Real time monitoring of plasma chemistry in air and on surfaces

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Introduction.
We have used mass spectrometry to analyze in real time the degradation of Volatile Organic Compounds (VOCs) diluted in air by Dielectric Barrier Discharge (DBD) plasma. In that case the mass spectrometer is a compact FTICR in which the magnetic field (1.5 T) is produced by a permanent magnet. The compound initially introduced as well as the degradation products are ionized using in cell chemical ionization. Plasmas can also be used for the analysis of species deposited on a surface. We investigate the interaction of argon plasma microjets with a surface on which molecules of low volatility have been deposited. The objective here is to desorb the species and analyze them by mass spectrometry or by gas chromatography.

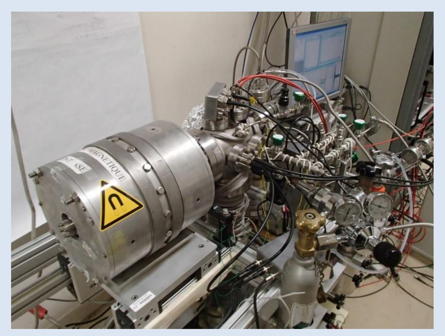
Compact FTICR instrument for real time analysis

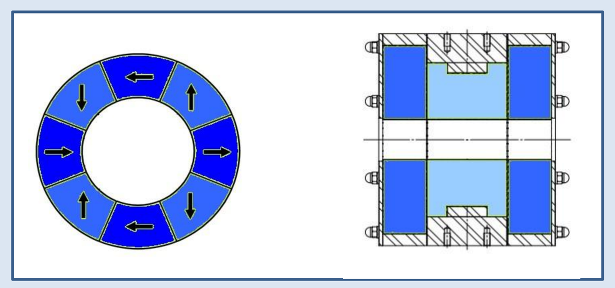
Chemical ionization

Chemical ionization is performed inside the ICR cell. The precursor ions are prepared using electron ionization on a first gas pulse. After a mass selection step they react with the sample introduced in a second gas pulse.

Magnetic field

The magnetic field is produced by a structured magnet made with NdFeB segments. It is composed of three Halbach cylinders each divided in 8 or16 segments. The nominal field can reach 1.5 T with a relative homogeneity better than 0.5% in the ICR cell volume.





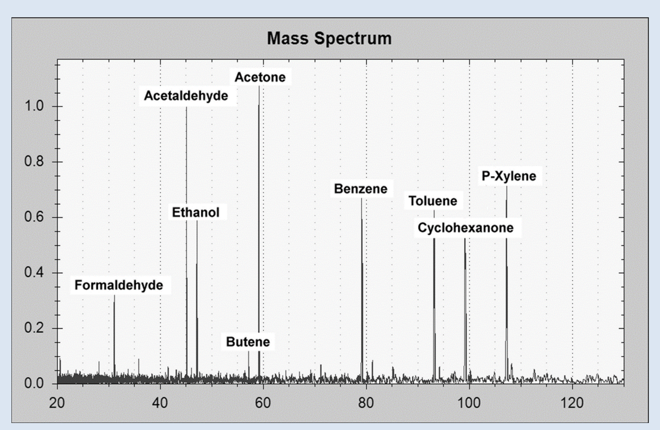
Schematic of a Halbach configuration for the production of a dipolar magnetic field and cross sectional view of a magnet composed of 3 Halbach cylinders.

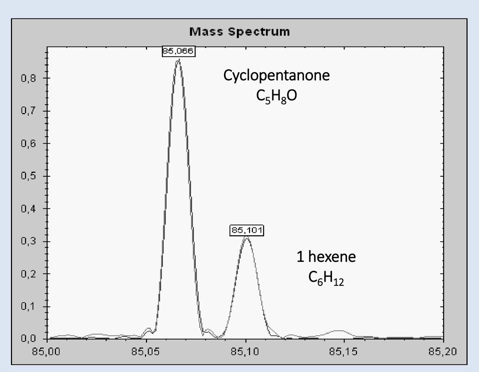
ICR cell

The ICR cell has an open geometry, so that the gas pulses will have a fast rise and re-pumping time.
Excitation and detection of the ions is performed using the same two electrodes.

Performances

Spectrum obtained using chemical ionization with H_3O^+ on air containing different volatile organic compounds (at a concentration of 5 ppm).
The sequence duration is 4 s
And the mass accuracy 5 10^{-3} u.



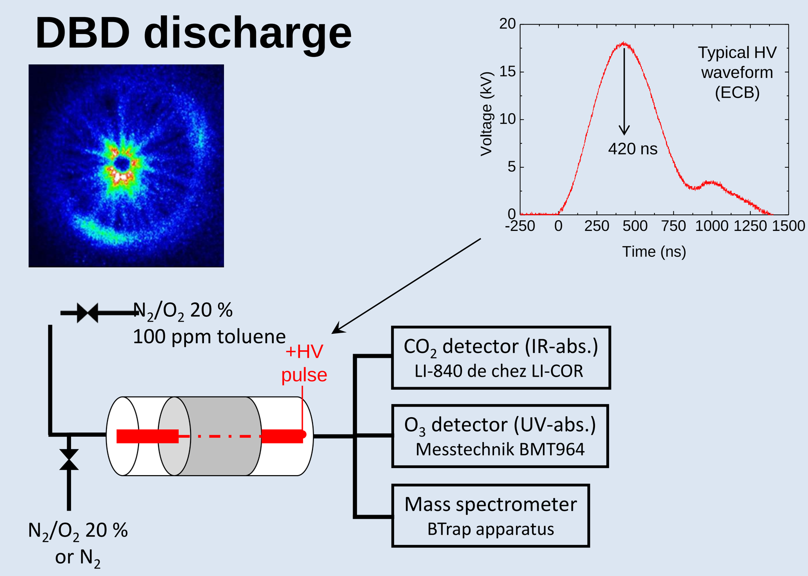


Spectrum showing the separation of two quasi-isobars, cyclopentanone and 1-hexene.

Monitoring the degradation of VOCS diluted in air by a DBD plasma

We present here the study of the removal of toluene by a DBD discharge. Toluene is diluted in dry air at atmospheric pressure with concentrations in the range 10 -100 ppm. It goes through the DBD reactor with a flow rate regulated at 1 L/min. The species present at the exit are analyzed with the compact FTICR instrument.

DBD discharge

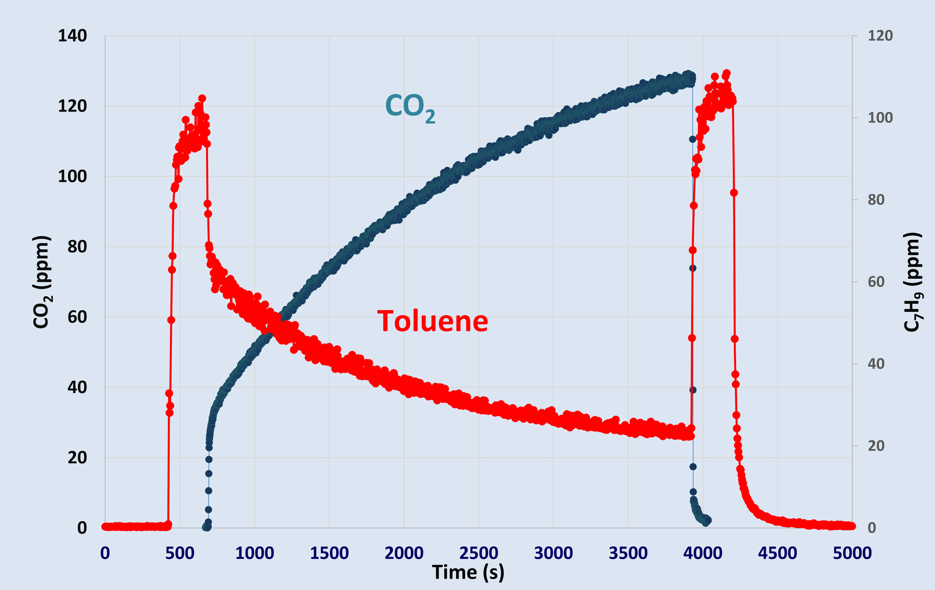


The DBD reactor has a cylindrical geometry, with a stainless steel rod (2 mm diameter) fitted inside an alumina tube (i.d. 20mm and 3mm thickness) and a grounded copper counter-electrode (5 cm length) wrapped around the tube.High voltage pulses are applied on the central rod at a repetition frequency of either 500 or 1000 Hz. The resulting discharge in the dry air flow containing traces of toluene is filamentary.

Disapearance of toluene

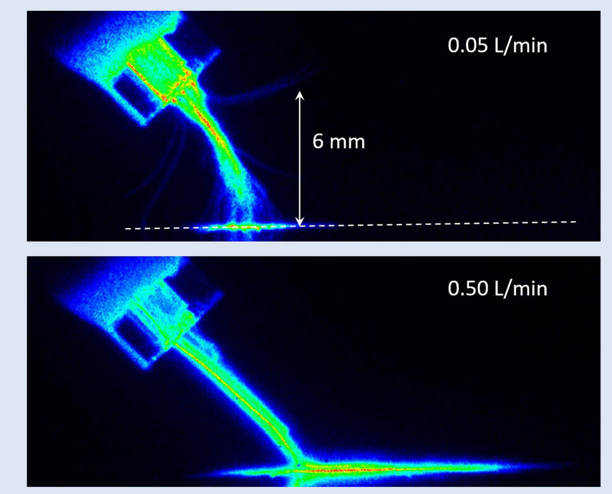
Toluene is analyzed using chemical ionization with H_3O^+.
$H_3O^+ + C_7H_8 \rightarrow C_7H_9^+ + H_2O$
When the discharge is turned on, the toluene concentration decreases immediatly, due to removal by the plasma. Then a slow decrease is observed, corresponding to a slow modification of the discharge operation, mostly related to temperature.

Real time monitoring of degradation products

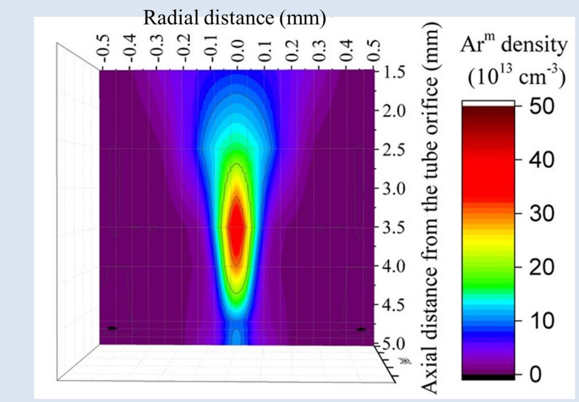


Argon plasma microjet for the analysis of surfaces

Argon plasma microjets have been studied and will be used to desorb molecules deposited on surfaces. With argon the microjet can be operated with a smaller gas flow.

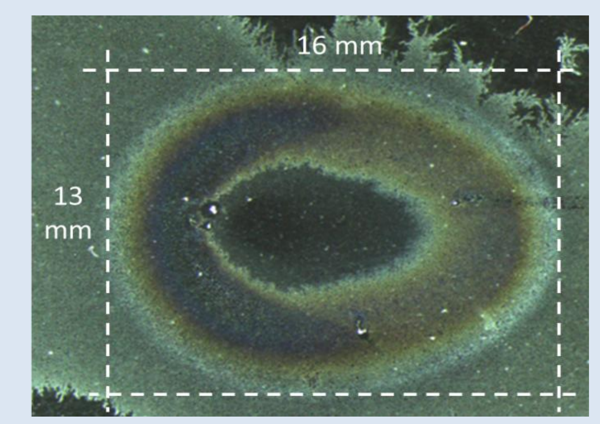


Argon plasma microjets directed with an angle of 45° toward a glass plate for two values of the gas flow. The radiative emissions of the plasma are here recorded with a fast pulsed intensified camera during 1 µs.

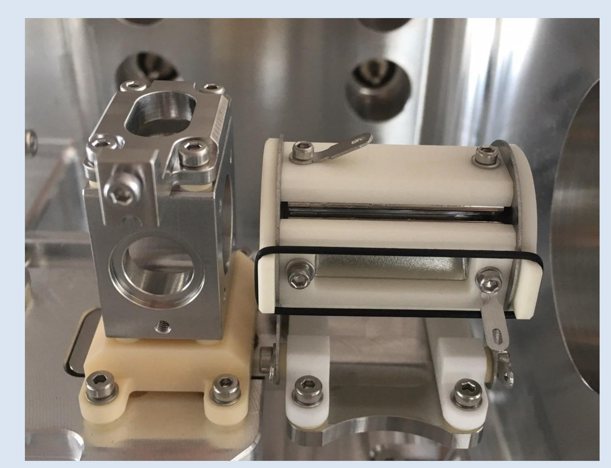


Distribution of the Ar metastables in the microjet Measured by IR laser absorption.

Degradation of bibenzyl deposited on a glass plate by the argon plasma microjet.



Linear Ion Trap



A small linear ion trap is being developed in order to couple a more compact instrument with the plasma desorption microjets. The length of the trap is 30 mm. On the left of the trap is the cubic ion source in which primary ions will be produced by electron ionization.

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Support of the ANR (French National Agency for Research) through project PLASPAMS is gratefully acknowledged.
We thank the technical support in the LCP laboratory (Hugo Bauduin and GIlles Perilhous) and in the AlyXan company (David Robin and Philippe Gremillet) for their contribution.