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Flexible Microplasma Discharge Device for the Detection of Biochemicals

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Abstract

A microplasma discharge device was fabricated for the detection of biochemicals. The device was fabricated on a flexible polyimide substrate. Silver (Ag) ink was deposited using screen printing process on one side of the substrate, as top electrode. The Ag electrodes were encapsulated by spray coating an acrylic layer. Copper tape, as bottom electrode, was attached to the opposite side of the substrate. The capability of the fabricated device was demonstrated by investigating its optical response toward different concentrations of sodium chloride (NaCl) test analyte. Peaks for sodium ions (Na^+) and chloride ions (Cl^-) was registered at around 600 nm and 750 nm, respectively, in the optical spectra for 1 mM and 100 mM NaCl solutions. The details of the fabrication and the microplasma discharge device response is presented in this paper.

Key words: Additive Manufacturing, Microplasma, Optical Spectroscopy, Salinization, Screen Printing.

Introduction

With the rise in global pollution, coastal lowlands are at an increasing risk of salinization from rise in sea levels which has a profound effect on the ecosystem of the affected water bodies [1]. Further, increased salinization of fresh water bodies can affect crop growth and also contaminate fresh water used for drinking and household uses [2]. This can affect the livelihood of millions of people around the world. Salinization is caused by chemicals such as Na^+, Ca^{2+}, Cl^- and SO_4^{2-} [3]. Optical detection devices for the sensing of these biochemicals are known to be advantageous, over electrical and chemical transducers, due to its higher sensitivity, and insusceptibility to electromagnetic interferences [4]. However, optical detection systems are often fabricated on rigid substrates using lithography based processes which involves complex deposition techniques and time consuming processes, thus making them relatively expensive. Flexible hybrid electronics (FHE), which employs additive printing processes for the development of electronic devices on flexible platforms, is a promising solution that can overcome the limitations of the current systems. This has led to research for the development of a flexible optical detection system that can be integrated into portable systems for the detection of biochemicals.

Methods and Results

The microplasma discharge device, with an overall dimension of 25 mm × 15 mm, was fabricated using additive screen printing process on a flexible DuPont™ Kapton® HN substrate (Fig. 1). A conductive silver (Ag) ink (Applied Inks AG-800) was deposited as top electrode, in an interdigitated configuration, using an MSP 485 screen printer (Affiliated Manufacturing Inc.) on one side of the substrate. The printed Ag was cured in a thermal VWR® 1320 oven at 120 °C for 10 minutes. The Ag electrodes was encapsulated by spray coating it with an acrylic conformal coat (ACL Staticide). The acrylic coating was sprayed three times, in intervals of 15 minutes, and cured in the thermal oven for 5 hours at 120 °C. A copper tape (Bertech CFT-2, 2 mil thick) was attached to the opposite side of the substrate, as the bottom electrode.

A DC power supply was used to supply voltage to a DC to AC high voltage converter, which is connected to the microplasma discharge device using high voltage connecting wires. 20 µl of 1 mM and 100 mM sodium chloride (NaCl) solutions, prepared in deionized (DI) water, was drop-casted and immobilized on the surface of the plasma device, as a test analyte. The microplasma discharge device was activated using high input AC voltages, ranging from

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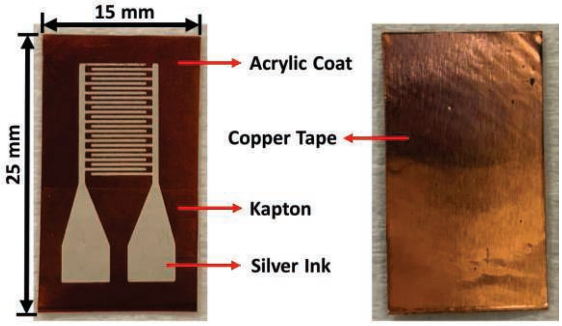

Fig. 1. Microplasma discharge device.

0.2 kV – 2 kV across the electrodes and surface plasma is generated on top of the fabricated device (Fig. 2).

The optical spectra of the 1 mM and 100 mM NaCl solutions were obtained through an optical fiber probe connected to a spectrometer (EPP 2000, 200-1100 nm). SpectraWiz® spectrometer software (StellarNet, Inc.) was used to analyze the optical spectra of the target analyte for the detection of sodium ions (Na^+) and chloride ions (Cl^-). From the optical spectra, a peak, which can be attributed to Na^+ [5], was detected at around 600 nm wavelength for the 1 mM (Fig. 3) and 100 mM (Fig. 4) NaCl solutions. In addition, peaks were also observed at around 750 nm wavelength for Cl^-. It was observed that the intensity of the Na^+ peak in the 100 mM NaCl solution was around 100% higher, when compared to the Na^+ peak in the 1 mM solution. The results demonstrate the capability of the developed flexible microplasma discharge device to be integrated in sensing systems for biochemical detection applications.

Conclusion and Future Work

A microplasma discharge device was successfully fabricated on a flexible polyimide substrate for the detection of biochemicals. The device was fabricated by screen printing Ag ink on one side of the substrate, as top electrode. An acrylic encapsulation layer was spray coated on the printed Ag. The bottom electrodes were fabricated by attaching a copper tape to the opposite side of the substrate. The performance of the fabricated device was investigated by measuring its

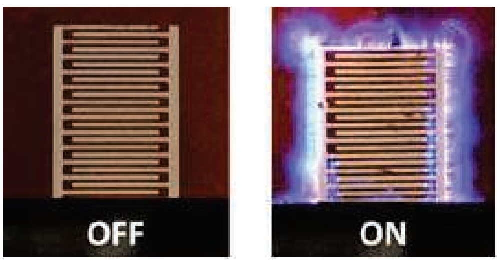

Fig. 2. OFF and ON stage of the microplasma discharge device.

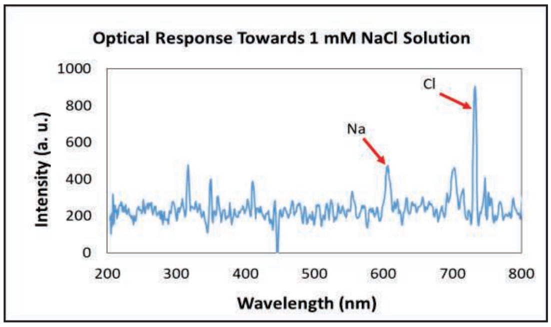

Fig. 3. Optical spectrum of 1 mM NaCl.

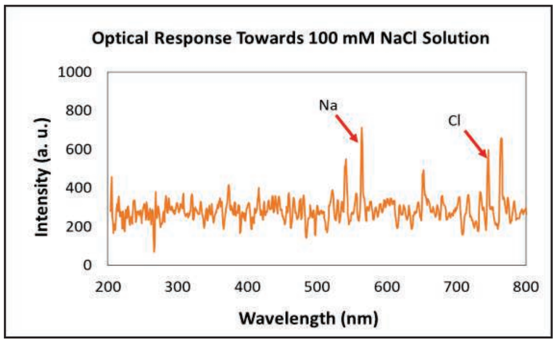

Fig. 4. Optical spectrum of 100 mM NaCl.

optical response toward different concentrations of NaCl solutions. Peaks for sodium ions (Na^+) and chloride ions (Cl^-) was observed at around 600 nm and 750 nm, respectively, in the optical spectra for 1 mM and 100 mM NaCl solutions. Further research is in progress to improve the detection capability of the fabricated device for a wider range of biochemical that cause water salinization.

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