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Using atmospheric pressure plasma jet as a tool for surface modification of screen-printed carbon electrodes for electrochemical applications

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Atmospheric pressure plasma jets (APPJs) are non-thermal plasmas that are widely used in various biomedicine and environmental applications. It can also be used in surface modification of biosensors such as screen-printed carbon electrodes (SPCEs), which have been applied in sensing analytes from a solution since a long time due to their low background current. Carbon black and graphite grains are used in ink formulation for printing the electrodes. Usually, binders are mixed with the ink for the adhesion of the ink on the polymer substrate. However, binders are made of ethyl cellulose or epoxy-based resins, which are non-conducting in nature; as a result, binders obstruct the electron flow from the analytes to the electrodes.

There has been much research on surface modification of SPCEs over the years to improve the electrochemical reactivity of the electrodes. Different techniques have been employed, such as wet treatment [1], pre-anodization [2], chemical treatment [3] etc. Furthermore, plasma treatment has also been conducted, as seen in various literature [4,5,6]. However, all the plasma treatments have been performed in low pressure, which needs a vacuum system and is non-portable [4,5,6]. However, in the case of APPJs, onsite surface modification and immediate application of the treated SPCEs can be feasible due to their portability.

APPJs have been created inside a quartz capillary of inner and outer diameters of 3 mm and 5 mm, respectively. A tungsten pin with a diameter of 1.6 mm is used as a high voltage electrode, and a copper ring electrode is used as a ground electrode, as shown in figure 1(a) [7,8]. The applied voltage and frequency can be varied in the range of 0.2-4 kV and 80-100 kHz, respectively. The gas flow rate and the frequency are kept at 3 lpm and 80 kHz for this experiment. SPCEs are kept 8 mm away from the orifice of the capillary. Even though inert gas argon is used to create the plasma, the reactive species present in the plasma due to ambient air participate in the surface modification. The working and counter electrode (radius: 3 mm) of SPCEs are made of graphitic powder, whereas the reference electrode is made of AgCl pellets.

In this study, different methods have been employed to characterize the plasma-treated samples, such as scanning electron microscopy (SEM), x-ray photoelectron spectroscopy (XPS), water contact angle measurement, and cyclic voltammetry (CV). The water contact angle measurement and electrochemical measurements show a significant improvement in the surface and electrochemical properties of the electrodes. The results of the experiments will be presented at the conference.

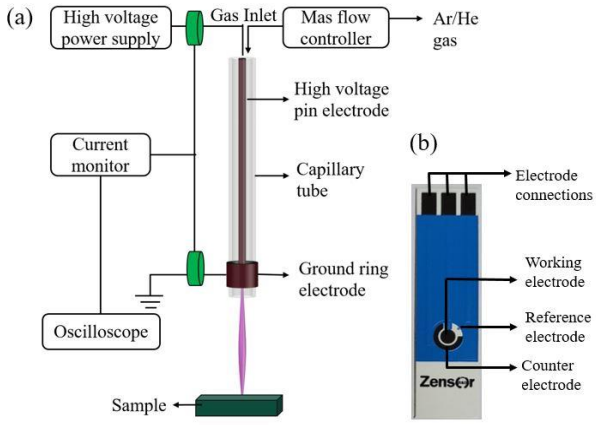

Figure 1: (a) Schematic diagram of the APPJ. (b) Digital photo of the SPCE.

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