# Electrochemical Ethylene Sensor for Fruit Monitoring based on an Ionic Liquid Electrolyte

J. F. M. Oudenhoven, M. A. G. Zevenbergen, W. Knoben, D. Wouters, R. van Schaijk

Holst Centre/imec
High Tech Campus 31
5656 AE, Eindhoven
The Netherlands

Ethylene is one of the most important hormones that regulates many aspects of plant physiology. Among these aspects are the senescence of flowers and leafs, seed germination and the ripening of fruit. Therefore, there is a need for accurate and continuous ethylene monitoring during the growth and post-harvest handling and transport of fruit and vegetables.

The monitoring of ethylene levels is especially important for tropical fruit, which is harvested unripe, subsequently shipped worldwide, and finally post-treated with ethylene to reach a ripeness level suitable for sale to the end user. During transportation, the ethylene levels need to be maintained sufficiently low, to prevent untimely ripening. For this purpose we developed a low-cost electrochemical ethylene sensor, that can be used to accurately monitor low concentration ethylene levels down to the sub-ppm range.

The sensing principle in this electrochemical sensor is based on a two-step process. At first, ethylene from the gas phase is dissolved in the electrolyte, and secondly the dissolved ethylene undergoes an oxidation reaction at a noble metal electrode that is kept at a suitable potential. The measured oxidation current is directly proportional to the concentration of dissolved ethylene at the electrode-electrolyte interface. The concentration of ethylene in the electrolyte is on its turn directly proportional to the concentration in the gas phase. Therefore, the measured current is linearly related to the ethylene concentration in the gas phase. [1-3]

A practical problem that will commonly occur in electrochemical cells that require contact with air is the evaporation of the solvent of the electrolyte solution. This is, for example, a common challenge for zinc-air batteries [4] and electrochemical gas sensors. With the evaporation of electrolyte solvent, the cells properties will change. For example, the ion conduction between the electrodes will vary with changes in the electrolyte concentration. Moreover, a change in the thickness of the electrolyte layer will result in a alteration in ethylene transport through it. Obviously, the current output will be influenced by these changes, resulting in a change in sensing current. To negate these effects, an electrolyte with a low vapour pressure is required for a prolonged stable operation of the sensor.

We have selected an ionic liquid to serve as the electrolyte for the electrochemical sensor. This has the advantage that its vapour pressure is negligible and that the ionic conductivity is high. The ionic liquid should be selected based on a high solubility for ethylene. Moreover, since the sensor is envisioned to be applied for agricultural products, it is beneficial to choose a specific ionic liquid that is bio-compatible and non-toxic.

The described sensor was made using standard lithographic techniques, and it was mounted and wire bonded in a ceramic dual in line package (DIL/DIP). It was subsequently connected to an in-house developed readout circuit (Figure 1). This readout circuit was a specially designed compact potentiostat, that could be used for the low current amperometric measurements necessary for this electrochemical sensor and for cyclic voltammetry. The sensor and readout performance was determined in controlled laboratory environment.

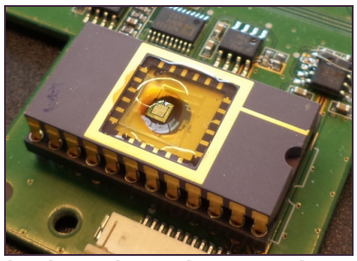

***Figure 1.*** *The electrochemical sensor and circuitry used for these experiments*

In this presentation, we will focus on the aspects that play a role in the design and testing of these type of electrochemical sensors. We will first demonstrate the sensitivity by measuring the current increase corresponding to a step-wise increased ethylene concentration (Fig. 2). Subsequently, we will give an overview of the recent improvements that were made for these sensors and we will show which design parameters play a crucial role for the sensitivity of a sensor. Moreover, we will demonstrate how the stability of this sensor may be improved, and will explore the consequences of realistic ambiences on the sensor performance, for example by determining the cross-sensitivity for relevant other gasses. Finally, we will give our view on how to improve the sensitivity of this sensor such that it can be used for field testing.

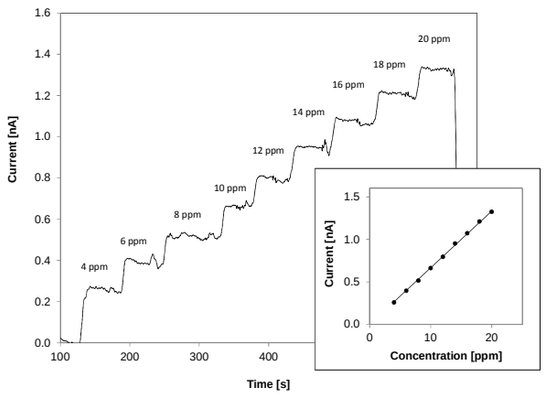


***Figure 2.*** *The current response of the sensor is linearly proportional to the concentration of ethylene*

**Acknowledgments**

C.C.S. Nicole and A. L Bouwkamp-Wijnoltz of Philips Research are acknowledged for their valuable input.

**References**

1. M. A. G. Zevenbergen, D. Wouters, V. A. T. Dam, S. H. Brongersma, M. Crego-Calama, *Anal. Chem.*, **2011**, 83 (16), 6300-6307.
2. M. A. G. Zevenbergen, D. Wouters, V. A. T. Dam, S. H. Brongersma, M. Crego-Calama, *Proceedings of IEEE Sensors 2011*, **2011**, 585-587.
3. W. Knoben, M. A. G. Zevenbergen, S. H. Brongersma, M. Crego-Calama, *Proceedings of the 14th IMCS*, **2012**, DOI 10.5162/IMCS2012/8.2.1.
4. J. F. M. Oudenhoven, R. J. M. Vullers, R. van Schaijk, *Int. J. Energy Res.*, **2012**, 36 (12), 1139-1150.