学 位 論 文 要 旨

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題 目 DESIGN AND DEVELOPMENT OF NDIR-BASED N_2O GAS MEASURING DEVICE FOR AGRICULTURAL FIELDS

(農地用 NDIR ベースの N_2O ガス測定装置の設計と開発)

Greenhouse gas emission raises serious consequences for the world by capturing the heat in the atmosphere. With its inherited characteristics, in the global warming potential, the N_2O gas is powerful 298 times more than CO_2. The agriculture and food production sector has achieved one of the highest anthropogenic N_2O gas emissions. Therefore, regulating the emission sources through the quantification of emissions from agricultural premises is vital. Gas measurement at the field level is costly since the instrument cost, bulky sizes of the instrument, requirement of supportive accessories for gas sampling and distribution, and lack of power. The major cost is based on the device cost and its maintenance activities. Geographically, emission estimation activities lagged at a certain location without expanding in the whole world, especially lower in developing countries. The requirements of low-cost devices, including small sized, low power consumed, and easy to assembly are timely needed.

Since the NDIR technology can be customized with different structural arrangements of optics and the gas cell, and the availability of low-cost parts, the required wavelengths can be selectable with filters, and a customized gas measuring device can be developed. Also, low-precision devices can be used if the measurements are conducted with soil gas where a higher amount of gas concentration is present than its surface. Therefore, this study was conducted aiming, (1) to develop a cost-effective NDIR gas measuring device through a simple optic structure appropriate for detecting a varied range of soil N_2O gas concentrations through passive sampled soil gas using a submerged silicone diffusion cell, and (2) to develop a simulation method for predicting N_2O surface flux (CF) from soil gas, which can be measured in a soil-interred silicone diffusion cell using a low-cost device.

The prototype device was developed by assembling a 59 cm path-length gas cell, a pyroelectric detector, microelectromechanical systems (MEMS)-based infrared emitter, convex lenses, and two anti-reflective (AR) coated optical windows into a simple structure. Laboratory tests on device functionality, humidity tolerance, and soil gas measurement were conducted. Results of the device functionality tests confirmed the ability of soil gas measurement in the range of 1–2000 ppm with silicone diffusion cell, and no interference by the humidity was recorded. The repeatability tests of the device achieved more than 0.9995 coefficient of determination (R2) with 1 ppm of the minimum measurable gas level. The laboratory soil experiment setup confirmed that the device has a great capability to measure the N_2O gas in the soil atmosphere with a serially interconnected, soil-submerged silicone diffusion cell. In the second experiment, the CF was predicted by simulating the measured soil N_2O gas (MF) in a silicone tube via the implicit finite difference analysis method on six soil gas diffusivity models. Two laboratory tests were conducted by varying the method and periods of soil moisture saturation for each fertilized soil sample to detect the CF and MF. The simulation method confirmed the best agreement of CF on the MF with the soil gas diffusivity models 4 and 5.

Keywords: N_2O gas sensor, NDIR, low-cost gas sensor, gas sensor calibration, soil gas flux, soil gas diffusivity, soil nitrous oxide release, silicone tube cell, soil gas flux simulation.