Explosives Detection with a Low Temperature Dielectric Barrier Discharge Ionisation Source for Mass Spectrometry

Carl Fletcher[1], Richard Sleeman[2], John Luke[2], Peter Luke[2], James W. Bradley[1]
[1] Dept. of Electrical Engineering & Electronics, University of Liverpool, Brownlow Hill, Liverpool, L69 3GJ, UK
[2] Mass Spec Analytical Ltd, Golf Course Lane, Filton, Bristol, BS34 7RP
T: 0117 317 3600
E: carl.fletcher@msaltd.co.uk

INTRODUCTION

- Increasing threats from improvised explosive devices requires cheap, reliable, high-throughput screening
- Current analytical screening methods rely on thermal desorption with ion mobility for the detection of illicit substances and explosive residues
- Ambient ionisation methods such as DART and DESI require sample preparation, discharge gases and operate with a small sampling surface area
- A plasma based ambient ionisation technique was developed, operating in ambient air and without solvents over a much larger sampling surface area

PROJECT SUMMARY

- A dielectric barrier discharge (DBD) plasma ion source was developed for the detection of explosives
- The DBD operates at 7 kV, 20 kHz and power of 26 W
- DBD has a sampling surface area larger than 500 mm^2
- An induced ionic wind (represented by IW in Fig. 1) is produced in the DBD, transporting ions in the direction of the mass spectrometer.
- An abundance of NO_3^- generated in the plasma can be used as an adduct for explosive detection
- Eliminates the need for sample preparation, solvents, adduct forming reagents or additional gases

DBD SCHEMATIC

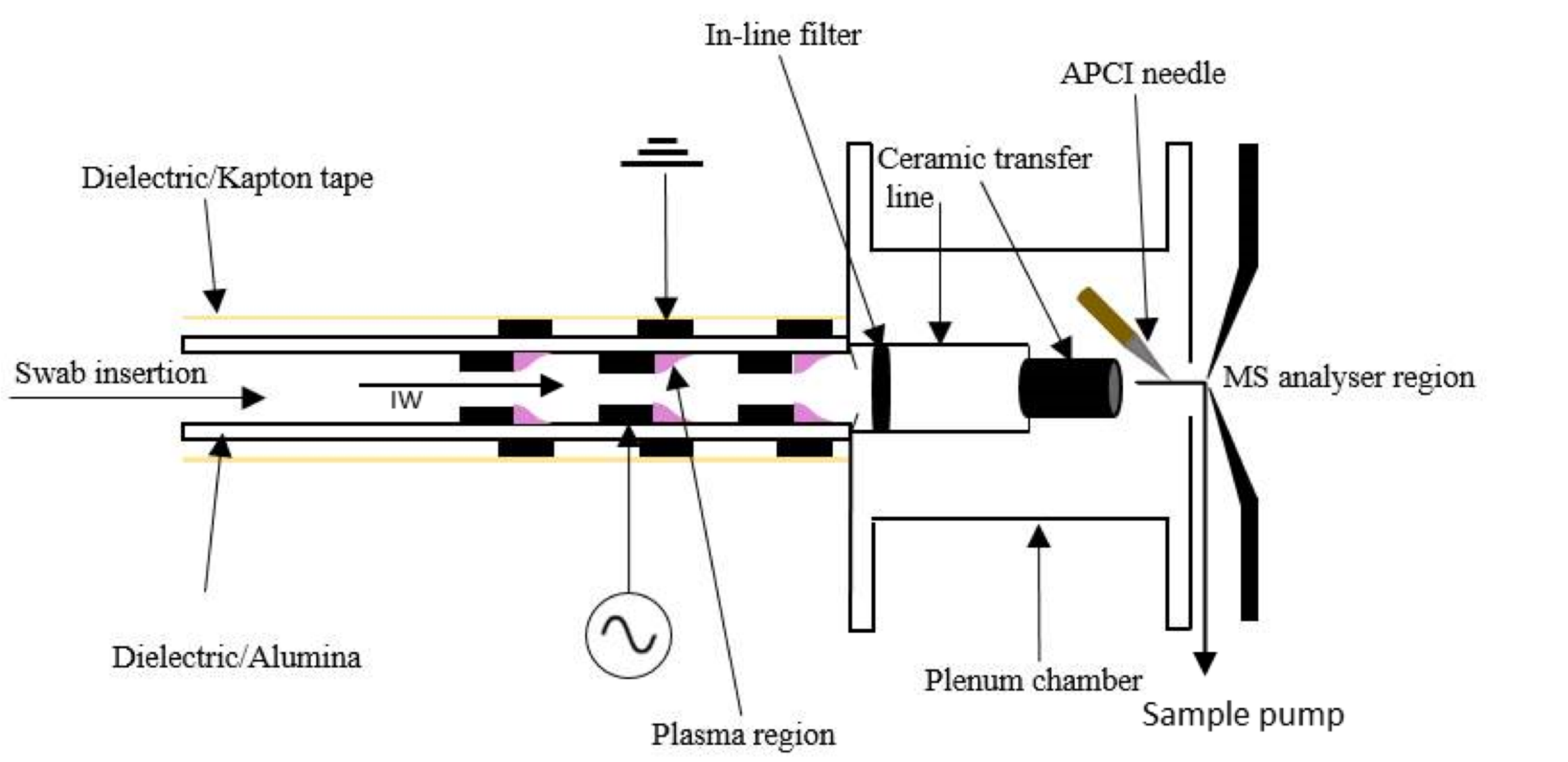

Figure 1: Schematic of DBD ionisation source with plenum chamber and APCI needle

RESULTS & DISCUSSION

- DBD was used to detect ions in positive and negative ion modes of four major chemical types of explosive:
  - Cyclotrimethylenetrinitramine (RDX) 100 pg
  - Pentaerythritol tetranitrate (PETN) 100 pg
  - Hexamethylene triperoxide diamine (HMTD) 1 ng
  - Trinitrotoluene (TNT) 5 ng
- Ions detected are different to those found in APCI
- TNT precursor ion was $[M-NO_2+HNO_3]^-$
- RDX and PETN was $[M+NO_3]^-$
- Suggests no need for adduct forming reagents

LIMITS OF DETECTION

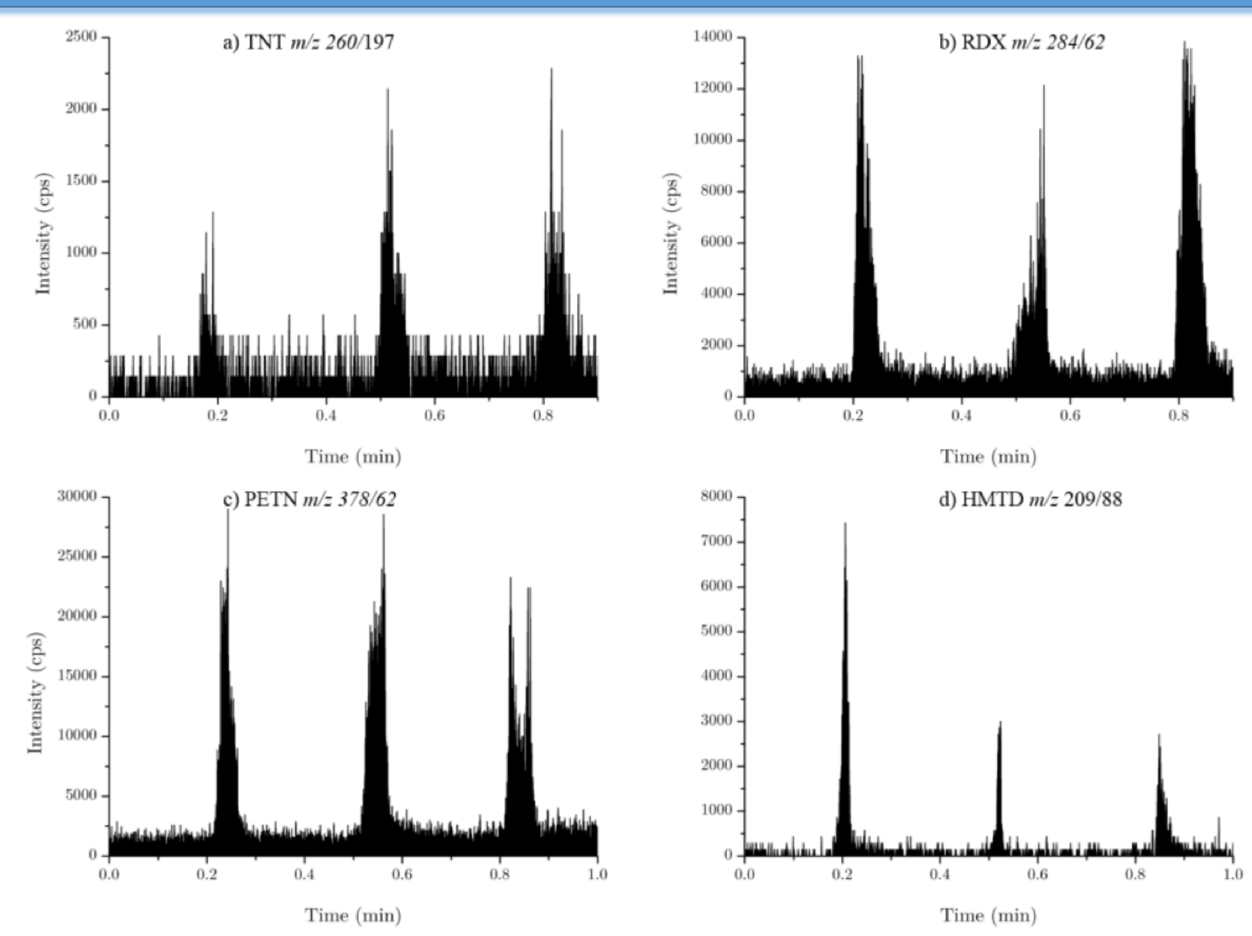

Figure 2: Limits of detection for RDX (100 pg) (top right), PETN (100 pg) (bottom left), HMTD (1 ng) (bottom right) and TNT (5ng) (top left).

CONCLUSIONS

- The DBD ion source is capable of detecting a variety of explosives to reasonable detection limits
- The DBD is at TRL-5. Performance is expected to improve with further development.
- The DBD is capable of detection in positive and negative ion modes suggesting potential for a wide range of applications
- The DBD demonstrates a wide range of capability, reducing consumable cost, analysis time and sample preparation resulting in a high throughput, highly selective and sensitive technique

ACKNOWLEDGMENTS

This project is a collaboration between the University of Liverpool (PhD funded by the Engineering and Physical Sciences Research Council, EPSRC) AND Mass Spec Analytical Ltd., and is funded under the Innovative Research Call 2016 for Explosives and Weapons Detection. This is a Cross-Government programme sponsored by a number of Departments and Agencies under the UK Governments CONTEST strategy in partnership with the US Department of Homeland Security, Science and Technology Directorate. The foreground IP for this DBD plasma source is covered by British Patent Application No. 1717618.1.