Recent Developments of Miniaturised Microwave Induced Plasma Sources
- Modelling and Applications -

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Introduction

Microwave induced plasma (MIP) sources have found applications in atomic spectrometry for several decades. Many efforts have been made to understand the physical processes in these types of discharges and to optimise the existing devices towards robustness and stability for analytical applications.

However, these sources are constructed of rigid high frequency elements, such as cavities, matching elements etc., requiring a certain device depending minimum size.

Recently, we developed an MIP source which is completely constructed in microstrip technology. This enables small set-ups which in turn allow for low power and gas consumption. Common microchip production processes for the formation of quasi two-dimensional structures are applicable for an inexpensive and easy production of these devices. These MIPs are intrinsically suitable as a part of a miniaturised Total Analysis System (µTAS) because of there design and production.

In the following we present different designs of our **M**icro**S**trip **P**lasma (**MSP**) Source optimised for different applications as Optical Emission Spectrometry (OES) and Atomic Absorption Spectrometry (AAS) for atmospheric and low pressure discharges in Ar and He.

Outlook

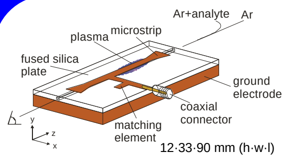
MIPs based on microstrip technology are of high potential for µTAS applications as shown by the MSP. Now designs are already available for discharges in Ar and He at atmospheric and low pressure for OES and AAS applications. Working conditions range from power levels of a few W up to 40 W and gas flows from some 10 mL·min $^{-1}$ up to 1500 mL·min $^{-1}$. Improvements of wafer materials and electrode designs led to smaller dimensions and lower power consumption.

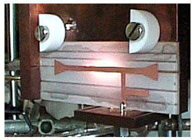
Further research should focus on the integration and miniaturisation of the supplementary and evaluation devices as:

- Very small (~ cm²) microwave semiconductor generators with frequency sweep using appropriate ICs already available for mobile phones.
- Integrated optical components for radiation collection.
- Use of small scale spectrometers.
- Sample introductions systems on chip.

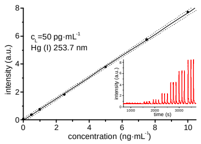
...and an advanced MSP production process like wet etching and gluing techniques.

MSP I for OES: Hg by Cold Vapour Technique

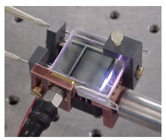


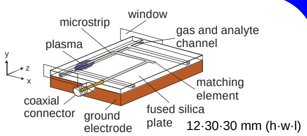


- frequency: 2.45 GHz
- forward power of 10 - 40 W
- gas flow: 200 - 1500 mL·min $^{-1}$
- atmospheric pressure
- plasma extension: 20 - 30 mm



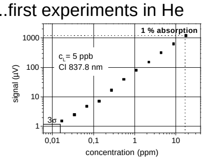
MSP III: Cl by Laser Diode AAS





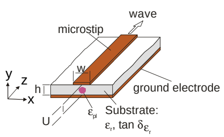
- forward power of 5 - 15 W (Ar) & 15 - 30 W (He)
- gas flow: 100 - 500 mL·min $^{-1}$
- low pressure (~20 mbar)
- plasma extension: 10 - 20 mm
- plasma modulation: 12.5 kHz

...first experiments in He

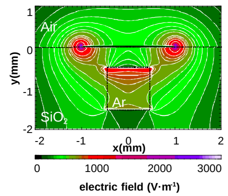


MSP Modelling

Electric field in the quasi static approximation



Electric field distribution



☑ electric field from scalar potential

☑ $\nabla \cdot \varepsilon_r \nabla j = 0 \quad \vec{E} = -\nabla j$

(TEM-approximation)

Electric field for a potential difference of 1V. Actual field values follow from equivalent voltage.

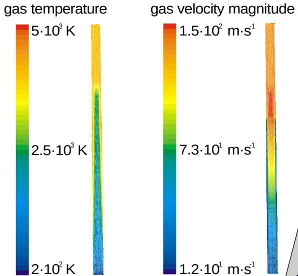
☑ characteristic impedance

☑ $$Z = \frac{1}{c_0}\sqrt{C'_{substr} C'_{air}}$$

☑ equivalent voltage

☑ $$U = \sqrt{2 P Z_c}$$

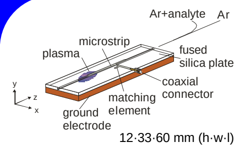
Fluid simulations in MSP channel (hot region)



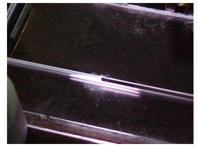
Modelling gives impact to:

- electrode design
- compensated edge
- substrate material (ε_r)
- electrode separation gap
- channel shape

MSP II : Optimised Setup for OES



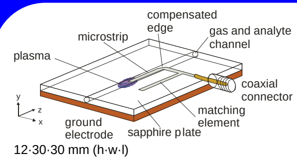
- forward power of 8 - 40 W
- He plasma possible at 30 W
- gas flow: 200 - 1500 mL·min $^{-1}$
- atmospheric pressure
- plasma extension: 20 - 35 mm

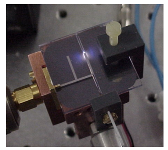


further applications:

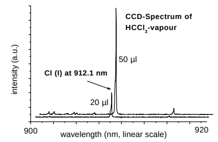
- MSP arrays for deposition at atmospheric pressure
- ion µ-etching device

MSP IV : Helium Plasma for OES





- forward power of 10 - 40 W
- gas flow: 100 - 1500 mL·min $^{-1}$
- atmospheric pressure
- plasma extension: 2 - 5 mm
- self ignition above 15 W



[1] U. Engel, A.M. Bilgiç, O. Haase, E. Voges, J.A.C. Broekaert, A Microwave-Induced Plasma Based on Microstrip Technology and Its Use for the Atomic Emission Spectrometric Determination of Mercury with the Aid of the Cold-Vapour Technique, *Anal. Chem.*, **72 (1)**, 193 - 197 (2000).
[2] A.M. Bilgiç, U. Engel, E. Voges, M. Kückelheim, J.A.C. Broekaert, A New Low Power Microwave Plasma Source using Microstrip Technology for Atomic Emission Spectrometry, *Plasma Sources Sci. Technol.*, in print (1999).

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