure gauge.

Assuming an effective pumping speed of about $100 \; 1 \, s^{-1}$—not to be mixed up with the total pumping speed applied to the whole plant—and a base pressure 10^{-12} mbar, the measured pressure at the partial pressure gauge is also 10^{-12} mbar if the degas rate is not higher than 10^{-10} mbar $1 \, s^{-1}$.

This simple calculation gives a limit for the maximum allowed degas rate of such instruments. At higher degas rates there would be a local higher pressure and the gauge would in principle measure its own gas atmosphere instead of the residual gas in the UHV system.

A total pressure gauge appropriate for high vacuum application may therefore be worthless for residual gas analysis in the UHV/XHV.

5.2 Influence of the gauge on the vacuum system

The gauge can influence the vacuum system in two ways. There is a hot filament which applies thermal radiation to the environment and can lead to desorption. Electrons are emitted from the filament which can hit the surface of the vacuum system and lead to gas releases or influence other instruments if the screening is insufficient.

These two effects have to be considered in the planning phase of an experiment, no general advice can be given here.

5.3 Bake-out of the vacuum system

In order to achieve a low degassing of the surfaces inside the vacuum chamber and thus a low base pressure, baking of the whole system is commonly applied. A pressure gauge suitable for UHV/XHV has to tolerate temperatures up to 400ºC.

It must be realized that the gauge is inside the system and during a short baking may not reach the same temperature as the other parts of the vacuum system. From this it is possible that material will condense at the colder parts of the plant—at the gauge.

Such cold spots can only be avoided if the bake-out time is sufficiently long.

Furthermore, under operation, the filament of the gauge is at 1000ºC or even above. Therefore it is strongly recommended to switch the filament on during bake-out or at least to switch it on during the cool-down phase.

5.4 Design criteria for (partial pressure) gauges in the UHV/XHV

For a partial pressure gauge to be used in UHV/XHV systems, the same design criteria as for the other components are mandatory. As mentioned before the gauge has to withstand a bake-out at up to 400ºC. Therefore, because of thermal expansion during bake-out, not every combination of materials can be used. If materials have to be in contact with each other their thermal expansion coefficients have to match, otherwise *ad minimum* a mechanical misalignment after bake-out may result.

Degassing of the device has to be kept at the lowest possible level. As a consequence, suitable materials have to be selected and the physical surface of the instrument has to be minimized by design. In addition, surface roughness has to be at a minimum. Further gaps with a low conductance are not allowed. Threads have to be avoided if possible and if they are unavoidable, additional holes for proper degassing are mandatory.

In particular, the surface of the ion source has to be minimized, otherwise this would be the largest source of desorption.

An example for a UHV design of an ion source is shown in Fig. 15.

Fig. 15: Grid ion source. The surface of this ion source is minimized by the grid design of the formation chamber.

6   Technical solutions

6.1   Choice of the material

Materials such as plastic can not be used at all, because of their low temperature stability, their low radiation stability and their high vapour pressure. Thus a whole class of materials for use as electrical insulator is ruled out.

The only materials allowed are metal and ceramics. Here the thermal expansion coefficients match sufficiently to allow bake-out temperatures up to 400ºC. The same is valid for an electrical feed through. In addition the junction between metal and ceramics has to be absolutely leak tight.

6.2   Pre-cleaning of the material

Even in high vacuum technology the material to be used has to be pre-cleaned. All materials such as lubricants from the machining process have to be removed from the surface. Cleaning in a supersonic bath with pure ethanol as the last step is mandatory. Thus one may be able to remove most of the impurities, however, water will stick in the form of a few monolayers on the surface and has to be removed by thermal treatment. Looking at a residual gas spectrum in the UHV/XHV, obviously H_2, CO, and CO_2 are the most dominant gases. The hydrogen partial pressure is most affected by the compression of the pump used. All three gases, however, are dissolved in the solid body in the metal. Therefore, if a very low degassing level is desired, the gases dissolved in the metal also have to be removed prior to the application in the vacuum. Firing these materials at temperatures up to 950ºC in a vacuum furnace is the most effective method here.

For XHV applications firing in a vacuum furnace is mandatory. (Only special types of high-grade steel can be fired at 950ºC without softening of the knife edges of the CF flange.)

6.3   Electrical design

So far methods keeping the degas rate of the gauge at the lowest level possible have been described. When such a gauge is operated—and the following is valid for every gauge in the UHV—the thermal

radiation of the hot filament and electrons emitted by the filament can contribute to undesired degassing of the other parts of the plant. To avoid most of the thermal degassing induced by the radiation of the hot filament, the position of the gauge has to be selected carefully.

Electron-induced degassing from the gauge, however, can only be avoided by electrical design. In Fig. 16 two electrical designs of gauges or ion sources are compared. Most common, the filament is electrically at negative potential, the cathode is positively biased and electrons mainly go from the anode (filament) towards the cathode. However, electrons may also get onto other surfaces in the system. Here electron-induced desorption will take place. To avoid this effect the whole gauge is positively biased. Thus electrons can end up only at well-defined surfaces of the ion source.
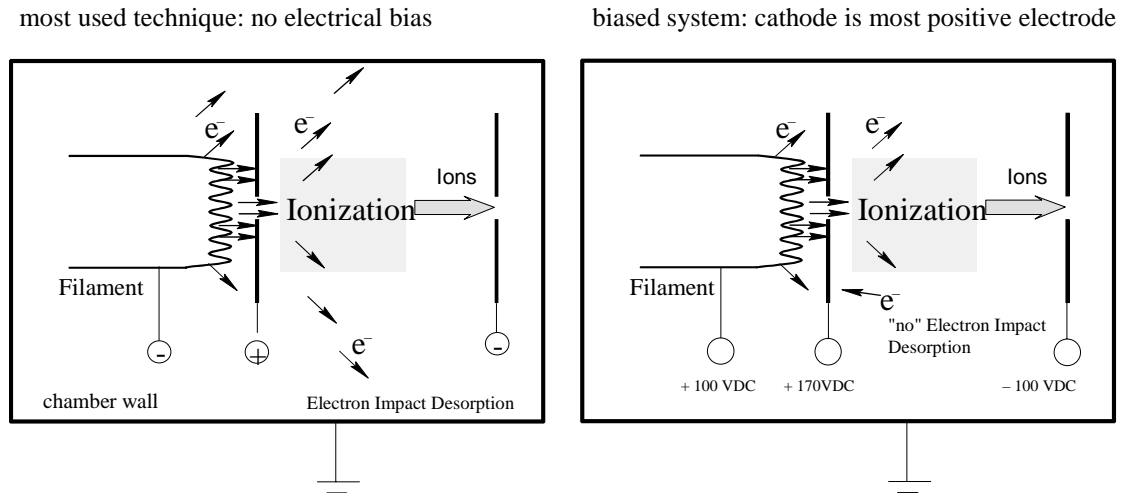

Fig. 16: Electrically biased ion source to further reduce EID

6.4   Radiation resistivity

The materials used to build up the analyser in the vacuum exhibit a sufficient resistivity against radiation. However, the electronics will suffer from radiation after some time. Therefore the electronics at best has to be separated from the analyser as indicated in Fig. 17.
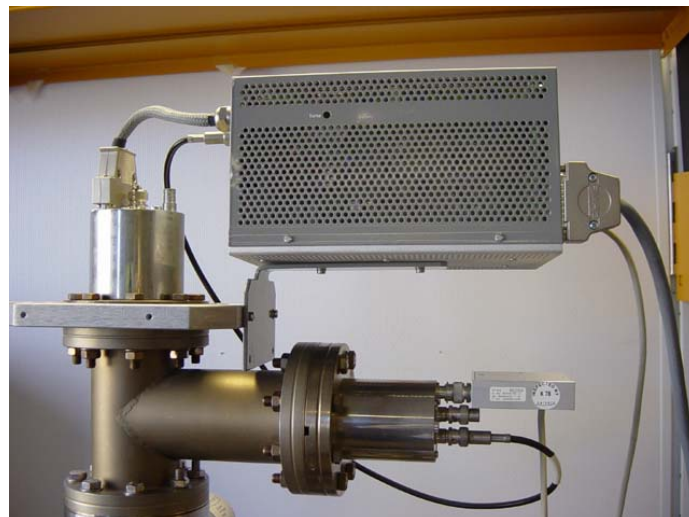

Fig. 17: Analyser and electronics separated to apply shielding against radiation (not shown here)

In practice distances up to 6 metres between the analyser and the electronics and the electrometer pre-amplifier may be necessary.

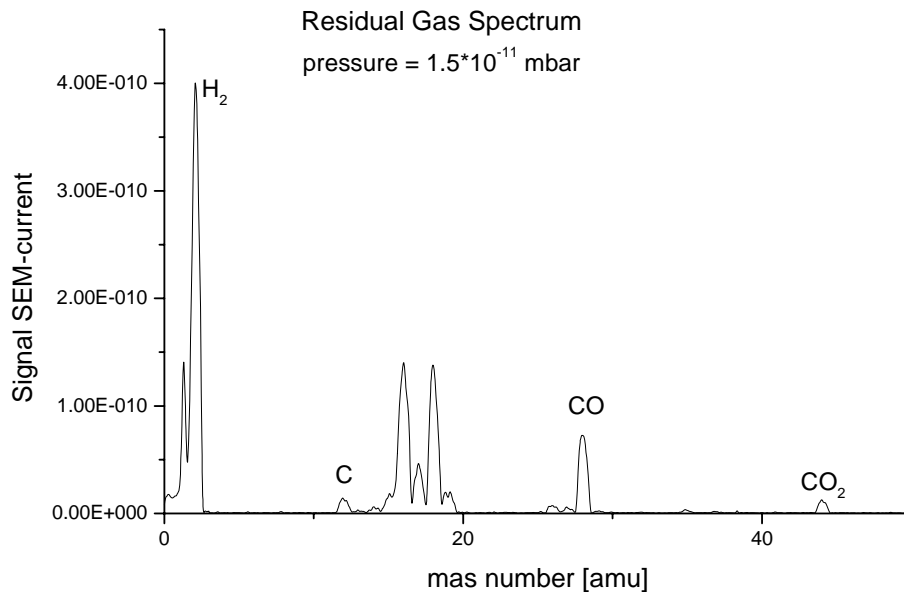# 7 Spectra obtained with RGAs in the UHV

Fig. 18: Residual gas spectrum in UHV

7.1 Artefacts, EID ions

EID ions are often found in residual gas spectra from UHV/XHV plants.

In the residual gas spectra of HV plants these ions also may be present, however, as there are so many other gas components and the partial pressure gauge's sensitivity is not so high, they are just not detected or overlapped by others under most circumstances (Fig. 19).
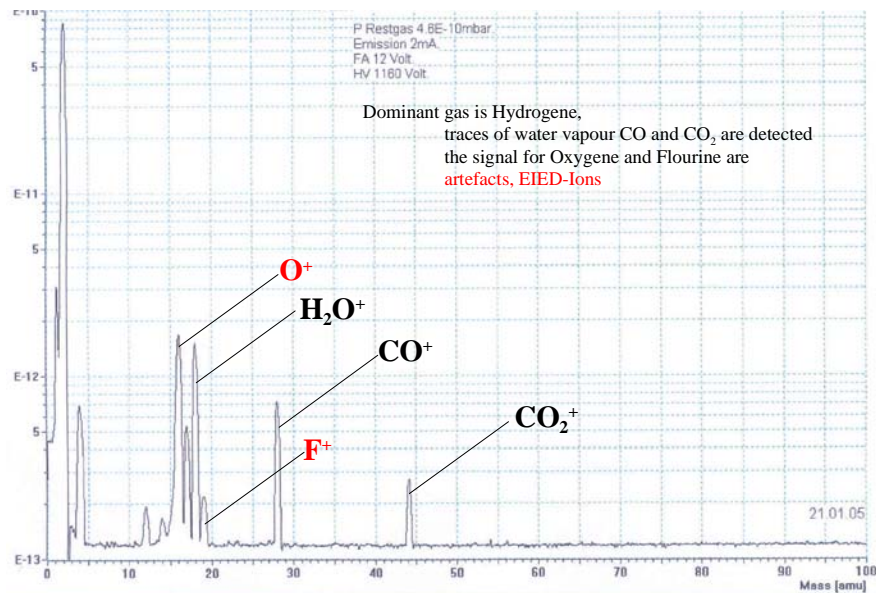

Fig. 19: EID ions in an UHV residual gas spectrum

EID ions originate from metallic surfaces. Depending on the cleanliness of the material, mostly the anode, they are set free as ions by electron bombardment. As these ions are not generated in the gas phase, their kinetic energy is higher than the energy of those generated in the gas phase.

Ions generated in the gas phase have to be extracted out of the 'formation room' and accelerated towards the mass filter. They travel with an energy of a few electronvolts through the filter. If the corresponding voltage is reduced, most of the ions out of the gas phase can no longer pass the filter. Only EID ions may pass the filter, because of their higher initial energy. Figure 20 shows a residual gas spectrum recorded at different ion energies (in the mass filter).

Clearly visible is that the signal generated by EID ions is less affected by the so-called 'field axis voltage' whereas the signal of the other ions strongly decreases.

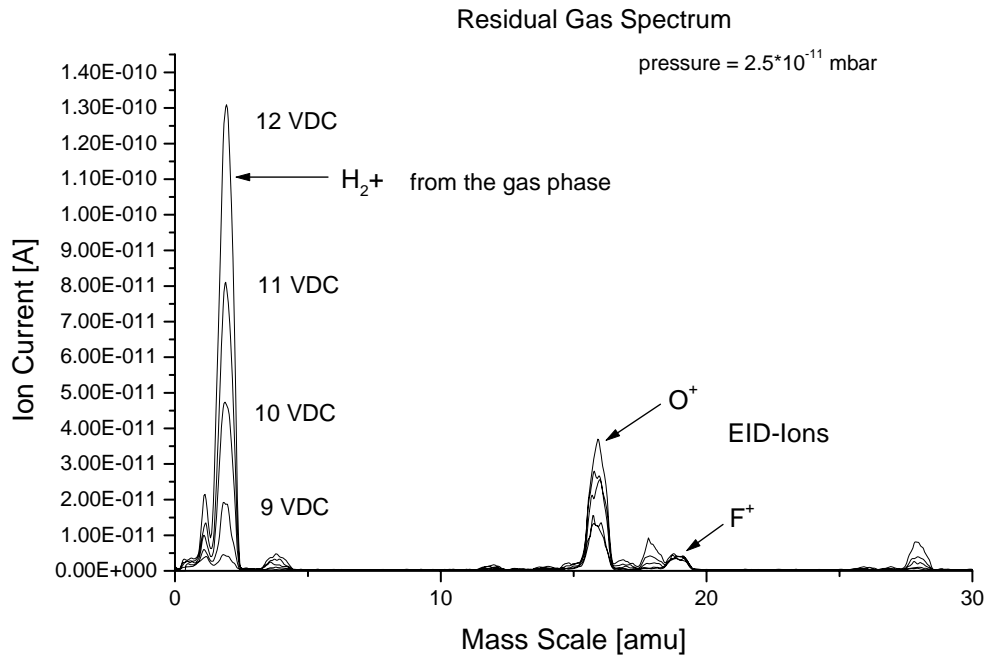(F^+ EID ions also show up in the spectrum below at a lower level than O^+.)

Fig. 20: EID ions and ions originating from the gas phase

8   Conclusion

Beneath the sensitivity in terms of ampere/mbar and a low detection limit required to detect critical gaseous components in the residual gas of an UHV system, a partial pressure gauge has to be of strict UHV design.

One effective method to achieve the low detection limit is the use of an SEM 90° off axis.

In the deep UHV and/or XHV region a UHV design of the gauge alone is not sufficient. The materials used to build the gauge have to be degassed at high temperatures in a vacuum furnace prior to assembly. Otherwise the gauge would measure its own gas atmosphere.

In order to avoid electron impact desorption from the vacuum system it is important to electrically bias the whole ionization chamber of the partial pressure gauge positively. This is important for UHV, XHV, and some analytical applications as well.

Even with this technique EID ions are detected in the mass spectrum, which result from the anode of the ion source.

Acknowledgements

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