proceedings

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Abstract

Optical Detection System of Heavy Metals Based on Microplasma Excitation †

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† Presented at the XXXV EUROSENSORS Conference, Lecce, Italy, 10–13 September 2023.

Abstract: This paper presents the outcome of a study on the reliability of sensors utilizing microplasma to analyze the amount of selected elements in aqueous solutions. Increasing environmental pollution poses new challenges for protective services through real-time monitoring. The aim of this work was to develop miniature plasma generators for the excitation and then analysis of aqueous solutions.

Keywords: optical sensor; ceramics; microplasma

1. Introduction

The motivation for research on ceramic microplasma generators is the need to increase their lifetime. Three types of systems were developed during the studies on this subject: one with a liquid electrode, one with two liquid electrodes and one drop system. The influence of geometrical dimensions on plasma generation and the intensity of the recorded signal were investigated. The LTCC ceramic material used in research works is characterized by a resistance to environmental factors (e.g., acids, alkalis) and resistance to electrical breakdown, which justifies its application potential in the analytical instruments discussed. This paper discusses the materials used for the construction of the microgenerator, in particular for use as electrode layers. This dissertation presents the method of operation of a plasma microgenerator, which ensures the stable operation of the sensor. The most promising results were obtained for the drop system, the application of which has many advantages, such as no microfluidic pumps, discharge stability and no liquid waste. Preliminary studies have been reported in [1–4].

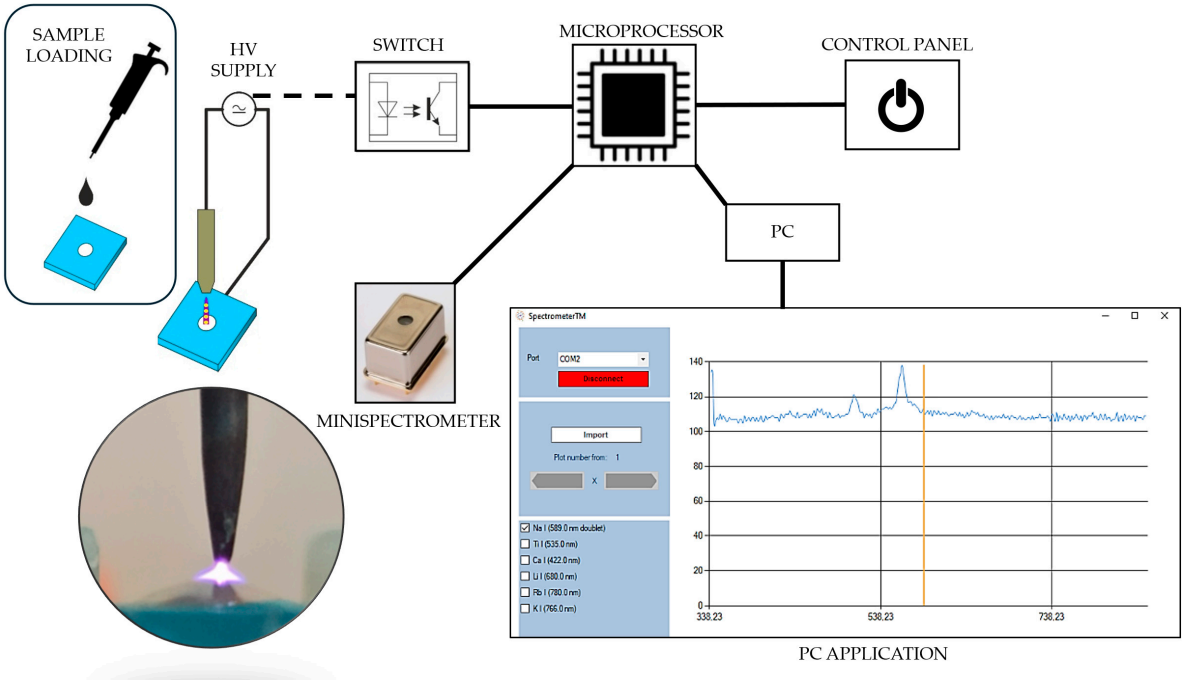
2. Materials and Methods

The LTCC and HTCC systems were verified for drop systems with reservoir diameters of 1, 2, 3, 5 mm and a depth of 0.6 mm. Based on the results, no difference was noticed between the drop system used in the LTCC and HTCC technique. The intensity of the spectra determined that for further work, LTCC chips with a reservoir diameter of 3 mm and a depth of 0.6 mm would be chosen. The counter-discharge electrode (anode) was a pointed tungsten rod (diameter 2 mm). On the basis of 10 measurements, it was found that the average time for the plasma impact on the liquid necessary for its evaporation was about 2 s. The rms value of the current that powered the discharge was about 10 mA. A block diagram of the device and the assembled setup are presented in Figure 1. Direct observation of the microplasma's spectra has been implemented by usage of minispectrometer Hamamatsu C12880MA. Logic side of the setup has been supported by microprocessor STM32 L152. The results were presented on the PC via desktop application.

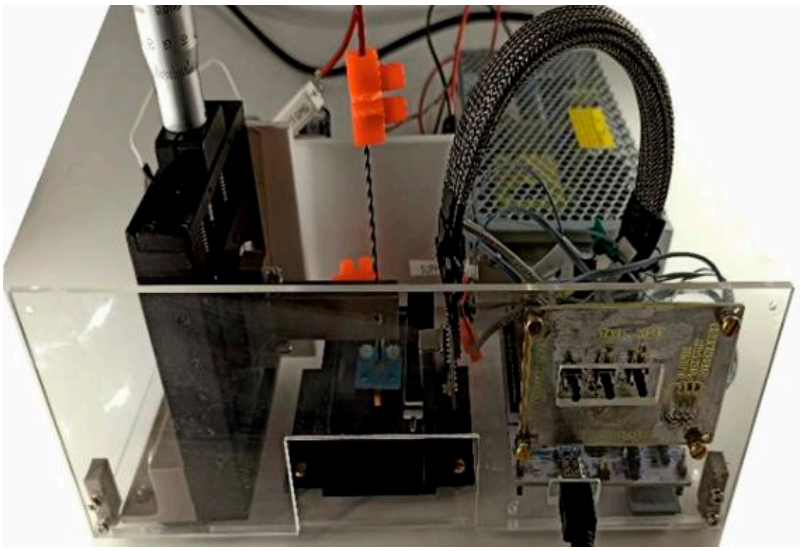
Citation: Matusiak, T.; Dąbrowski, A.; Golonka, L. Optical Detection System of Heavy Metals Based on Microplasma Excitation. *Proceedings* **2024**, *97*, 80. https://doi.org/10.3390/proceedings2024097080

Academic Editors: Pietro Siciliano and Luca Francioso

Published: 22 March 2024



(**a**)



(**b**)

Figure 1. Optical system: (**a**) block diagram and (**b**) front view of the device.

3. Discussion

A solution of 0.1 mol/dm^3 HNO_3 was treated as a relative background of a blank sample in this method. The spectral responses were obtained of blank solutions with 5 and 10 ppm of Ca, Cu, K, Li and Na. For the system presented in Figure 1, a saturation of the detector for Li and Na can be seen. Ten measurements of the background were used for the calculation of the standard deviation (σ) = 6.2. Limits of Detection (*LoD*) were calculated with the equation below (1), where α is the slope factor. The *LoD* results are presented in Table 1.

$$LoD = \frac{3\sigma}{\alpha}[ppb] \quad (1)$$

Table 1. Limits of Detection based on the registered spectra.

Element	Wavelength [nm]	Intensity [a.u.]			*LoD* [ppm]
		0.1 M HNO_3	5 ppm	10 ppm	
Ca	422.7	1429	1706	2480	0.035
Cu	510.5	1230	1435	2451	0.030
Na	589.59	2281	2687	4095	0.021
Li	670.8	2035	2563	4095	0.018
K	766.5	892	908	1344	0.082

Author Contributions: Conceptualization, T.M., A.D. and L.G.; methodology, T.M. and A.D.; software, T.M.; investigation, T.M.; writing—review and editing, T.M. and A.D.; visualization, T.M.; supervision, L.G. All authors have read and agreed to the published version of the manuscript.

Funding: The work was financed from funds of Wroclaw University of Science and Technology.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data are contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

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