

Compact Filter Photometer for Ethylene Monitoring.

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Abstract— Precise and continuous ethylene detection is needed in various fruit storage applications. One of the main goals of the presented work is the development of gas sensor systems for ethylene monitoring based on miniaturized low cost infrared spectroscopy. The work is focused on the development of a novel micromachined IR-emitter, a small multi pass reflection cell and a compact detection module to monitor ethylene and interfering gases at different spectral ranges.

Topic: Optical devices

1. INTRODUCTION

The online-monitoring of ethylene plays a crucial role during storage, ripening, transport and vending of fruits. While in long-term storage low levels of ethylene have to be detected, ethylene is actively added when the ripeness of the fruit in storage is to be promoted. In the case of apples, ethylene concentrations during storage of 1-100 ppm are normal. The amount of 400 ppm can be considered as an alarm level. In any case, precise and continuous ethylene detection would be mostly welcome in these applications but up to now no suitable measurement system is available at the market.

2. EXPERIMENTAL

Compared to spectroscopic lab equipment food monitoring systems have to be low cost devices. For this reason a small and comparably cheap infrared optical system for ethylene monitoring in the mid-infrared at 10.6 μm wavelength has been developed. To reach the required sensitivity of 20ppm self-developed compact optical components will be integrated in the system. Next to a microstructured

thermal emitter, a miniaturized multi-reflection gas cell and a compact detection module for multi-spectral analysis of ethylene and the interfering gases ammonia and ethanol are in development.

A novel type of micromachined thermal IR-emitter with a higher emission in the range of 10 μm wavelength. The main difference compared with common thermal micro emitters is the use of 3D structured bulk silicon (fig. 1). The regular ordered macropores of the emitter are obtained by electrochemical etching of prepatterned silicon substrates. The macroporous silicon shows a black-body-like emission profile for a wide wavelength range. The fabrication technology is described in detail in [1] and [2].

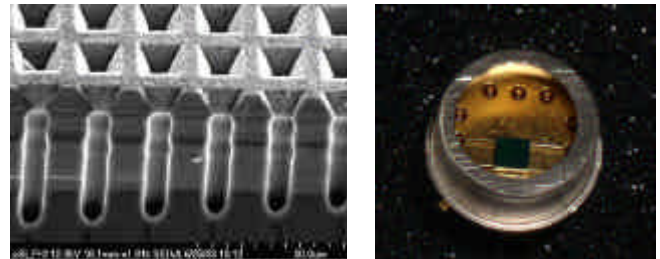


Figure 1: SEM-picture of the IR-emitter-structure based on micro-structured silicon (left), emitter mounted in TO8-housing (right).

Furthermore a miniaturized White cell [3] with 1.6m optical path and a size of about 10cm x 5cm x 6cm has been developed. The main components of the White cell are an aluminium body, three gold coated spherical mirrors with the same radius of curvature and a gas in- and outlet, respectively. The White cell has been tested with the microstructured IR-emitter, a commercial thermopile-detector and Lock-in-amplifier with an ethylene concentration of 100ppm (fig.3). For the integration of the IR-emitter and the miniaturized White cell ray-tracing-simulations were performed. Thereupon a coupling optic with two spherical mirrors were designed and fabricated (fig.2).

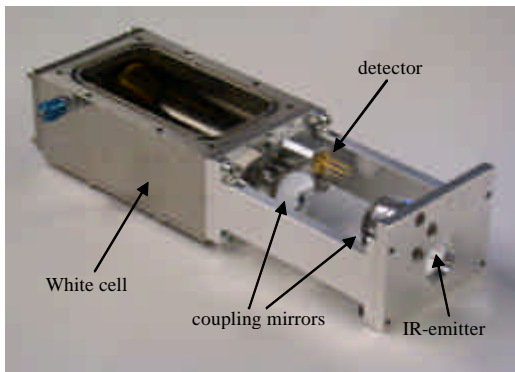


Figure 2: Miniaturized White cell with coupling optics, thermal emitter and commercial thermopile-detector.

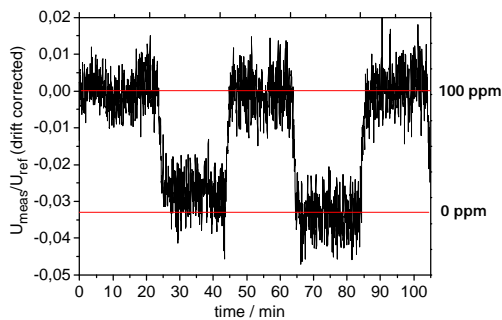


Figure 3: Ethylene measurement using a 1,6m-white cell, self-developed microstructured emitter, commercial two-element thermopile detector (Perkin Elmer, reference at 3.95 μ m, ethylene at 10,5 μ m) and Lock-in-amplifier.

In parallel a compact detection module consisting of a silicon-based thermopile-detector array with integrated optical filters at different wavelengths was developed. The detector array consists of 4 bulk micromachined elements, each one composed of 40 thermocouples. One of the channels is used for reference, one for ethylene and the other two for other application relevant gases (such as ethanol or ammonia, for instance). The optical filters, providing the selectivity of each channel, are commercial narrow band IR filters properly diced and conditioned to integrate them onto the thermopile-array by flip-chip bonding. Detector modules of sizes compatible with TO8 and TO5 packages have been assembled and are being characterized. In fig. 4 (left), one of such detectors can be seen; one of the channels has been left without filter for illustration. In order to increase the radiation capture cross-section of the thermopile absorbers, and therefore improving the detector sensitivity, a focusing unit based on micro-structured Silicon-Fresnel lenses is being designed and will be mounted in front of the thermopile-array. Single 8-level silicon Fresnel lenses, as the one depicted in fig. 4 (right), have been already fabricated and characterized [5].

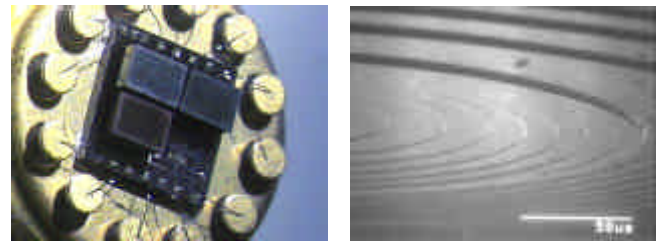


Figure 4: Thermopile-array with integrated optical filters (left) and microstructured Silicon-Fresnel lens (right)

3. SUMMARY AND OUTLOOK

Ethylene measurements with the White cell and commercial emitters and thermopile-detectors were performed and proved the feasibility of detecting ethylene at 10.6 μ m wavelength with a compact system. Next to the White cell a microstructured IR-emitter and a compact detection module was developed. Furthermore a coupling optic for the White cell is currently tested.

In the next steps the self-developed detection module with optical filters and Fresnel lens array will be integrated to the White cell-setup and tested in ethylene measurements with laboratory electronics.

A compact system electronic consisting of a multiplexer, a preamplification board and lock-in-processing is in development.

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