HIDEN ANALYTICAL

Atmospheric Plasma Applications

Plasma Medicine

Cold Atmospheric Plasmas for Wound Healing

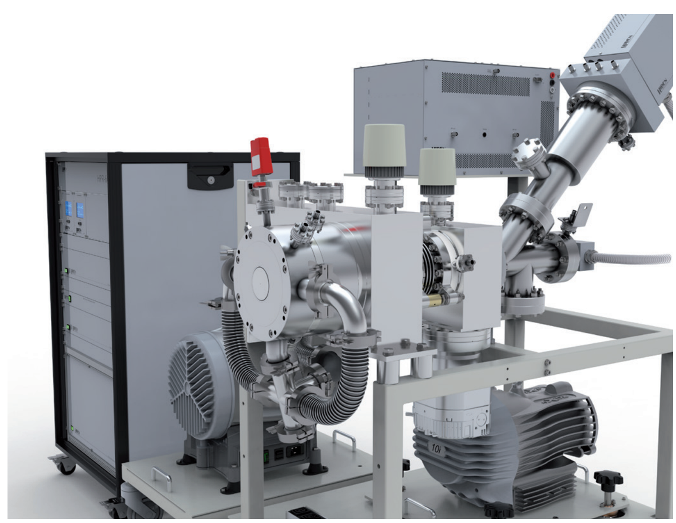
The use of atmospheric plasmas for plasma medicine is a novel field of research which combines the fields of plasma physics with medical sciences, over recent years there has been an acceleration of research in this field. “Cold” atmospheric pressure plasmas are generated using specialised atmospheric plasma devices, where a small flow of gas is ionised using a DBD or DC type plasma source, in order to achieve therapeutic effects directly on or in the patient. Currently, the main focus of this research is focussed upon improved healing of infected wounds and pathogen related skin diseases. There is also promising studies to suggest that atmospheric plasma treatments can be used to inhibit the growth of tumours by inactivation of plasma cells.

Wound healing process

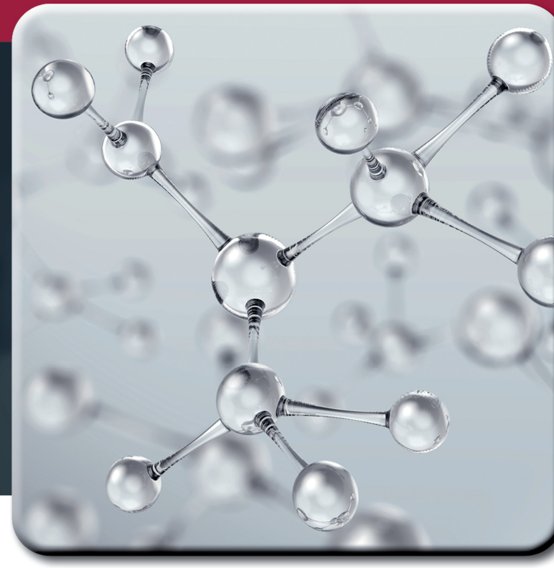
Atmospheric cold plasma treatment has been found to accelerate the healing of infected wounds by reducing the bacterial load on the wound site, allowing the healing process to continue without inhibition by external bacteria. It is thought that this is caused by the presence of oxygen and nitrogen ions in the plasma, as well as UV radiation.

Many devices used in plasma medicine are able to vary parameters such as power, gas species and gas flow, allowing plasma modification and subsequently allowing the effects of these to be studied. The affects of changing parameters on the plasma can be directly measured by the HPR-60 MBMS.

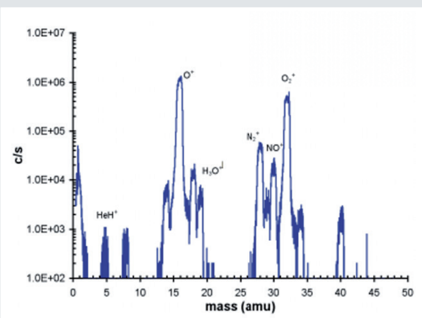
The HPR-60 MBMS is ideal to characterise plasmas of this type, allowing both mass and energy of the plasma ions to be directly measured from the plasma. The three-stage skimmer cone arrangement of the HPR-60 MBMS allows for pressure reduction to UHV for mass and energy analysis, as well as the creation of a supersonic “silent” region behind the first skimmer cone, preventing any further collisions and preserving the integrity of the sampled species to the MS system.



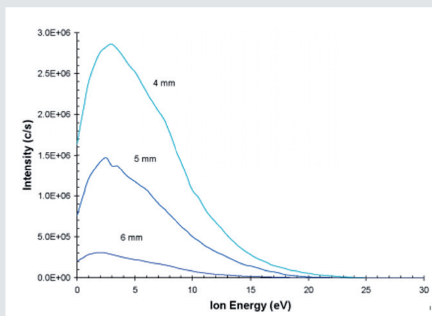
HPR-60 MBMS for atmospheric plasma analysis.



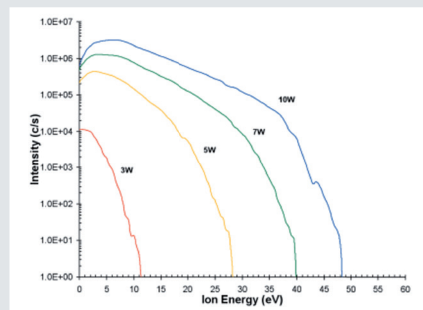
CHARACTERISATION OF ATMOSPHERIC PLASMA DEVICES



Positive ion mass spectrum from a typical atmospheric treatment device

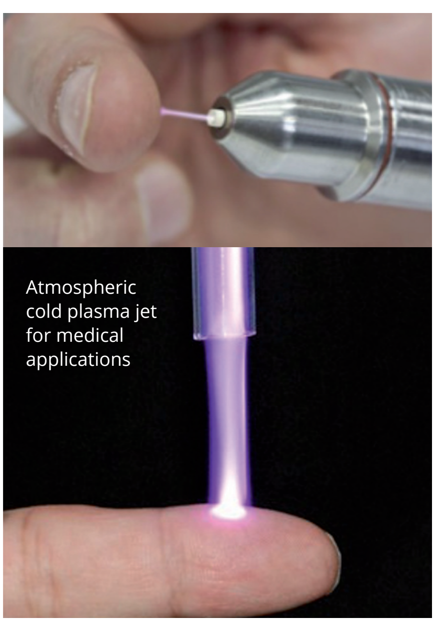


Nitrogen Ion Energy Distribution as a function of distance from an atmospheric plasma treatment device



Oxygen ion energy as a function of plasma power from an atmospheric plasma treatment device

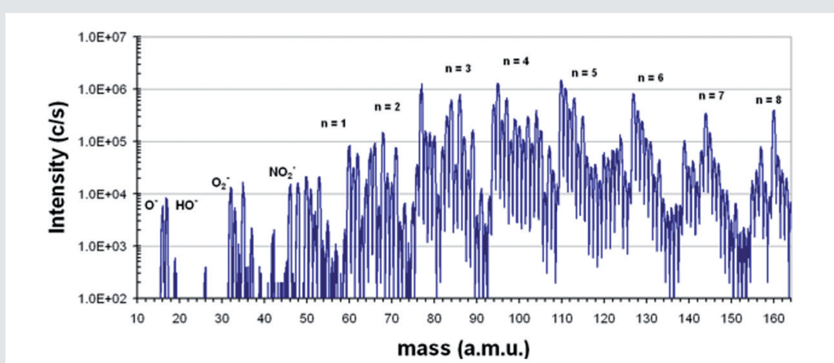
Both the composition and quantity of plasma-generated nitrogen and oxygen ions are dependent on specific physical and technical plasma source and device parameters as working gas composition, power input, or distance from the plasma source. These phenomena can be seen in the figures above.



Atmospheric cold plasma jet for medical applications

HIGH MASS ANALYSIS

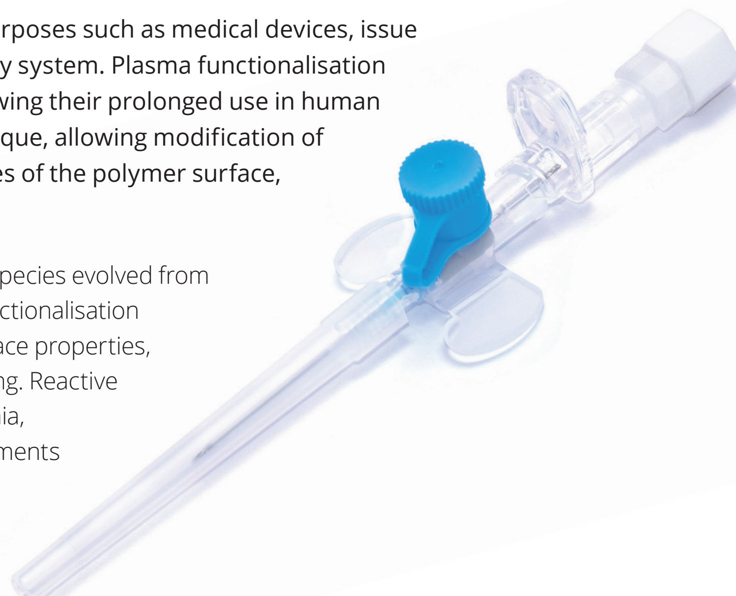
The HPR-60 MBMS can be equipped with the EQP or EPIC range of Hiden MS systems, with mass options to 5000 amu, making it ideal for the analysis of hydrated cluster species that have been found to form in atmospheric plasma processes.



Plasma Medicine

Plasma Surface Modification of Polymers for Medical Applications

Polymers are widely used widely used for biomedical purposes such as medical devices, issue engineering scaffolds, and drug carriers for drug delivery system. Plasma functionalisation increases biocompatibility of the polymer surfaces, allowing their prolonged use in human tissue. Plasma surface modification is an efficient technique, allowing modification of the surface functional groups and the physical properties of the polymer surface, leaving the bulk material intact.



The Hiden EQP system was used to determine the neutral species evolved from typical medical polymer surfaces during plasma surface functionalisation treatments. The plasma used could tailor the resultant surface properties, with inert gas, such as argon, plasmas, leading to cross linking. Reactive gas plasmas, with the additions of nitrogen, oxygen, ammonia, tetrafluoromethane and suphurhexafluoride, give enhancements such as increasing hydrophobicity by depositing non-polar functional groups onto the surface.

PLASMA POLYMER FUNCTIONALISATION PROCESS FROM A CF_4 PLASMA

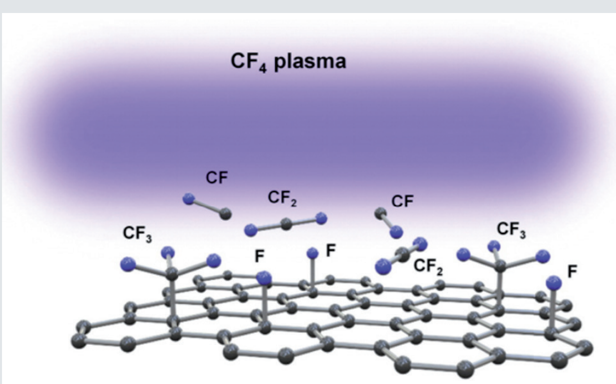
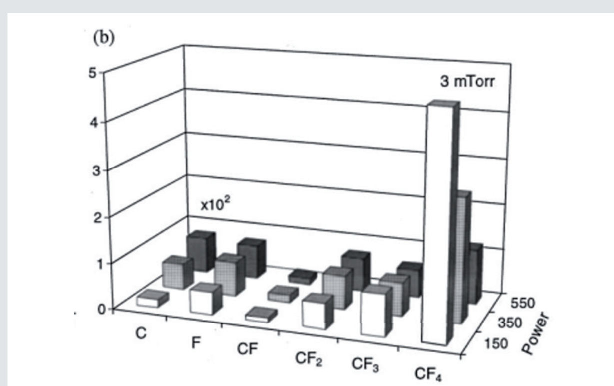


Diagram showing the deposition of non-polar functional groups via plasma functionalisation of a polymer surface.

CHARACTERISATION FO NEUTRAL SPECIES FROM A CF_4 PLASMA FOR POLYMER FUNCTIONALISATION.



Typical concentration of neutral species measured from a CF_4 plasma for polymer functionalisation with respect to power in watts.

Explosive Detection

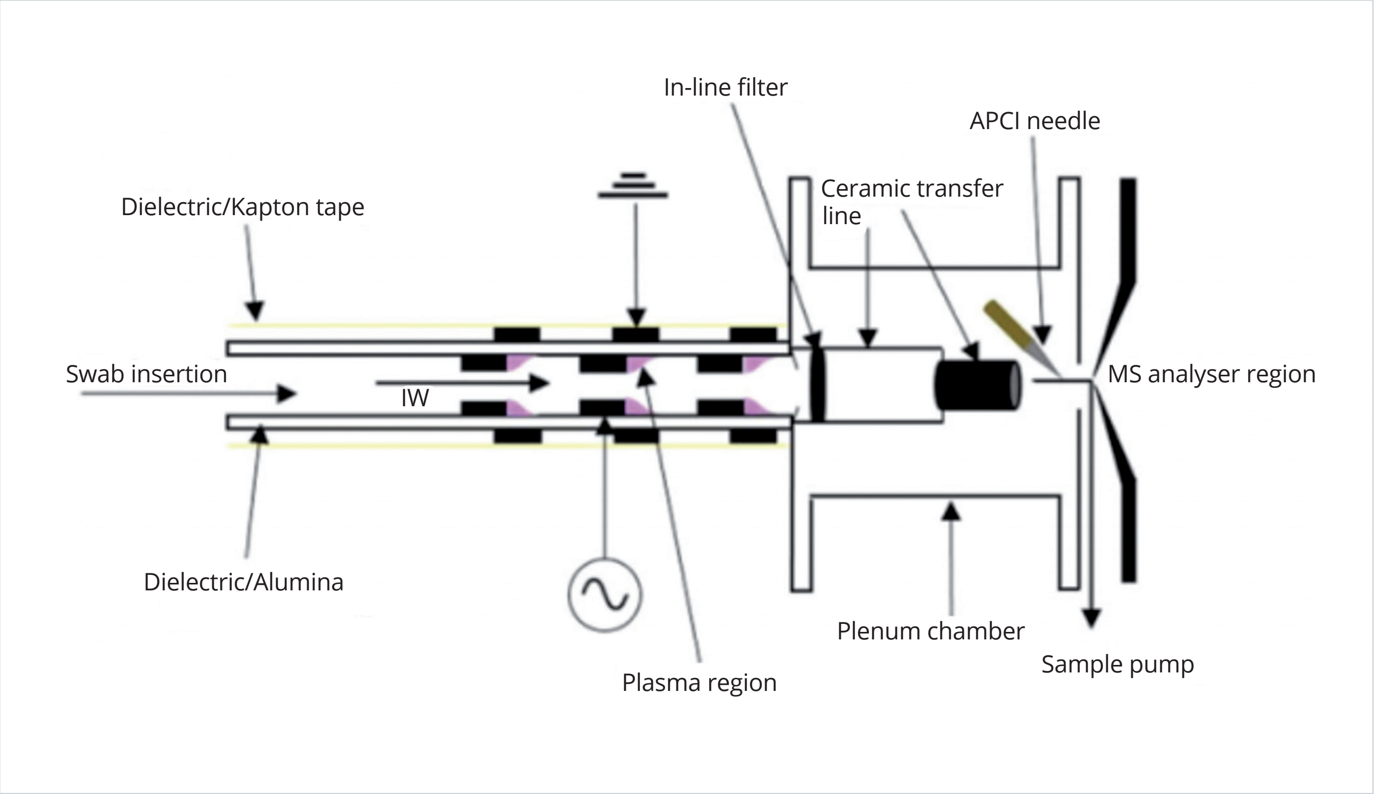
Using Plasma Assisted Desorption Ionisation (PADI)

Detection of common explosive compounds is of high importance for security applications. For airline travel in particular, there is a need for techniques that combine high reliability with low sample preparation requirements and detection speed.

An atmospheric plasma jet, created using a dielectric barrier discharge (DBD), can be used to both ionise and desorb species from the sample surface. These ionised species are then detected by the HPR-60 MBMS, where their characteristic mass spectrum can be matched to the reference standard for each explosive material.

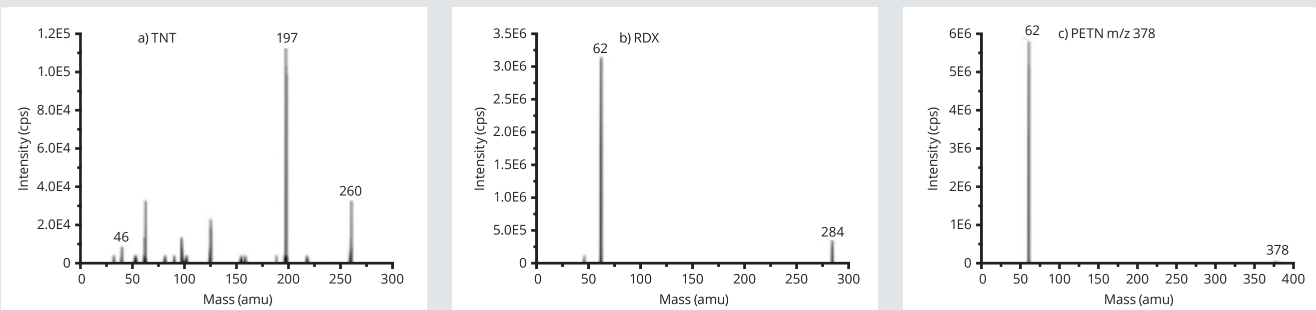
The DBD plasma source operates in ambient air, which is in contrast to the limitations of other plasma-based techniques which typically analyse smaller surface areas and require solvents or gases. Sample throughput is fast, as the HPR-60 MBMS samples constantly, and spectra can be gained in seconds for each sample.

Many typical explosive compounds such as trinitrotoluene (TNT), Pentaerythritol tetranitrate (PETN) and triacetone triperoxide (TATP) can be detected to trace levels.



Typical analytical arrangement for plasma ionisation and analysis of potential explosive samples.

CHARACTERISATION OF COMMON EXPLOSIVE COMPOUNDS USING PADI



Example plasma assisted positive ion mass spectrum of some typical explosive compounds.

PADI mass spectra can be seen on the figure above, where representative fingerprints for each of the labelled explosive compounds are shown.

Dermatology

Atmospheric Pressure Plasmas in Dermatology

Research of the use of atmospheric plasmas use medical treatments has gathered apace over recent years. Many plasma constituents have been found to interact with the body to allow plasma to be used for a variety of applications in medicine such as; electric current, UV radiation and reactive and ionised gas species.

These components are thought to be able to act synergistically. In both in-vivo and in-vitro experiments, anti-inflammatory, antimicrobial, anti-itch, blood flow-enhancing, tissue-stimulating and proapoptotic effects have been reported without signs of pathogen resistance.

Atmospheric pressure plasmas can be used in the treatment of tissues for therapeutic applications as well as biological decontamination and surface modification.

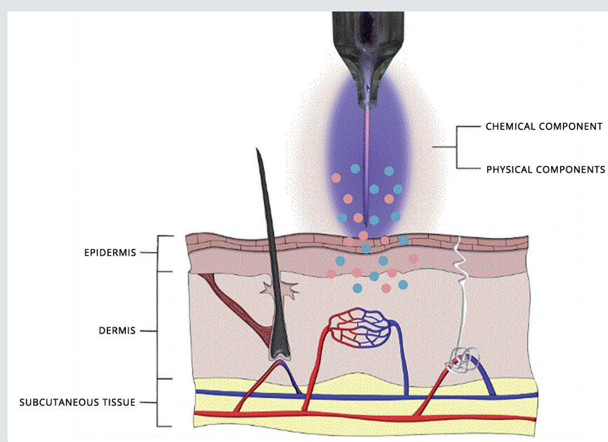
A range of cold atmospheric pressure plasma devices are available for research purposes. These devices can be classified as direct, where plasma is directly applied to the cell surface, or indirect, where plasma is produced remotely and a carrier gas is used to transport the components to the surface. The most common devices use an indirect plasma, where an inert carrier gas, typically Ar or He, is used.

Atmospheric plasmas are used predominantly in the dermatology sector, with the main applications being wound healing and treatment of pathogenic skin diseases and melanomas. Applying atmospheric plasma can have the synergistic effects of decreasing the bacterial load on wound sites and stimulating tissue regeneration concurrently, thus increasing the speed of the healing process.

Atmospheric plasmas are typically sources of gaseous reactive oxygen and nitrogen species (RONS). It has been reported that RONS lead to redox based changes in lipid and protein structures as well as stimulating redox-controlled cell pathways. These mechanisms are thought to enhance the healing effects of the plasma.

ATMOSPHERIC PLASMAS FOR DERMATOLOGY

The HPR-60 MBMS molecular beam mass spectrometer system is optimised for the characterisation of atmospheric plasmas. The three-stage skimmer cone configuration allows for the ions, radicals and neutrals to be 'frozen' in the supersonic silent region behind the initial skimmer cone stopping any further collisions and interactions of the species that are sampled. They can then be analysed for kinetic energy as and mass. This allows full characterisation of atmospheric plasma species.



Gan, L., Jiang, J., Duan, J., Wu, X., Zhang, S., Duan, X., Song, J., & Chen, H. (2021). Cold atmospheric plasma applications in dermatology: A systematic review. Journal of Biophotonics, 14(3), n/a-n/a.

HidenAPPLICATIONS

Hiden's quadrupole mass spectrometer systems address a broad application range in:

GAS ANALYSIS

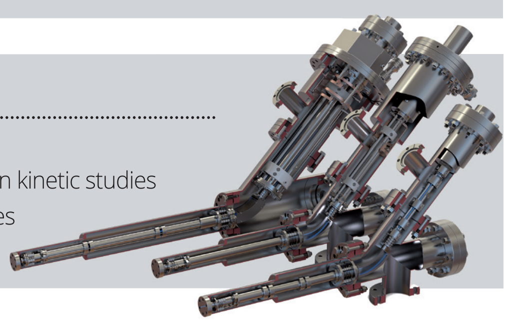
- dynamic measurement of reaction gas streams
- catalysis and thermal analysis
- molecular beam studies
- dissolved species probes
- fermentation, environmental and ecological studies

SURFACE ANALYSIS

- UHV TPD
- ToF qSIMS and SIMS analysers
- end point detection in ion beam etch
- elemental imaging – 3D mapping

PLASMA DIAGNOSTICS

- plasma source characterisation
- etch and deposition process reaction kinetic studies
- analysis of neutral and radical species



VACUUM ANALYSIS

- partial pressure measurement and control of process gases
- reactive sputter process control
- vacuum diagnostics
- vacuum coating process monitoring

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