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# Integration of MEMS-based plasma emission sources in a low volume flow cell

*Abélia Ellingsen, Karolina Milenko, Enrique Escobedo-Cousin, Do Chi Huong Hoang, Simone Zonetti, Alessandro Liberale and Elizaveta Vereshchagina*
*SINTEF Digital, Gaustadalléen 23C, Oslo, Norway*
*abeliaellingsen@gmail.com*

**Summary:**
This paper discusses the integration and testing of micro-electro-mechanical systems (MEMS)-based microplasma devices with low-volume flow cells at the PCB level for emission spectroscopy of volatile organic compounds (VOCs). We introduced a novel bonding process that ensures a tight gas seal, stable pressure control down to 150 mbar, and the exchange of top fluidic glass substrates to assess their influence on the emission spectrum. The bonding process facilitates the assembly of pre-packaged MEMS components for reconfigurable and repeatable gas exposure experiments.

**Keywords:** MEMS, microplasma, plasma emission spectroscopy, microfluidics, bonding, packaging

## Introduction

MEMS-based plasma emission sources based on dielectric-barrier discharges can serve as components in systems for the analysis of VOCs [1]. Integrating microplasmas with low-volume chambers is a logical step towards compact, portable analysis systems. Before proceeding with wafer-level integration of miniaturized chambers, a low-cost prototyping phase is often useful for screening of chamber materials and designs, as well as prototypes testing. Here, we report a demonstrator assembled using a straightforward and novel bonding method and testing approach.

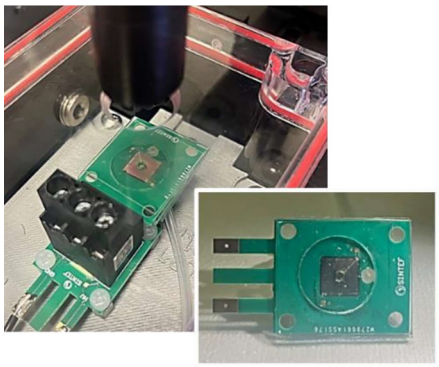

*Fig. 1. Photographs of the device assembled with a low volume chamber and vacuum tube. The device is fixed in a mount connected to a voltage amplifier below a spectrometer.*

## Experimental

A microplasma source pre-packaged on a custom-made PCB was integrated into a low-volume chamber (241 mm³) using Flexdym™ as a sealing material [2]. The chamber consisted of the 1200 µm sealing layer and top glass substrate. The method provides a sufficiently strong bond to enable plasma ignition experiments at pressures down to 150 mbar, while permitting exchange of the glass chamber top to study the effects of material properties and chamber volume on optical detection.

All tests were conducted using the same microplasma chip tested in two chamber configurations: a compact, low-volume chamber (Compact) and a larger chamber (Box), each fitted with different types of top glass substrates through which detection occurs. Flexdym™ (Eden Microfluidics, available in 250 µm – 2 mm thickness) was thermally bonded to the PCB with an already wire-bonded chip at 120 °C for 180 seconds. Switching between chambers in different materials involved exchanging glass on the unbonded side of the FlexDym and adjusting the vacuum tubing. The pressure was initially set to either 150 mbar or atmospheric pressure. The voltage was then gradually increased until a stable plasma glow was achieved and maintained for 2 minutes. Optical emission spectra (OES) from the plasma were recorded using OceanOptics 2000+ spectrometer and a multimode fiber. The data was used to evaluate stability of intensity signal and to compare emission profiles.

## Results and Discussion

Stable plasma was consistently obtained for all tests. The intensity of the OES at 434.875 nm - corresponding to the nitrogen ($N_2$) emission peak – was monitored over time to assess plasma stability after re-ignition during tests with different glass types. The stable plasma observed at 150 mbar in the compact chamber

(Fig. 2) indicates sealing allowing consistent pressure. The fact that the same ignition voltage (920 Vpp at 10 kHz) was required in both the compact and the large chambers further supports that the pressure was comparable, and that the small chamber reliably maintained the 150 mbar setpoint. A quantitative assessment of plasma stability was performed using the coefficient of variation (CV) of emission intensity at 434.875 nm.

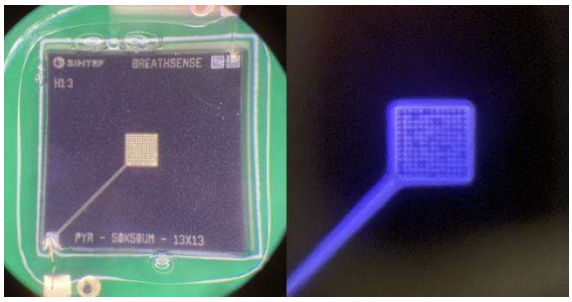


*Fig. 2. An optical microscope image of the tested devices before and during operation.*

*Tab. 1: Overview of experiments. G1 : Borofloat (300 µm), G2: Borofloat (525 µm), G3: Fused silica (500 µm), G4: Borosilicate (500 µm), PN: Polycarbonate (3 mm).*

| # | Chamber type | Pressure/ Voltage | Glass type |
|---|---|---|---|
| 1 | Box | 150 mbar/ 920 Vpp | G1, G2, G3, G4, PN |
| 2 | Compact | 150 mbar/ 920 Vpp | G1, G2, G3, G4 |
| 3 | Box | Atm/ 1040 Vpp | G1, G2, G3, G4, Air |
| 4 | Compact | Atm/1060-1070 Vpp | G1, G2, G3, G4 |

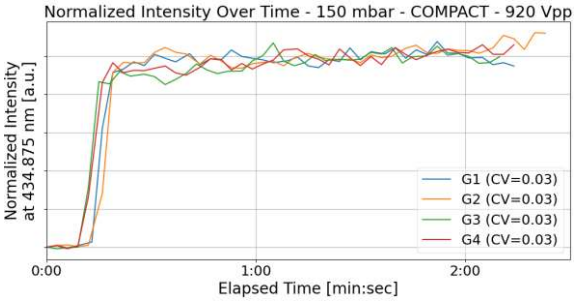


*Fig. 3. Comparison of stability of emission intensity at 434.875 nm following plasma re-ignition through glass types G1 to G4 in the compact chamber at 150 mbar. Intensities are normalized to the mean between 1 and 2 minutes. The coefficient of variation, calculated as the standard deviation in this interval, was 0.03 for all glass types.*

As shown in Fig. 3, CV values between 1-2 minutes of emission were identical (0.03) for all glass types, indicating consistent performance across materials. As shown in Fig. 4, spectral profiles were consistent across all glass types except for PN, which attenuates transmission and blocks UV below 400 nm completely. The shape of the spectra (normalised for intensity) remained constant and closely matched these profiles, regardless of the chamber configuration, pressure, or applied voltage. Therefore, the choice among G1-G4 should prioritise practical factors such as future manufacturability of design of interest and costs, as all tested glass materials exhibit comparable and satisfactory optical transmission.

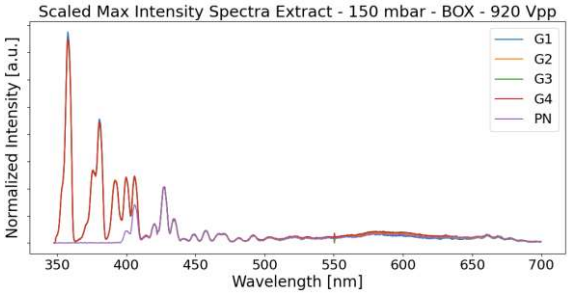


*Fig. 4. Comparison of optical emission spectra collected from larger gas volume chamber (Box) at 150 mbar and 920 Vpp. The spectra have been scaled to the maximum intensity peak of PN. Glass types G1 to G4 have minimal impact on spectra, while PN blocks UV transmission.*

## Conclusions

The integration and testing of MEMS-based microplasma devices with low-volume flow cells at the PCB level represents a significant advancement towards emission spectroscopy platforms for gas analysis, including VOCs. The presented bonding and testing methodology based on Flexdym™ sealing to PCB ensures a reliable seal and stable pressure. This approach is well suited for the prototyping and troubleshooting of materials and designs during the development phase of MEMS-based gas sensing components.

## References

[1] R. Brandenburg et al., Barrier Discharges in Science and Technology Since 2003: A Tribute and Update. *Plasma Chem. Plasma Process*. 43 (2023), 1303–1334.

[2] J. Lachaux et al., Thermoplastic elastomer with advanced hydrophilization and bonding performances for rapid (30 s) and easy molding of microfluidic devices, *Lab Chip* (2017), 17, 2581-2594.

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