MEASUREMENT OF THE DENSITY OF CO_2 SOLUTION BY MACH-ZEHNDER INTERFEROMETRY

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For the last two decades, the impact of increasing the concentration of greenhouse gases, particularly CO_2, on the earth's atmosphere has become a subject of intense scientific and engineering investigations. Several technologies were proposed for limiting CO_2 emission and mitigating CO_2 concentration from atmosphere. Among these, CO_2 ocean sequestration was considered to be one of the acceptable options. To look into the potential possibility of applying this technology in practical engineering, an international cooperating project was launched in Japan, with a focus on developing technologies and assessing a model of the impact of CO_2 ocean sequestration on the ocean environment. As part of this project, dealing with the study of chemical and physical parameters measurements, we report here the latest results on the density of solutions of CO_2 dissolved in water.

EXPERIMENTAL

The density of CO_2 solution in fresh water is measured based on the method of Laser Mach-Zehnder Interferometry. Fig. 1 gives the schematic diagram of experimental apparatus. The fundamental principle is that the difference of refractive indexes indicated by the result of interference from two laser beams, divided by a half-silvered mirror, one of which passes through the test cell of CO_2 solution and the other is a reference beam. The fringe shift between CO_2 solution and fresh water is related by[1]:

$$\Delta n\delta = (n - n_{h2o})\delta = \lambda \Delta S \qquad (1)$$

where, Δn: the difference of refractive indexes; δ: the distance inside of test cell; λ: laser wave length; ΔS: fringe shift between CO_2 solution and fresh water; n_{h2o} and n are the refractive indexes of water and CO_2 solution respectively.

According to the theory of developed by Feynman[2], the following equation can be derived:

$$\frac{n^2-1}{n^2+2} = \frac{n_{h2o}^2-1}{n_{h2o}^2+2} + \frac{n_{h2o}^2-1}{n_{h2o}^2+2} = \frac{3.71}{18}\rho_{h2o} + \frac{6.68}{44}\rho_{co2} \qquad (2)$$

where, ρ_{h2o} and ρ_{co2} are the density of water and CO_2. The density and the refractive index of CO_2 can be calculated by solving the Eqs. (1) and (2) since fringe shift between CO_2 solution and fresh water can be directly measured. The other parameters appearing in these two equations, the density of water, the distance inside of test cell, laser wave-length, and refractive index of water, are known parameters. Therefore, the density of CO_2 solution and the mass fraction of CO_2 are given by:

$$\rho = \rho_{co2} + \rho_{h2o} \qquad (3)$$

$$C = \frac{\rho_{co2}}{\rho} = \frac{\rho_{co2}}{\rho_{co2} + \rho_{h2o}} \qquad (4)$$

The time evolution of CO_2 dissolving into water is recorded and is shown in Fig. 2.

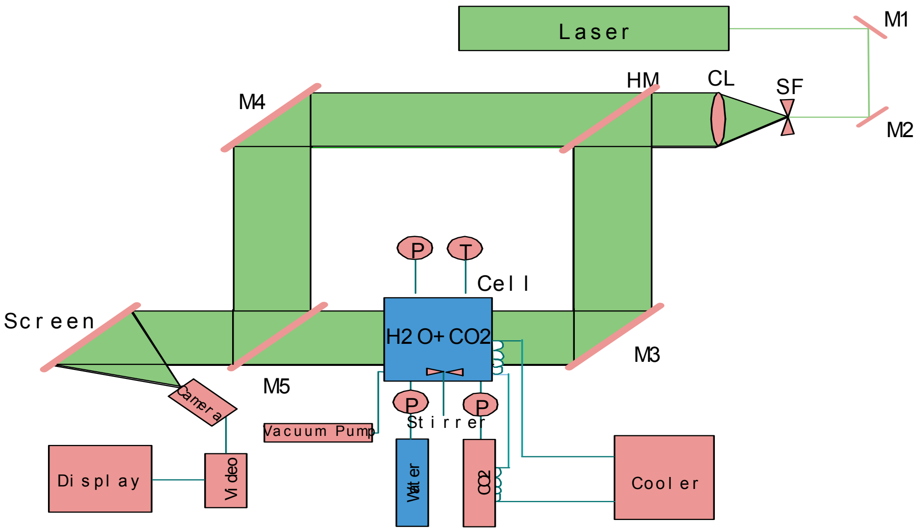

Fig. 1. The experiment apparatus

RESULTS & DISCUSSION

Two sets of data were obtained at pressures ranging from 5.0 to 12.5 MPa, temperatures from 273.25 to 284.15 K, and CO_2 mass fraction in the CO_2 dissolved water from 0.00 to 0.062. It is found from those data that, in general, the density of CO_2 dissolved water is nonlinearly proportional to the CO_2 mass fraction. However, the ratio of density of CO_2 dissolved water to that of water with a density at the same pressure and temperate, and the difference between those densities appears to be monotonically linear with CO_2 mass fraction and seem to be independent on pressure and temperature at the experimental conditions mentioned above. The slope of this linear function is 0.275, calculated by curve fitting the experiment data. Fig. 3 gives the measured and curve fitted data.

The overall accuracy of the data obtained, the experimental set-up, which consists of high pressure cylinder, cooling system, CO_2 injection system and optical system, the fundamental principle applied in this study, and the technology used for data processing, are introduced and discussed in detail in this presentation

REFERENCES

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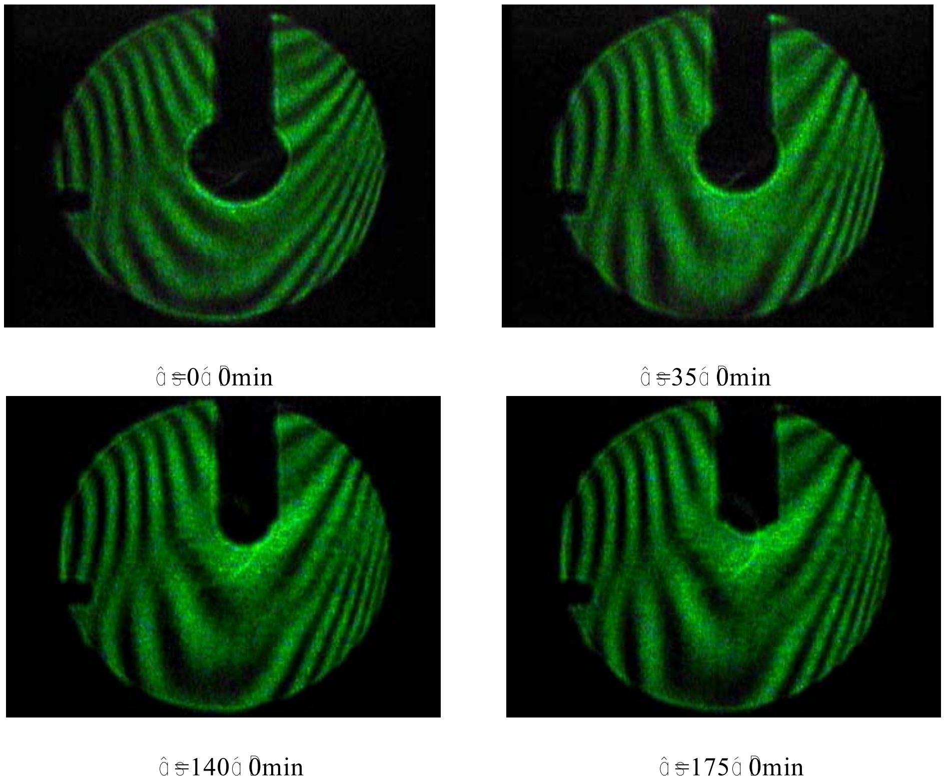

Fig.2, Time evolution of CO_2 droplet dissolution in water

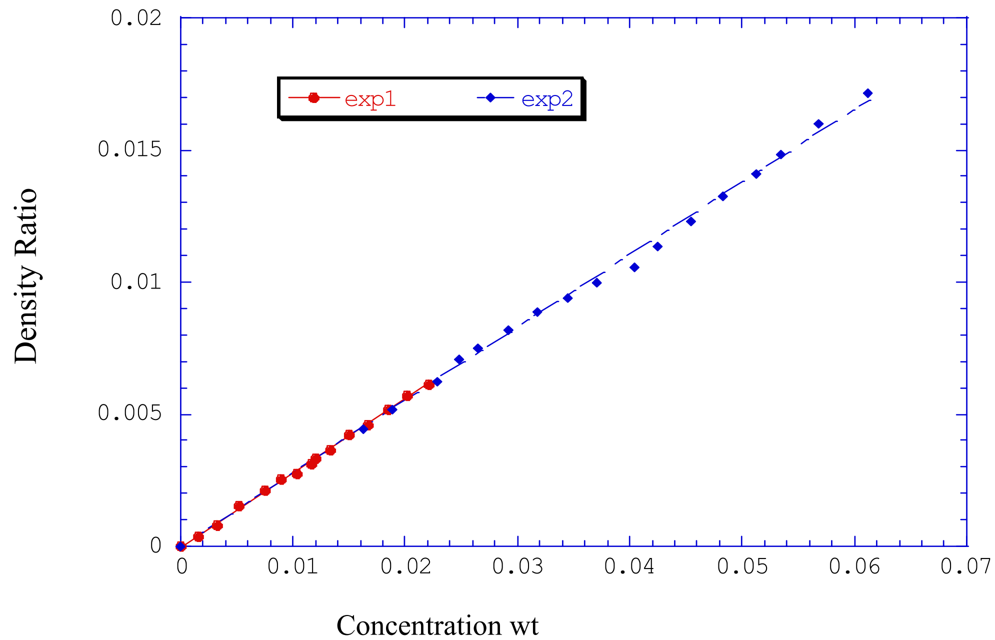

Fig. 3. Experimental data and fitted curve of CO_2 solution density normalized by that of pure water.