3D printed PLA-carbon electrodes activated by atmospheric air plasma: Toward improved performance in electrochemical sensing

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Three-dimensional printing has become widely available due to the development of inexpensive devices as well as a wide variety of modelling and operational software that controls the device itself. As a result, the applications for 3D-printing are extensive, ranging from the production of spare parts to biological organs. Our study focuses on 3D-printed electronics, specifically plasma modification of miniaturized disposable 3D-printed electrodes for electrochemical sensing.

The printed electrodes were fabricated using commercial conductive filament consisting of carbon black nanoparticles (CB) dispersed in a polymer matrix of polylactic acid (PLA). Here, we examined the effect of cold atmospheric plasma treatment (Diffuse Coplanar Surface Barrier Discharge Plasma – DCSBD) on the activation of electrode surface (etching the PLA) using scanning electron microscopy (SEM), X-ray photoelectron spectroscopy (XPS), Raman spectroscopy, surface free energy, and cyclic voltammetry. Electrodes were treated by plasma generated in atmospheric air, with various exposure times ranging from 5 seconds to 5 minutes. The electrochemical performance of plasma-activated electrodes was compared with standard activation by chemical treatment in dimethylformamide.

Compared to the unmodified reference 3D-printed electrodes, rapid activation by plasma within a few seconds led to significantly enhanced electrochemical activity in $[Fe(CN)_6]^{-3/-4}$ redox probe and comparable results with standard ten-minute activation in DMF. Thus, atmospheric air plasma treatment provides an opportunity of becoming a promising alternative to chemical modification of the miniaturized disposable 3D-printed CB/PLA electrode surface while being extremely fast, simple, and easy to incorporate into industrial production lines.

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