Performance of an RGA with a transverse magnetic field applied to the mass filter

S. Sarfaraz Uddin (s.syed@liv.ac.uk), B. Brkić, J. R. Gibson, J. Sreekumar and S. Taylor

Department of Electrical Engineering and Electronics, University of Liverpool, Liverpool, L69 3GJ, UK

Introduction and motivation

A Quadrupole Mass Spectrometer (QMS) is an instrument for measuring concentrations of atoms and molecules by separating atomic and molecular ions according to their mass-to-charge ratios (m/z). It consists of an ion source, quadrupole mass filter (QMF) and detector. QMSs have a wide range of applications, varying considerably and covering most disciplines. The term RGA is derived from Residual Gas Analyser, one of the earliest and most common uses of quadrupole mass spectrometers.

Usually, the resolution of the QMS can be improved by increasing the number of rf cycles of the rf electric field experienced by the ions when passing through mass filter [1]. An alternative method to increase the performance of a QMS is to apply static magnetic field to the mass filter [2, 3].

In this work, the mass filter of a QMS has been simulated using a numerical solution to the Mathieu equation. In addition to conventional electric fields, a static magnetic field is applied and the effect on QMS resolution has been investigated. Moreover, the effect of change in different parameters of QMS and input parameters such as ion energy, length and rf frequency in the presence of static magnetic field has also been investigated. It was assumed in the model that the QMS has hyperbolic form electrodes and that the magnetic field penetrates along the full length of the mass filter assembly.

The effect of magnetic field on ion trajectories

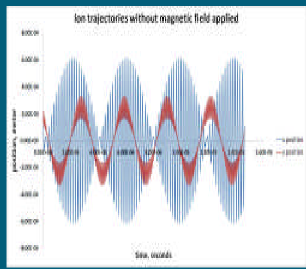

Figure 6. Numerical simulation of ion trajectories in x and y directions for Ar^+ without magnetic field applied to the QMF electrodes.

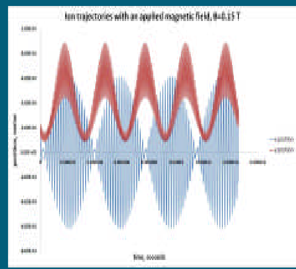

Figure 7. Numerical simulation of ion trajectories in x and y directions for Ar^+ with magnetic field of 0.15 T applied to the QMF electrodes.

Ion motion in both Figures 6 and 7 starts at the same initial point with x = 0.119 mm and y = 0.121 mm. As can be seen from Figure 7, the magnetic field has no effect on ion motion in the x direction, but has major effect in the y direction. The ion trajectory is shifted along y-axis and its amplitude is increased from 0.65 mm peak-to-peak to 0.79 mm peak-to-peak.

The effect of magnetic field on resolution of the QMS

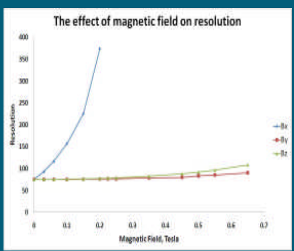

Figure 1. The effect of magnetic field on QMS resolution applied in the x, y and z directions respectively.

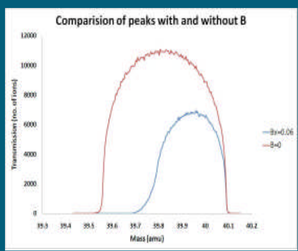

Figure 2. Behaviour of the simulated transmission peak with and without magnetic field.

Figure 1 shows the behaviour of the resolution, measured at 10% peak height, as a function of magnetic field. It can be seen that as magnetic field is varied between 0 and 0.2 T the resolution increases. It can also be seen from the plot that the maximum increase in resolution occurs when the magnetic field is applied in the x direction (R≈375 at 0.2 T), with minor resolution increase with B applied in y and z directions. Figure 2 shows the behaviour of a mass spectral peak with and without a magnetic field applied to the QMF electrodes. It is clear that with added magnetic field the low mass tail is considerably reduced and the resolution improves howbeit at the expense of sensitivity.

Previous experimental work

The use of magnetic field in quadrupole ion sources, ion traps and sector instruments is well known. However, little work has been done concerning the application of magnetic field to the QMS filter. In 1999, the effect of magnetic field on the mass spectra of argon gas has been studied by Tunstall et al. by applying the transverse magnetic field through the use of a bar magnet fixed in a steel yoke around the mass filter.

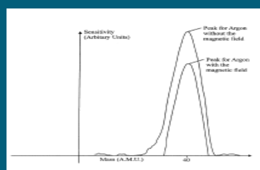

Figure 8. Experimental mass spectra for argon gas without and with the transverse magnetic field [2].

Figure 8 shows two argon mass peaks, which are reproduced from their work [2]. It is clear from the figure that both low mass and high mass sides are sharper and that the resolution has improved at the expense of sensitivity. Later B. Srigengan and team used a similar setup to apply transverse magnetic field along the length of the QMS filter [3] with a similar effect being observed.

Performance of the QMS with transverse magnetic field

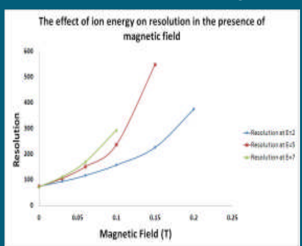

Figure 3. The effect of ion energy on QMS resolution with applied magnetic field in x direction.

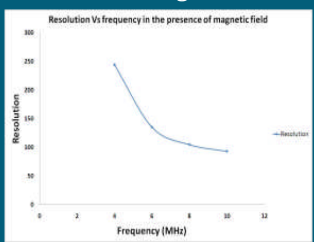

Figure 4. The effect of drive frequency on QMS resolution with applied magnetic field in x direction.

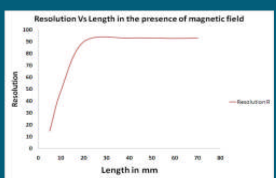

Figure 5. The effect of change in QMF electrodes length on QMS resolution with applied magnetic field in x direction.

The results from Figures 3-5 show that:

- resolution ***increases*** with increase in ion energy which we attribute to the Lorentz force (**v** x **B**).
- resolution decreases with increase in rf frequency either because of the Lorentz force or because of increased ion interaction with field at lower rf frequency.
- resolution increases with QMF electrode length, but then saturates.

Conclusions

Simulation results for a QMS have been presented showing the effect of magnetic field, applied along the whole length of the mass filter. Clearly enhanced resolution observed experimentally has been simulated theoretically using our model. The effects may be explained by considering the additional Lorentz force produced by ion motion in the magnetic field. The effects of different input parameters such as variation of ion energy, drive frequency and electrodes length have been examined and remain the subject of ongoing investigation.

References

1. P. H. Dawson, *Quadrupole mass spectrometry and its applications*, Elsevier, Amsterdam (1976).
2. J. J Tunstall, S. Taylor, A. Vourdas, J. H. Leck and J. H. Batey, *Application of static magnetic field to the mass filter of a quadrupole mass spectrometer*, *Vacuum* **53,** 211-213 (1999).
3. B. Srigengan, J. R. Gibson and S. Taylor, *Ion trajectories in quadrupole mass spectrometer with a static transverse magnetic field applied to mass filter*, IEE Proc. Sci. Meas. Technol. **147,** 274-278 (2000).