Title Tin dioxide nanoparticle based sensor integrated with microstrip antenna for passive wireless ethylene sensing

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Abstract

In this dissertation, we present the development and integration of a passive ethylene gas sensor with triangular microstrip patch antenna for wireless monitoring of climacteric fruit freshness. The existing ethylene sensors are mostly SnO_2 resistor based active sensors, fabricated on rigid substrates requiring high fabrication temperatures and cannot be used for wireless applications. The proposed passive ethylene gas sensor is a novel nanoparticle based SnO_2 capacitive sensor which, unlike the other existing SnO_2 resistor based active thick film and thin film sensors, consists of 10 nm to 15 nm SnO_2 nanoparticles coated as a thin dielectric film of 1300 nm thickness. The nanoscale particle size and film thickness of the sensing dielectric layer in the capacitor model aids in sensing ethylene at room temperature and eliminates the need for micro hotplates used in existing SnO_2 based resistive sensors. In comparison to the high sintering deposition temperatures used for many currently available ethylene sensors fabricated on rigid substrates, the SnO_2 sensing layer is deposited using a room temperature dip coating process on flexible polyimide substrates. The capacitive sensor fabricated with pure SnO_2 nanoparticles as the dielectric showed a 5 pF change in capacitance when ethylene gas concentration was increased from 0 to 100 ppm. The change in capacitance was increased to 7 pF by introducing a 10 nm layer of platinum (Pt) and palladium (Pd) alloy deposited by sputter deposition. This also improved the selectivity of the sensor to ethylene mixed in a CO_2 gas environment. The response time was decreased to 3 min for SnO_2 samples with Pt/Pd layer (5 min for pure SnO_2 samples) and its recovery time was decreased to 5 min compared to 7 min for pure SnO_2 samples.

The passive SnO_2 capacitive ethylene sensor is integrated with a triangular microstrip patch antenna using capacitively loaded integration methodology which represents a one of a kind passive wireless sensor tag used for detecting freshness of climacteric fruit. The integration methodology adapted also reduced the size of the triangular patch antenna by 63 percent. The decrease in sensor capacitance due to the presence of ethylene (0 to 100 ppm) changes the antenna resonant frequency by 7 MHz and return loss by 9.5 dB, which makes the system reliable for far field wireless ethylene monitoring applications.

The sensor tag output was also detected using an RFID reader showing a change in demodulated signal amplitude of 3 mV. Experimental result is presented for detecting multiple sensor tags at varying distances based on the wireless measurement of return loss which eliminates the common distance problem existing in backscatter signal based tags.