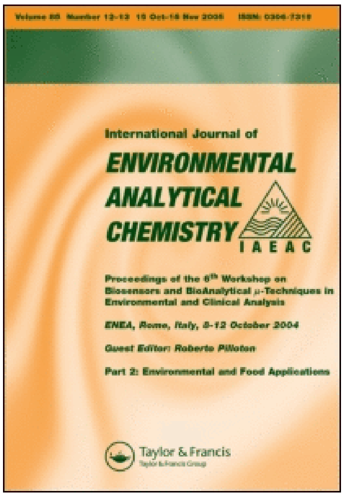

International Journal of Environmental Analytical Chemistry
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713640455

Ion Mobility Sensor In Environmental Analytical Chemistry—Concept And First Results

J. I. Baumbach[a]; D. Berger[b]; J. W. Leonhardt[b]; D. Klockow[a]
[a] Institute of Spectrochemistry and Applied Spectroscopy, Dortmund 1, Germany [b] Central Institute of Electronphysics, Berlin, Germany

To cite this Article Baumbach, J. I. , Berger, D. , Leonhardt, J. W. and Klockow, D.(1993) 'Ion Mobility Sensor In Environmental Analytical Chemistry—Concept And First Results', International Journal of Environmental Analytical Chemistry, 52: 1, 189 — 193
To link to this Article: DOI: 10.1080/03067319308042859
URL: http://dx.doi.org/10.1080/03067319308042859

Intern. J. Environ. Anal. Chem., Vol. 52, pp. 189-193
Reprints available directly from the publisher
Photocopying permitted by license only

ION MOBILITY SENSOR IN ENVIRONMENTAL ANALYTICAL CHEMISTRY – CONCEPT AND FIRST RESULTS

J.I. BAUMBACH*, D. BERGER†, J.W. LEONHARDT† and D. KLOCKOW*

**Institute of Spectrochemistry and Applied Spectroscopy, Bunsen-Kirchhoff-Str. 11, D-4600 Dortmund 1, Germany,*
†Central Institute of Electronphysics, Hausvogteiplatz 5–7, D-1086 Berlin, Germany

(Received, 20 October 1992; in final form, 23 November 1992)

Ion mobility spectrometry is a technique for generating ions at atmospheric pressure via ion-molecule reactions, and for analysing them in an ion drift tube.

The time required for the ions to traverse the length of the drift tube is mainly a function of the mass and the charge of the ions. Besides, ion shape and polarizability also affect the drift time.

Ion mobility spectrometry does not allow structural identification and quantification of unknown substances in mixtures. However, under certain boundary conditions it provides selective fingerprints of the substances to be observed, and operates at the ppbv concentration level and the millisecond time scale.

Through further miniaturization of a recently developed instrument of this type an ion mobility sensor is to be constructed. This sensor includes drift channel, operating shutter, collecting electrode, electronic data acquisition and translation board. The sensor makes possible to obtain real-time ion mobility spectra.

We present and discuss the concept of a small ion mobility spectrometer, its operation principle and first results on the way towards its further miniaturization.

KEY WORDS: Gas analysis, ion mobility spectrometry, miniaturization, monitoring, sensors.

INTRODUCTION

An ion mobility sensor is a miniaturized ion mobility spectrometer and operates as an ambient pressure ionization detector, suitable for real time detection and characterization of trace vapor constituents in gaseous mixtures.

It works in a similar way as a time-of-flight mass spectrometer. The major difference is, that a time-of-flight mass spectrometer requires a vacuum where the mean free path length of the gaseous molecules is many times the dimensions of the instrument. The ion mobility sensor, in contrast, operates at ambient pressure where the mean free path length of the gas molecules is smaller then the dimensions of the sensor.

A typical ion mobility spectrometer [1-7,16] comprises an ion-molecule reaction chamber, an ionization source associated with the ion reaction chamber, an ion drift chamber, an

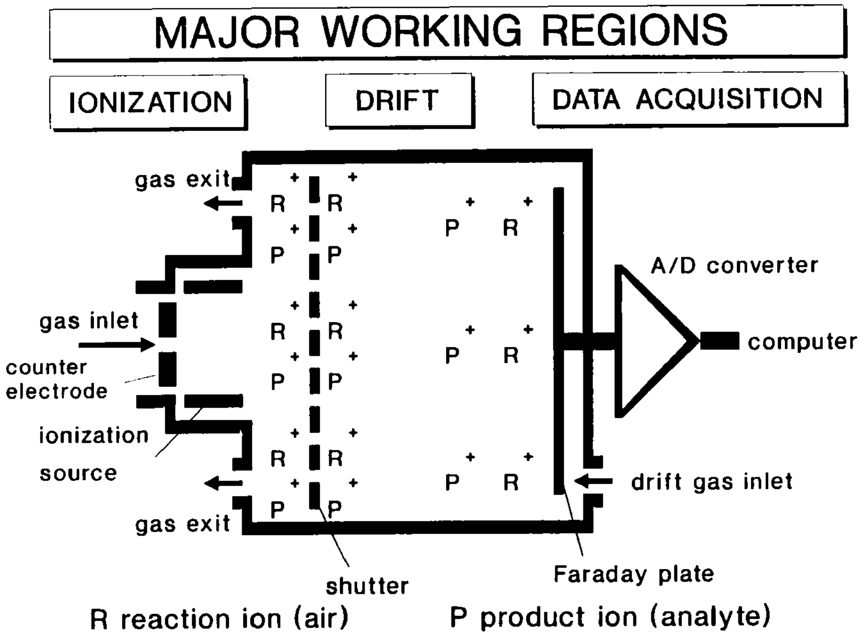

Figure 1 Basic construction of an ion mobility spectrometer.

ion/molecule injection shutter (Bradbury-Nielsen-Shutter) placed between the ion reaction chamber and the ion drift chamber, and an ion collector (Faraday plate). An illustration of the basic construction of an ion mobility spectrometer with ionization and drift region, data acquisition board and main gas flow directions is presented in Figure 1.

A carrier gas, normally air or nitrogen, transports gases or vapors from material to be analysed into the ion mobility spectrometer. There, the carrier gas with the analyte molecules is ionized by the ionization source. For the last mentioned purpose β-radiation sources are usually employed [1-7], but lasers [8-11] and discharge lamps [12] have also been used.

Because of the great excess of carrier gas, the ions generated are almost exclusively from carrier gas molecules. Since the mean free path length of the ions is many times smaller than the dimensions of the reaction chamber of the spectrometer, multiple collisions between ionized species and the analyte molecules occur. In these collisions the charge of the ions is transferred to the analyte molecules.

The charged molecules are accelerated by an electrostatic field gradient maintained between counter electrode and Faraday plate, causing them to travel towards the injection shutter interface of the ion drift chamber, in which they quickly reach the terminal velocity.

Periodically, the potential of the ion shutter is adjusted for a very short period of time to a value permitting a swarm or pulse of ions to pass from the ion reaction chamber into the ion drift region. There, under the influence of the electrostatic field, the ions are pulled to the ion collector (Faraday plate).

The time of arrival at the ion collector plate of each ionic species, derived of both, carrier gas and analyte gas molecules, is determined by the particular ion mobility in the non ionized gas filling of the drift chamber. Thus, it is possible to identify the different ionic species by monitoring the time between the introduction of the ions into the drift region at the electric shutter, and the arrival of the ions at the collector plate. The quantity of ions collected as a function of drift time is recorded as a current and directly treated by a microprocessor.

EXPERIMENTAL

The parameters chosen for the instrumentation and construction of the ion mobility spectrometer are presented in Table 1. In the ionization region a 15 mCi ^{63}Ni radioactive foil was used as a source of ionization, and standard power supplies were employed to establish an electrostatic field in the drift region. At the Bradbury-Nielsen-shutter ion swarms are created for time intervals less than 50.10^{-6}s. Through this short gate time all ions start to travel in a single plane of the drift field. The Bradbury-Nielsen-shutter consists of a single grid of spaced wires, alternating wires being biased to +50 V or -50 V as to the gate reference voltage. Thus an orthogonal gate field with respect to the drift field in the tube was created. The control unit for the shutter pulse drive circuit and the A/D-converter are on-line connected with a computer.

Purified air was used for the sample transport, carrier and drift gas (also air) in the drift region flow as indicated in Figure 1. This means, the ion mobility spectrometer works under conventional bidirectional gas flow conditions. Currents caused by ions reaching the collector plate were amplified by a pre-amplifier. Analysis of the ion mobility signals and

Table 1 Instrumentation parameters of already constructed spectrometer and planned sensor at ISAS.

	at present (spectrometer)	*in future (sensor)*
Mechanical Parameters		
Ionization region diameter	1.0 cm	0.3 cm
Ionization region length	2.0 cm	1.0 cm
Drift region diameter	1.5 cm	0.7 cm
Drift region length	5.0 cm	3.0 cm
Ionization source	15 mCi Ni-63	Ni-63/UV-light corona discharge
Electrical Parameters		
High voltage (+/-)	3000 V	2000 V
Drift field (+/-)	333 V/cm	333 V/cm
Shutter width	50.10^{-6s}	10.10^{-6s}
Total ion current (+/-)	1 nA	?
Operational Parameters		
Carrier gas	air	air/nitrogen
Drift gas	air	air/nitrogen
Temperature	ambient	ambient
Pressure	ambient	ambient
Carrier gas flow	2 l/min	?
Drift gas flow	10 l/min	?

data storage were provided by a Burr-Brown-A/D-converting card integrated in a lap-top computer. The whole drift tube was surrounded by an aluminium tube to reduce electrostatic field effects and to reach the lowest level of ion current measurement possible as well as very short gating pulse widths.

Ions are directed down the drift tube towards the collector by an electric field of about 333 V/cm, created by the voltage potential between the counter electrode and the collector, which is grounded. This field was maintained and controlled by enclosing the drift region within stainless steel guard rings spaced by ceramic or Teflon rings. The voltage at each guard ring was produced by a line of resistors, connected in series down the length of the drift tube from the ionization region to the collector plate.

RESULTS AND CONCLUSIONS WITH RESPECT TO MINIATURIZATION

The present instrument has outer dimensions of about 15 cm length and 5 cm diameter, including the ionization and the drift region as well as the guard rings necessary to stabilize the electric field within the drift region. It is smaller than any of the spectrometers listed in Table 2.

For further miniaturization, the design of the drift channel and the time intervall of ion swarm creation have to be carefully considered. By changing the number of guard rings, the drift path was reduced to a few cm length, without observing significant changes in resolution, sensitivity and total ion current. For comparison with the work of other authors [14,15], spectra of diisopropylmethyl-phosphonate (DIMP) were taken, and mobilities of 2.3, 1.5, and 1.03 cm^2/Vs for the reaction ions, monomer and dimer ions, respectively, were obtained (see Figure 2). The monomer peak is formed by $DIMP(H_2O)H^+$ ions and the dimer peak by $(DIMP)_2H^+$. In Figure 2 also the concept of spectra analysis via Gaussian curve fitting is shown.

A comparison of the instrument just described and commercially available ion mobility spectrometers is made in Table 2 (for a detailed discussion of resolution of ion mobility spectrometers see [13]).

Table 2 Resolutions and operating parameters of commercially available ion mobility spectrometers[1] in comparison with the instrument developed at ISAS.

Ion-Mobility-Spectrometer	*Resolution*	*Shutter time*	*Drift length*	*Electrostatic field*
		10^{-6}s	cm	V cm^{-1}
Graseby Ionics, UK	20	180	3.8	215
PhemtoChemProducts, USA	40	50	8.0	350
HRT Graseby Ionics, UK	100	50	44	500
Barringer, Canada	?	200	7	200
ISAS-IMS, Germany, present status	50	50	5.0	333
ISAS-Sensor, Germany, future design	100	10	3.0	333

[1] Specifications partially from P. Watts and A. Wilders: On the resolution in practical ion mobility systems, Int. J. Mass Spectrom. Ion Proc. **112** (1992) 179, and partially from official information brochures of the manufacturers. The figures for Barringer are rough estimates on the basis of private communication.

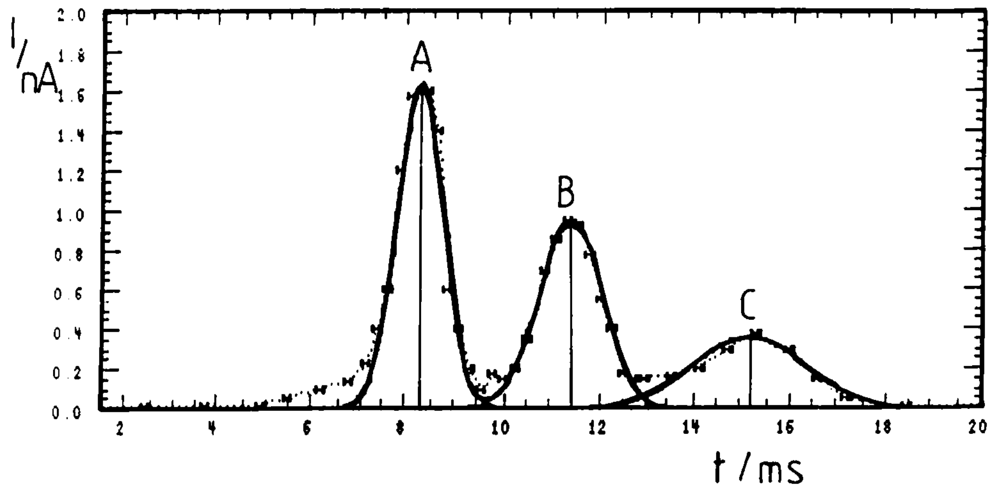

Figure 2 Ion mobility spectrum of diisopropylmethylphosphonate.

The concept of further miniaturization is indicated by the already experimentally supported parameters listed in Table 1. It is planned to integrate drift channel and signal acquisition in a silicon wafer directly connected to a high speed portable computer, in order to realize a sensor applicable to multidimensional field analysis conditions.

References

1. T. Carr (Ed.), *Plasma Chromatography* (Plenum, New York, 1984) 249pp.
2. H.H. Hill, W.F. Siems and R.H. St. Louis, *Anal. Chem.*, **62**, 1210A-1209A (1990).
3. R.H. St. Louis and H.H. Hill, *Crit. Rev. Anal. Chem.*, **21**, 321-355 (1990).
4. H.M. Widmer, *Chimia*, **43**, 268-277 (1989).
5. J.E. Roehl, *Appl. Spectrosc. Rev.*, **26**, 1-57 (1991).
6. G.A. Eiceman, *Crit. Rev. Anal. Chem.*, **22**, 17-36 (1991).
7. J. Adler, G. Arnold, J.I. Baumbach and R. Döring, *Zfl-Mitt.*, **154**, 1-11 (1992).
8. G.A. Eiceman, V.J. Vandiver and C.S. Leasure, *Anal. Chem.*, **58**, 1690-1695 (1986).
9. D.M. Lubman, Report ARO-22444.16CH (1988).
10. L. Kolaitis and D.M. Lubman, *Anal. Chem.*, **58**, 1993-2001 (1986).
11. J. Gormally and J. Phillips, *Int. J. Mass Spectr. Ion Proc.*, **107**, 441-451 (1991).
12. C.S. Leasure, M.E. Fleischer, G.K. Anderson and G.A. Eiceman, *Anal. Chem.*, **58**, 2142-2147 (1992).
13. P. Watts and A. Wilders, *Int. J. Mass Spectrom. Ion Proc.*, **112**, 179-190 (1992).
14. J.M. Preston, F.W. Karasek and S.H. Kim, *Anal. Chem.*, **49**, 1746-1751 (1977)
15. Z. Karpas and Y. Pellovoy, *Anal. Chim. Acta*, **259**, 333-338 (1992)
16. R.E. Clement, K.W.M. Siu, and H.H. Hill, Jr. (Ed.), *Instrum. Trace Org. Monit.*, (Lewis Publ., Chelsea, Mich., 1992) 300pp.