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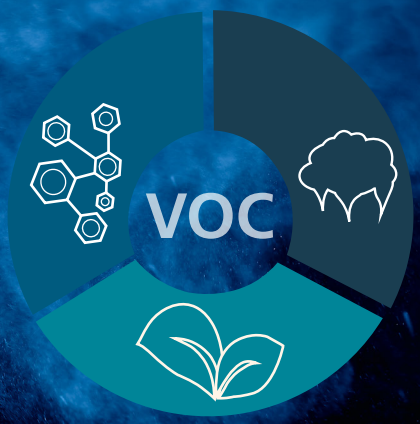


Modular device platform for the development of compact gas sensing systems

Chip-based ion mobility spectrometry for the detection of low concentrated VOCs in air

Modular device platform

The selective detection of low concentrated substances in the ppb concentration range under ambient conditions plays a major role in different applications. Volatile organic compounds (VOCs) are one exemplary group of substances that must be reliably detected in a large number of applications, like environmental sensing or process controlling. Solvents like acetone or toluene are two volatile compounds that are of common interest.

Subject of the current development is a compact module-based unit, that can be easily integrated into new gas sensing systems and contains all needed components. Core part is a chip based component, that contains an ion filter and detector with a tiny footprint. The underlying sensing technology is ion mobility spectrometry (IMS). IMS enables a fast and reliable detection of very low concentrated analytes directly under ambient conditions. This makes it very convenient for a use at the point of interest. Needed electronics to drive the ion filter, the ion source, and the interface to the secondary electronics and the analyte gas flow are also part of the module based unit. This reduces hurdles for further product-orientated system development and offers the following advantages:

- Compact size for the integration into portable measurement systems for detection of volatile substances
- Use of a reliable microfabrication technology enables a cost-efficient production for large quantities
- IMS-based chip device with integrated ion filter and detector shows a high sensitivity towards volatile organic compounds and enables the identification on several substances

Potential applications

Environmental sensing

- detection of harmful substances and emissions

Quality control

- unmasking counterfeit products

Biomedicine

- detection of marker substances for non-invasive diagnostics (e.g. breath gas analysis)

Figure 1: Demonstrator setup with integrated IMS chip module

Highly sensitive detection – Ion Mobility Spectrometry IMS

Ion mobility spectrometry (IMS) is a promising gas sensing technology that enables the detection of low concentrated substances like common VOCs in the lower ppb-range under ambient conditions [1-3]. Moreover, IMS can identify individual substances in a gas mixture within certain limits. An ionization source generates the analyte ions, e.g., by using a UV discharge lamp. Electrical fields are used in the ion filter to separate ion species according to their specific ion mobility, K. The mean drift velocity, v, the electrical field strength, E, and ion mobility, K, are related as follows:

$$v = E\,K.$$

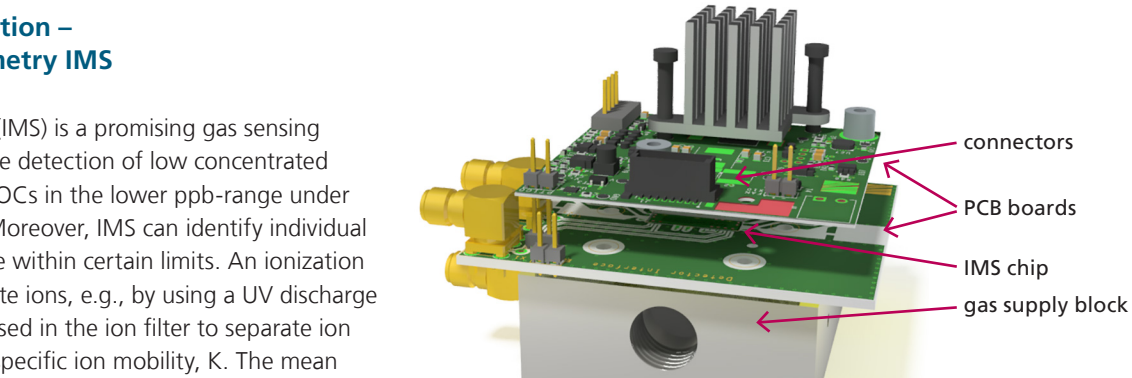
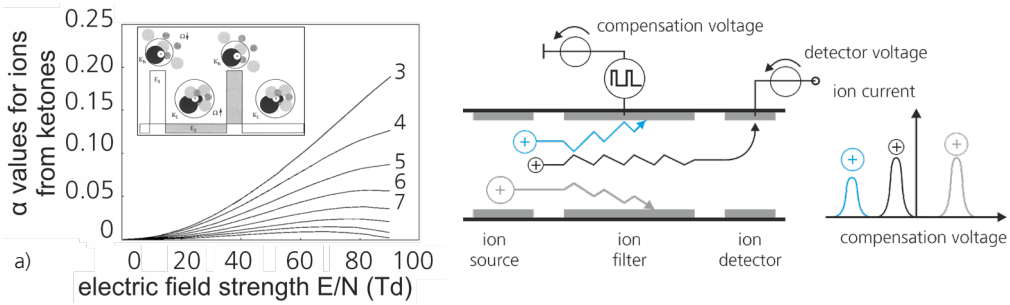


Figure 3: Gas sensing module with IMS chip device and electronic boards.



[1] Eiceman, G. A.et al..: Ion Mobility Spectrometry. 3. ed. Boca Raton : CRC Press, 2014
[2] Borsdorf, H. et al. Applied Spectroscopy Reviews 41 (2006), 4, pp. 323–375
[3] Cumeras, R. et al. The Analyst 140 (2015), 5, pp. 1376–1390
[4] Graf, A.et al. SMSI 2023 (2023), pp. 306–307.

Figure 2: a) typical alpha curves show the field dependency of the ion mobility of ketones [1], b) de- and reclustering of ions during high and low field conditions [1] and c) characteristic ion trajectories in the ion filter due to field dependent ion mobility K(E) and the resulting spectrum.

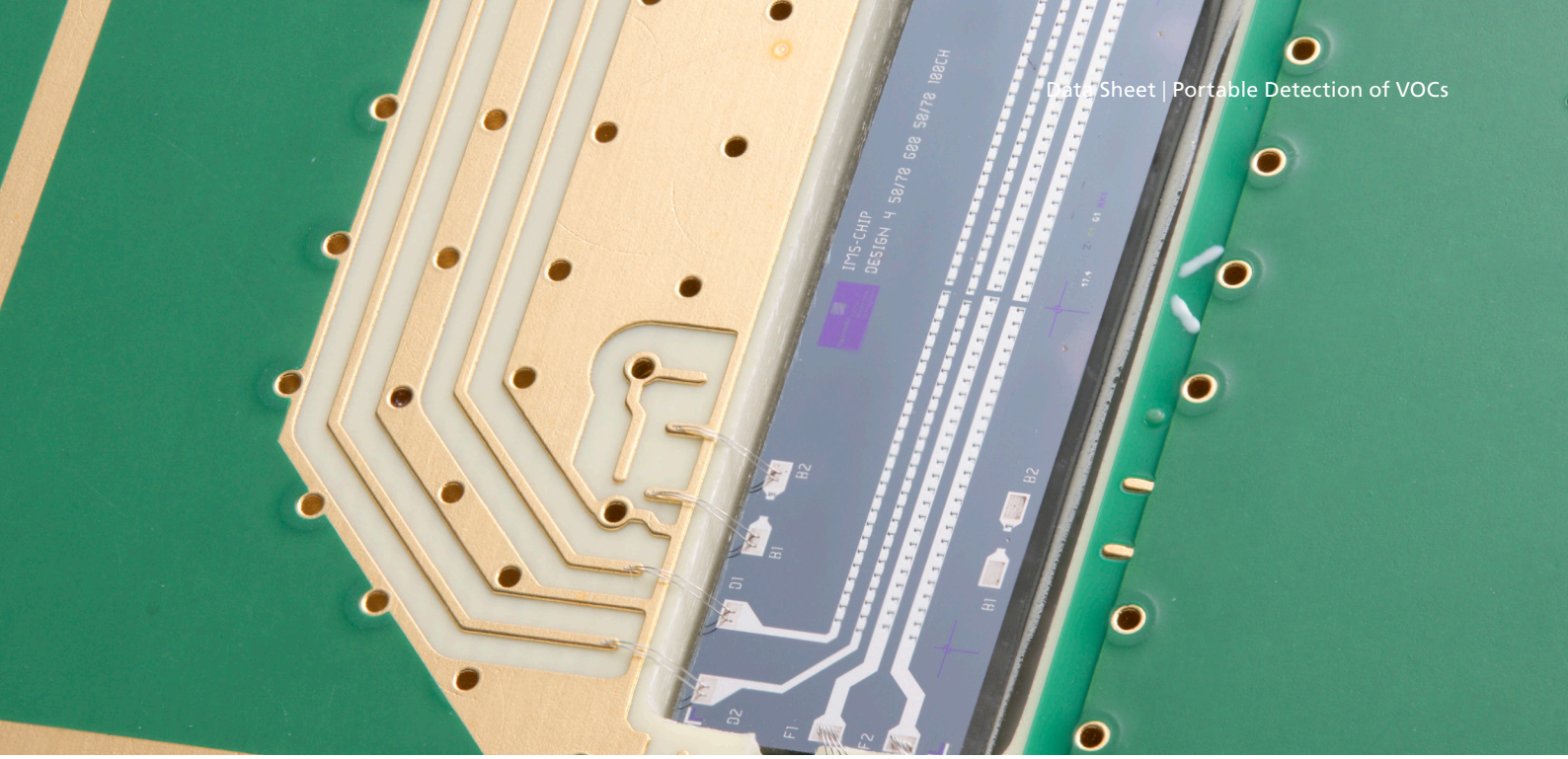


Figure 4: Chip device with integrated ion filter and detector

Chip-based Ion Mobility Spectrometry

Fraunhofer IPMS developed a chip device that uses differential ion mobility spectrometry (DMS), also known as high-field asymmetric waveform ion mobility spectrometry (FAIMS), for the ion filter. DMS/FAIMS uses high electrical field strengths that affect the ion mobility K(E). The dependency can be described as follows:

$$K(E)=K_0\,(1+\alpha(E/N)).$$

The α-value and hence the mobility K(E) is ion specific and is caused by ion cluster reactions that occur under ambient conditions. The basic setup of DMS and an exemplary α-curve for ketones can be found in Fig. 2. By applying specific voltage waveforms, only ions with a specific α-value reach the end of the filter. An additional compensation voltage adjusts the filter behavior and other types of ions with other α-values reach the detector. The compensation voltage at the peak maximum can be used to determine the ion species.

In addition to the chip-based component, the electronics required to control the ion filter and carry out measurements are also available. Figure 5 shows typical results of measurements with different ketones obtained with the modular setup.

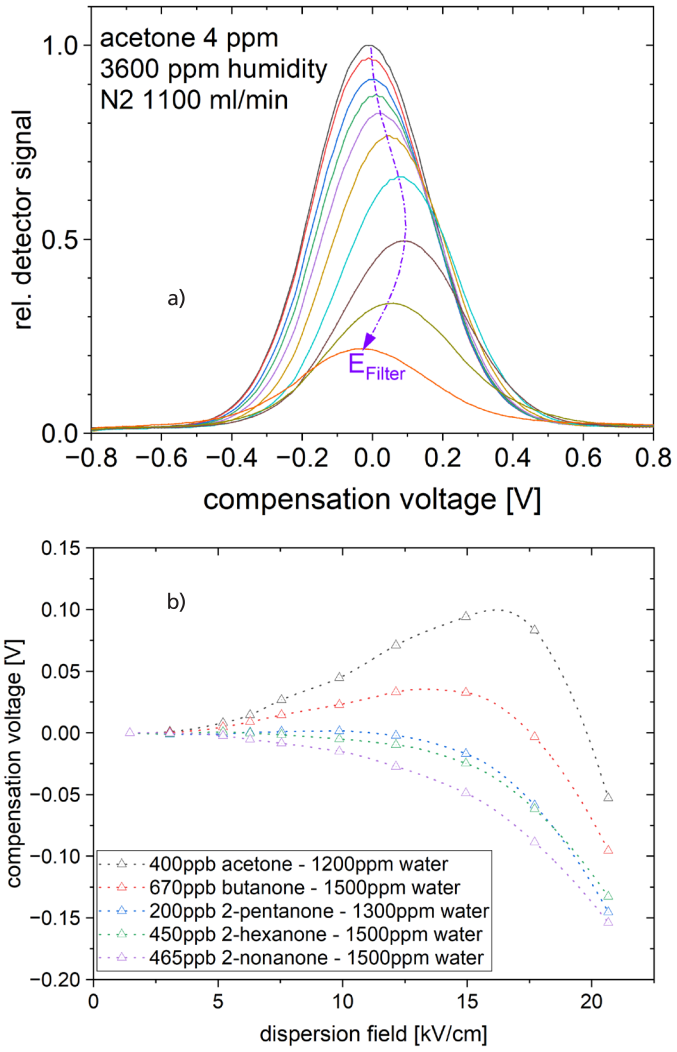
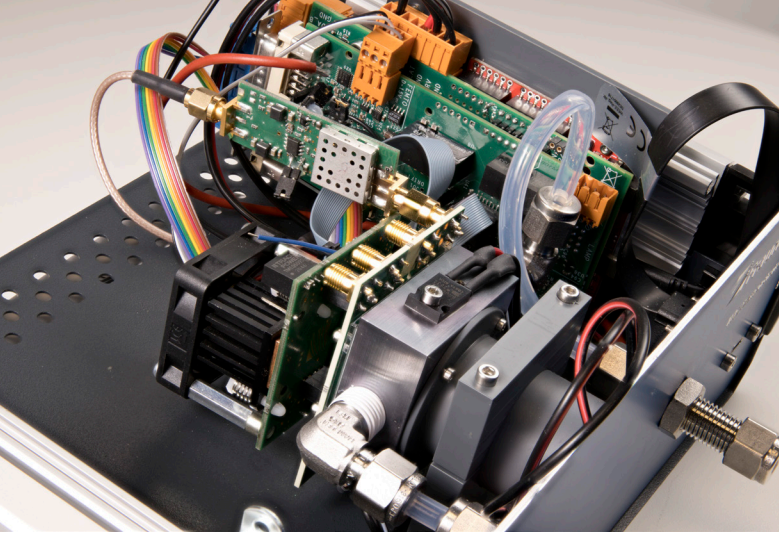


Figure 5: a) measured spectra for acetone in nitrogen (N2) that shows the typical DMS behavior. The shift of the peak maximum at different filter field strengths depends on the analyte and can be used to distinguish them according to b) (from [4]).



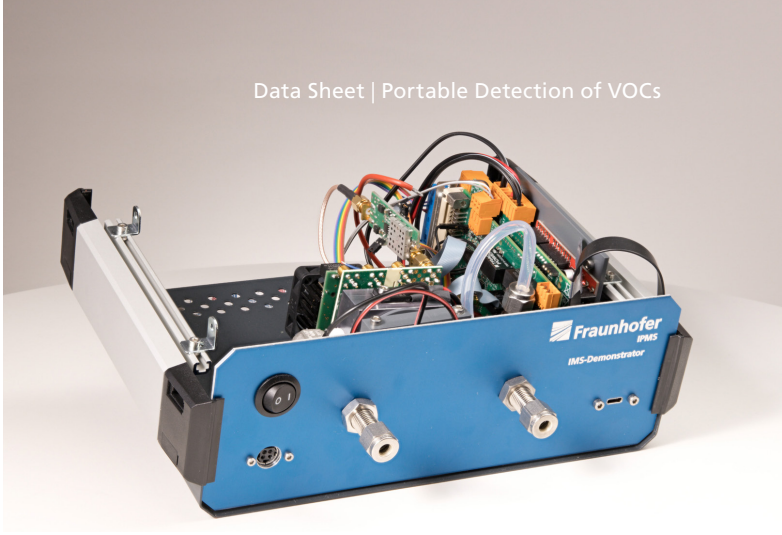


Figure 6: Modular device platform with miniaturized IMS chip and required electronic components.

What we offer:

- IMS-based chip devices and experience in sensors development
- application-specific further development of our available laboratory demonstrator
- sensor components as a basis for future device developments

Who are we looking for:

- partners from industry and science to further develop the existing concept in an application-specific context
- Aims of further development:
  - Integration of our components in an application-related demonstrator, proof of functionality based on application
  - expanding the performance and functionality of existing technology and sensor functionality

Ongoing Research and Development

The presented modular device platform is promising towards an integration into portable and handheld devices. There is a need for sensitive devices, that can detect harmful substances at the point of interest. The given module based on Ion Mobility spectrometry is a promising solution therefore and can be adapted towards the application specific needs. Based on the modular device platform, next steps are applications-specific development and hence, an integration of this IMS chip module into portable instruments, that can be used in various fields of applications.

We are **looking for partners** for potential R&D projects/ cooperations to **further develop** our device, to combine it with other needed components and to start **application-specific** development!

Contact

Dr. Alexander Graf
+49 351 8823-247
alexander.graf@ipms.fraunhofer.de

Fraunhofer Institute for
Photonic Microsystems IPMS
Maria-Reiche-Straße 2
01109 Dresden, Germany
www.ipms.fraunhofer.de/en