Lab-made conductive filament for the 3D printing of ready-to-use multiplexed electrochemical sensors

Eleni Koukouviti[a], Anastasios Economou[a], Christos Kokkinos[a]
[a]Laboratory of Analytical Chemistry, Department of Chemistry, National and Kapodistrian University of Athens, Zografou GR-15771, Greece
e-mail:lenimalice@gmail.com

In the last decade, Fused Deposition Modeling (FDM), a state-of-the-art 3D printing technology, has been increasingly adopted in the production of electrochemical sensors, facilitated by the availability of commercially available conductive filaments, such as PLA loaded with carbon-based materials, which can be easily converted to electrodes [1,2]. Utilizing these commercially available carbon-based conductive filaments, the as-printed sensors exhibit poor electrochemical performance and require chemical or electrochemical surface activation or post-fabrication surface modification with external functional materials in order to improve their operational properties [3,4].

In this presentation, we report a novel biodegradable conductive PLA filament doped with Bi_2O_3 and CuO, which was synthesized and used for the 3D printing of multiplexed sensors [5]. The as-printed sensors do not need any surface treatment or activation and serve as multifunctional transducers for the direct and sensitive detection and quantification of two heavy metals (Pb and Cd) and two significant health biomarkers: glucose and uric acid. Lead and cadmium are voltammetrically determined through the formation of alloys with Bi nanoparticles, electrogenerated from Bi_2O_3, with limits of detection (LODs) of 0.39 μg L^{-1} for Pb and 0.68 μg L^{-1} for Cd. The electrochemical determination of the above-mentioned health biomarkers does not require the presence of any enzyme, as glucose oxidation is catalysed by Cu(III) electroformed from embedded CuO, while uric acid undergoes direct oxidation at the sensor. Glucose was determined amperometrically with a LOD of 0,182 mg dL^{-1} and uric acid was detected by Differential Pulse Voltammetry (DPV) with a LOD of 1,1 μmol L^{-1}. The validation of the sensors was performed by the analysis of samples with satisfactory recoveries ranging from 96% to 103%. The new generation multifunctional filament represents an important advancement toward the development of low-cost, environmentally friendly, multiplexed 3D printed sensors.

Acknowledgements: *I thank the Special Account for Research Grants of National and Kapodistrian University of Athens for the financial support.*

References:

[1] A. Abdalla, B. A. Patel, Annu. Rev. Anal. Chem. 14 (2021) 47-63.
[2] E. J. Carrasco-Correa, E. F. Simmo-Alfonso, J. M. Herrero-Martínez, M. Mirro, TrAC – Trends Anal. Chem. 136 (2021) 116177.
[3] R. D. Crapnell, E. Bernalte, A. G. M. Ferrari, M. J. Whittingham, R. J. Williams, N. J. Hurst, C. E. Banks, ACS Meas Sci Au 2, (2022), 167.
[4] J. Fabri, L. R. G. Silva, J. S. Stefano, J. F. S. Pereira, D. R. Cocco, R. A. A. Munoz, D. P. Rocha, Microchem. J. 191 (2023), 108810.
[5] E. Koukouviti, A. Economou, C. Kokkinos, Adv. Funct. Mater. 34 (2024) 2402094.