Inkjet printed inorganic sensors and devices

Abstract

Printable sensors offer a cost-effective, scalable platform for developing next-generation sensing devices, with applications in magnetic field sensing, gas sensing, wearable sensors, packaging, and heavy-metal ion sensing. Printing has emerged as a promising fabrication technique owing to its low cost and reduced material wastage compared to lithography-based processes. This dissertation includes the synthesis of inks for fabricating printable sensors and sensor backplanes. A novel magnetoelectric magnetic field sensor was fabricated by inkjet-printing a potassium sodium niobate (KNN) film onto a machined Metglas substrate. The KNN ink was successfully synthesized, and a comprehensive characterization was conducted to assess its suitability. A Helmholtz coil setup was employed for device measurements, achieving a sensitivity of 219.26 mV/Oe and an output voltage of 113.4 mV (7 kHz, 0.5 Oe). The KNN thin film has a lower thermal expansion coefficient and a high Curie temperature, resulting in the device demonstrating stable performance with 0.0783 mV/°C degradation up to 200°C. The sensor design eliminates the need for adhesives, which can cause significant output voltage drift at elevated temperatures. This sensor demonstrates significant potential for high-temperature magnetic sensing applications. The other sensor explored was an inkjet-printed cadmium sulfide (CdS)- based ion-sensitive electrode (ISE) with varying thicknesses. CdS ink was synthesized and characterized to confirm its phase, compound formation, and stoichiometry. Potentiometric analysis of the devices for sensing cadmium metal ions in water revealed that the limit of detection (LoD) and the linear working range vary with thickness, while the sensitivity remains constant. The best LoD of 23.64 ppb was obtained among the fabricated ISEs. The sensors demonstrated a monotonic response with a rapid response time of 1-15 seconds. Interference studies revealed that Pb^{2+} showed the least interference among Zn^{2+}, Ni^{2+}, and Pb^{2+}. These results demonstrate the potential of inkjet-printed CdS-based sensors for effective cadmium ion monitoring in aqueous environments. Further, fully inkjet-printed passive circuit elements, including resistors (R), inductors (L), and interdigitated capacitors (C), were fabricated using a sol-gel synthesized vanadium pentoxide (V_2O_5) ink. The printed resistors demonstrated tunable electrical properties, and a series R-L-C circuit was fabricated using the printed passive components. The frequency response of the circuit (R = 11.5 ± 0.54 kω, L = 27 ± 0.55 nH/mm², and C = 8.25 ± 0.02 pF/cm²) showed a decrease in impedance with increasing frequency, indicating that capacitive behavior dominated the circuit's performance. Printed passives have potential applications in sensor backplanes, smart packaging, and IoT devices, employing a non-lithographic additive manufacturing technique with relatively low materials usage.