3D Printed GC Column for Ethylene Detection

LogDynamics
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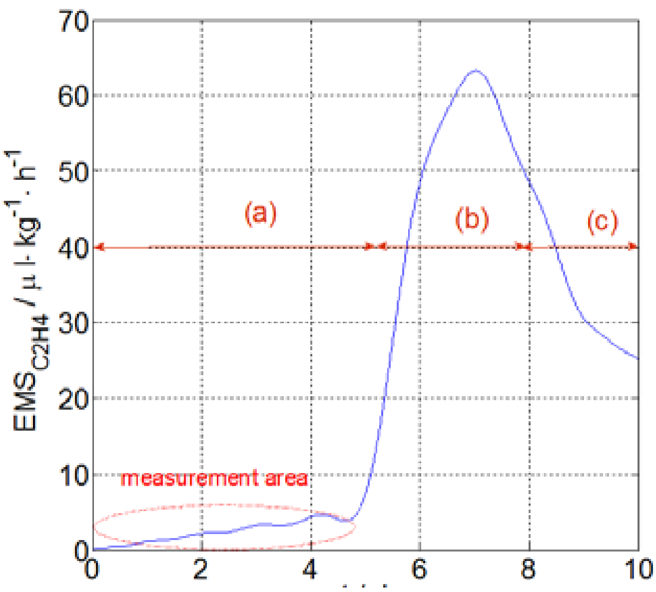
In 2010 IMSAS got a research funding for a project on intelligent containers funded by the Federal Ministry of Education and Research. In this project, three things are in the focus of this research, i.e. sensor technology, sensor network and logistic processes. In the research area of sensor technology involves the sensors that can detect temperature, humidity, oxygen, carbon dioxide and especially the ethylene gas. These sensors will installed in the fruit logistic container to measure gasses and thus the damage because of overripening of fruits can be avoided.

Ethylene is an invisible, colorless and odorless gas emitted from fruits during ripening processes. It is a hydrocarbon having two carbon atoms and four hydrogen atoms and is emitted during the ripeness of climacteric fruits like bananas. The amount of ethylene emission depends on the quantity and ripeness state of the fruit as shown in the figure. In (a) the bananas are in a pre-climacteric state emitting a very small amount of ethylene (b) In the climacteric state the bananas will be in yellow color. In this state, it emits the maximum amount of ethylene and in the post-climacteric state, the amount decreases. To detect ethylene inside of the banana container, about 50 ppmv concentration of ethylene must be detected in order to avoid damage.

To detect the ethylene gas several methods and techniques are proposed. The most common and methods are the Portable electronic Nose (PEN) and the Electronic Olfactory System (EOS835) which consists of an array of metal oxide sensors. These electronic noses not only detect the ethylene but also the sensor arrays inside it that can detect the fungal or bacterial diseases. However, these electronic noses are they have nonlinear lifetime so they must be trained every time before use which is tedious and timeconsuming. These electronic noses are directly subject to the gas thus there is a limitation because the metal oxide sensors have cross sensitivity this limit their operation to use in the container because the concentration of the gas to be measured is in parts per billion by volume ppb. This makes the electronic nose impractical to be used in the container.

Another method used for the detection of ethylene gas is Non-Dispersive-Infrared (NDIR). This system consists of a chamber, an Infrared source, and a detector. To increase the sensitivity of the system, scientists have placed a Pre-concentrator. Passive sensitivity improvements like the shape of the chamber spherical, rectangular and triangular are polishing it with a silver coating to make the surface as reflective as possible to avoid the reflection losses. However, this improvement makes the system expensive and it is still unable to meet the requirements for the ethylene detection in intelligent containers.



The emission of ethylene by climacteric fruits (banana). To monitor the small rise in the pre-climacteric phase (a) a measurement method with very high resolution is needed.

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Gas chromatographic System

The GC system for the measurement of ethylene consists of a GC column, a Pre-concentrator, a Gas sensor and four valves as shown in the figure below. 2. The four valves are used to direct the flow into the pre-concentrator PC and the GC column or to bypass them. The concentration of ethylene is introduced to the PC in which the ethylene molecules are trapped. This process is called adsorption and normally in this process the PC is kept at room temperature. This requires approximately 25 min to capture the ethylene in the pre-concentrator. Then, synthetic air is used to bypass the PC and enter into GC in order to flush out the ethylene from the pneumatic channels to get a based line. This baseline can be seen in a Labview program through a National instrument DAC card used to interface the sensor to the Computer. After getting the baseline, the PC is heated to 250oC for 10 min. Heating the PC detaches the ethylene molecules from the stationary phase. Synthetic air flows then into the PC using the valves that take the detached ethylene molecules into the GC. The non-selective gas sensor gives an ethylene peak.

The 3D-printed Gas chromatographic column is replaced with the silicon fabricated gas chromate-graphic. The system shows good separation results of ethylene from humidity.

3D-printed GC column

In this work, we 3D-printing technology is used to print the GC column as shown in Fig. 3. The methodology to print the 3D printed GC column is the layout of the design is made in inventor software. The design contains stacked spiral column with 450mm length and 1mm diameter. The heater is designed at the top surface of the GC column with making 2mm tubes. After making the design, the design files are exported into a 3D printer which approximately takes 5 hours to print. The printing technology used to print the GC column is stereolithography. The benefits of using the 3D printer are that it does not require complex housing one unit capability to make sure that there is no gas leakage and it also saves the device GC column from breakages. Carbosieve®-SII is used as a stationary phase for the retention of ethylene gas in the GC column.

Outlook

In my Ph.D. thesis, we work on to miniaturize the GC system and make it portable that can run on battery for several weeks and store the data on an SD card. We are also working on to measure the ethylene gas from bananas instead of commercially available ethylene cylinders.

Contribution

The application of my Ph.D. work will be the portable GC system that can be transported in the container to measure the concentration of ethylene gas which can avoid the over-ripening of bananas during transport-tation.