A CO_2 Measurement System for Low-Cost Applications using Chemical Transduction

by

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Abstract

It is demonstrated that by using a miniature chemical reaction vessel under adaptive mechatronic control, it is possible to design and construct a low-cost carbon dioxide measurement system. With further development such a system would be potentially suitable for low-cost commercial application, in particular as sacrificial, single-mission instrumentation packages in horticultural cargo monitoring.

Current instrumentation systems for carbon dioxide (CO_2) gas measurement are reviewed and their limitations with respect to low cost commercial applications determined. These utilise technology intended for laboratory measurements. In particular the optical energy absorbance of CO_2 in the infra-red electromagnetic spectrum. These systems require large optical paths (typically 10cm) in order to measure small CO_2 concentrations. This in turn has a large impact on the physical size of the sensing system.

Of the many applications requiring online CO_2 sensing packages (such as medical, petroleum, environmental and water treatment) the horticultural industry is the primary focus for this research. CO_2 sensing systems are primarily used in horticulture to monitor the produce environment and help extend storage time. For these applications CO_2 concentrations are typically low (in the range 0 to 1%) and the paramount need is for low-cost (and possibly disposable) sensing packages.

The basis of the measurement technique is the use of bulk (but small volume) aqueous chemical reaction under mechatronic control. Unlike thin film technologies where very thin membranes are passively exposed to the gaseous sample, here a small volume (approximately 2mL) of simple and very cheap liquid chemical indicator (calcium hydroxide solution) is used to produce an opaque precipitate. CO_2 concentration is then assessed by low-cost optical attenuation measurements of the developing opacity of the solution. The instrumentation package comprises pumps, flowmeter, reaction cell and infra-red optics for the turbidity measurement, plus reagent and waste vessels, pipelines and electronics.

During each measurement cycle, the reaction cell is flushed, with fresh chemical indicator and a sample of gas admitted. The indicator and the sample gas are then vigorously mixed and the change in the indicators optical properties measured at regular intervals. An embedded 8-bit microcontroller performs the necessary analysis to deduce the CO_2 concentration (as percentage by volume) for the sample gas by reference to one or more of five “Time-To-Threshold” calibration models. These models evaluate the trend in turbidity development as precipitate is formed.

First and second prototypes of the measurement system have been constructed and their (low-cost) components and overall performance evaluated, the first a ‘proof-of-concept’ and the second to investigate methodology shortcomings. As a result the design of a third prototype is outlined. The measurement systems have been shown to work adequately well within expected limitations, resulting in a usable low-cost measurement technique. The current prototypes have a useful range of at least 5% to 100% CO_2 with a discrimination of typically $\pm 6\%$. Deficiencies, particularly performance at low concentrations, are identified and potential enhancements for future prototypes proposed.

Certification of Thesis

I certify that the ideas, experimental work, results, analyses, software and conclusions reported in this dissertation are entirely my own effort, except where otherwise acknowledged. I also certify that the work is original and has not been previously submitted for any other award, except where otherwise acknowledged.

Signature of Candidate	Date

ENDORSEMENT

Signature of Supervisors	Date

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