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ISS における Soret 効果を利用した拡散係数測定の解析手法の精度評価

Accuracy Evaluation of Analytical Method for Diffusion Coefficient Measurement Using Soret Effect in ISS

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1. Introduction

If diffusion experiments in liquid can be performed using an initial concentration difference ΔC_{app} induced by the Soret effect, the same sample can be used repeatedly under various conditions. This method is very advantageous for space missions, however, is difficult to realize due to the small concentration. Recently, our group performed diffusion experiments using an interferometry on the International Space Station (ISS), and then, the concentration time change $\Delta C(t)$ for data with a relatively large temperature difference ΔT_{app} to induce ΔC_{app} was obtained[1)] by using a simple thinning method[2)]. The reliable diffusion coefficient D_{exp} could be then obtained by applying the finite difference diffusion equation to each $\Delta C(t)$ and processing statistically the apparent values D. However, it is thought that noises in $\Delta C(t)$ becomes more pronounced as ΔC_{app} decreases and, which makes difficult to obtain D_{exp}. The objective of this study is to clarify the change in accuracy of D_{exp} with decreasing ΔC_{app} and whether reliable D_{exp} can be obtained even at small ΔC_{app} by analyzing the observed data with different ΔT_{app} (ΔC_{app}) using the more accurate analysis method[3,4)].

2. Experimental and Analysis Procedures

The vertical direction of salol - 2.58 mol% *tert*-butyl alcohol filled in a glass cell was kept with ΔT_{app} = 6 K and 30 K to induce two different ΔC_{app}. The fringe intensity time change $I(X,Y,t)$ during the concentration mitigation process after setting ΔT_{app} = 0 K was observed by using a two-wavelength interferometry (532 nm and 780 nm) at each observation point (X,Y). The values of $I(X,Y,t)$ were converted to the phase changes $\Delta\phi(X,Y,t)$ by using the fringe analysis method[3,4)]. The concentration change $\Delta C(X,Y,t)$ was then obtained by substituting $\Delta\phi(X,Y,t)$ at t > 0.25 h (temperature steady time) into the phase-concentration equation. The apparent diffusion coefficient $D(X,Y,t)$ was obtained by applying the finite difference diffusion equation to $\Delta C(X,Y,t)$ in each of N patterns of (X,Y,t). Finally, the representative diffusion coefficient D_{exp} was determined as the median values of the N_0 patterns of $D(X,Y,t)$ where zero, infinity and missing values were eliminated.

3. Results

Figure 1 shows the obtained values of $\Delta C(100,100,t)$ with ΔT_{app} = 6 K and 30 K for 532 nm. The values of $|\Delta C|$ with ΔT_{app} = 30 K were larger than with ΔT_{app} = 6 K even with the almost the same fluctuations. **Figure 2** shows the histograms of $D(X,Y,t)$ with both ΔT_{app} for 532 nm. The sharpness of the histogram with ΔT_{app} = 30 K was higher than with ΔT_{app} = 6 K. The values of D_{exp} with both ΔT_{app} were about 0.9×10^{-9} m²s⁻¹.

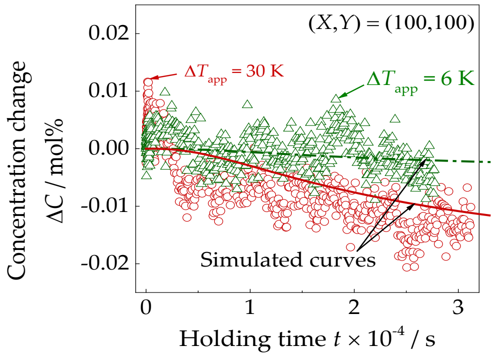

Figure 1. Time series of $\Delta C(X,Y,t)$ for 532 nm.

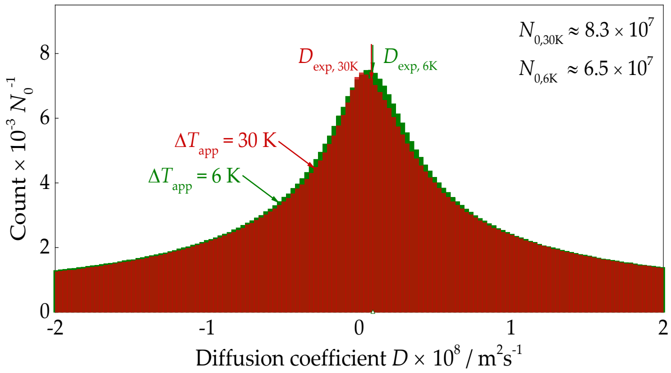

Figure 2. Histograms of D for 532 nm.

4. Discussion

From **Fig. 1**, the optical noise in $\Delta C(X,Y,t)$ with ΔT_{app} = 6 K is relatively large compared with ΔT_{app} =30 K. It is thought that this relatively large noise with ΔT_{app} = 6 K increased the errors of $D(X,Y,t)$ and decreased the sharpness of the histogram as shown in **Fig. 2**. We calculated the error rate $\delta_{ref} = |(D_{exp} - D_{ref}) / D_{ref}|$ of the D_{exp} against the reference value $D_{ref} = 1.3 \times 10^{-9}$ m²s⁻¹ [2]. As a result, especially with ΔT_{app} = 6 K for 532 nm and $N \approx 8 \times 10^7$, the value of δ_{ref} was about 30%. Therefore, we revealed that the diffusion coefficients D_{exp} with the error of about 30 % against literature one can be obtained even at small ΔC_{app}.

5. Conclusion

In this study, we analyzed the concentration mitigation process in the diffusion coefficient D_{exp} measurements using the two different concentration differences ΔC_{app} induced by the Soret effect using the accurate fringe analysis method[3,4] and revealed follows. As ΔC_{app} decreases, the optical noise in the concentration time change $\Delta C(X,Y,t)$ becomes relatively larger and the accuracy of D_{exp} decreases. The values of D_{exp} can be obtained with the error of about 30 % against literature one even at small ΔC_{app}.

References

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