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

Author: Mercyma Balachandran

Citation: Thesis, Doctor of Philosophy (Electrical engineering), Louisiana Tech University. 119 pages. 2008.

Keywords: Tin dioxide; Nanoparticle; Microstrip antenna; Ethylene sensors; Wireless sensors

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.