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# Soret-Facet ISS 実験で得られた干渉縞の解析手法改善とソーレ係数の温度依存性

# Improvement of Analysis Methods for Interference Fringes obtained by Soret-Facet Mission on the ISS and the temperature dependence of Soret coefficients

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## 1. Introduction

The Soret effect is one of transport phenomena and the mass and thermal transports are described by the Soret coefficient $S_T$[1]. This value is calculated as the ratio of temperature gradient to concentration gradient in a stable state. In 2014, $S_T$ was measured with an interferometer on the International Space Station (ISS) in Soret-Facet Misson. Our group proposed two methods of obtaining and analyzing interference fringes, that is fixed-view analysis[2] and moved-view analysis[3]. The moved-view analysis was devised in order to eliminate two disadvantages of the fixed-view analysis. One is that the concentration gradient is often determined as the opposite direction due to a narrow field of view. The other is that it is computationally expensive and susceptible to noise because it requires a long observation period. However, $S_T$ obtained by the moved-view analysis had not been fully examined. The objective is to confirm the improvement of $S_T$ measurements by the moved-view analysis compared with the results by the fixed-view analysis, and then discuss the temperature dependence of the $S_T$ values.

## 2. Experiment and Analysis Procedures

The Soret coefficient $S_T$ of salol /*tert*-butyl alcohol was measured with a two-wavelength interferometer (wavelength $\lambda = 532, 780$ nm) on the ISS [4]. The initial concentration of the sample $C_0$ was 2.58 mol% butyl alcohol. The top and bottom temperatures of the sample cell was controlled with Peltier devices and the thickness of the cell $d$ was 1 mm. Two types of temperature conditions were set: i) the temperature of the center $\Delta T_{\mathrm{c}}$ was fixed at 318 K and the applied temperature difference $\Delta T_{\mathrm{app}}$ was varied from 6 to 30 K, and ii) $\Delta T_{\mathrm{app}}$ was fixed at 10 K and $\Delta T_{\mathrm{c}}$ was varied from 313 to 333 K. **Figure 1** shows the size of the field of view and moving distance. The $X$ and $Y$ coordinates were set on the field of view and $X$-axis was vertical to the direction of $\Delta T_{\mathrm{app}}$. The field of view was fixed during the measurement, but it was vertically moved 7.1 mm just before the end of the measurement.

The analysis methods of recorded interference fringes were as follows. First, the intensity $I$ of the interference fringes of each point was converted into phase change from the initial phase $\Delta\phi$[5]. In the fixed-view analysis, the phase change $\Delta\phi_F$ was considered as the sum of $\Delta\phi_F^T$ and $\Delta\phi_F^C$ caused by time-dependent temperature and concentration change, respectively. The temperature change $\Delta T_F$ and the concentration change $\Delta C_F$ were calculated by Eq. (1) and (2), respectively[2].

$$\Delta T_F = \frac{\lambda}{2\pi d}\left\{\left(\frac{\partial n}{\partial T}\right)_{C,\lambda}^{-1} \Delta\phi_F^T\right\} \tag{1}$$

$$\Delta C_F = \frac{\lambda}{2\pi d}\left\{\left(\frac{\partial n}{\partial C}\right)_{T,\lambda}^{-1} \Delta\phi_F^C\right\} \tag{2}$$

Here, $n$ is refractive index.

In the moved view analysis, temperature change $\Delta T_F$ was used, which was calculated in the fixed-view analysis in the same experimental run. The condition of the sample just before view moving (**Fig. 1 (a) A**) was set as the standard. The phase change $\Delta\phi_M$ was obtained by determining the deference between the phase after view moving and the phase of the standard. The phase change $\Delta\phi_M$ was considered as the sum of $\Delta\phi_M^T$ and $\Delta\phi_M^C$. The phase change caused by temperature difference from the standard $\Delta\phi_M^T$ was obtained from Eq. (1) with $\Delta T_F$. The concentration change from the standard $\Delta C_M$ was calculated by Eq. (2) substituting $\Delta\phi_F^C$ by $\Delta\phi_M^C$ and $\Delta C_F$ by $\Delta C_M$, respectively.[3] After that, temperature gradient $\nabla T$ and concentration gradient $\nabla C$ were obtained by linear approximations of $\Delta T$ and $\Delta C$ at each $Y$, respectively. Finally, $S_T$ was calculated at each $Y$ and the measurement value was determined as the mean of them.

$$S_T = -\frac{1}{C_0(1-C_0)}\frac{\nabla C}{\nabla T} \tag{3}$$

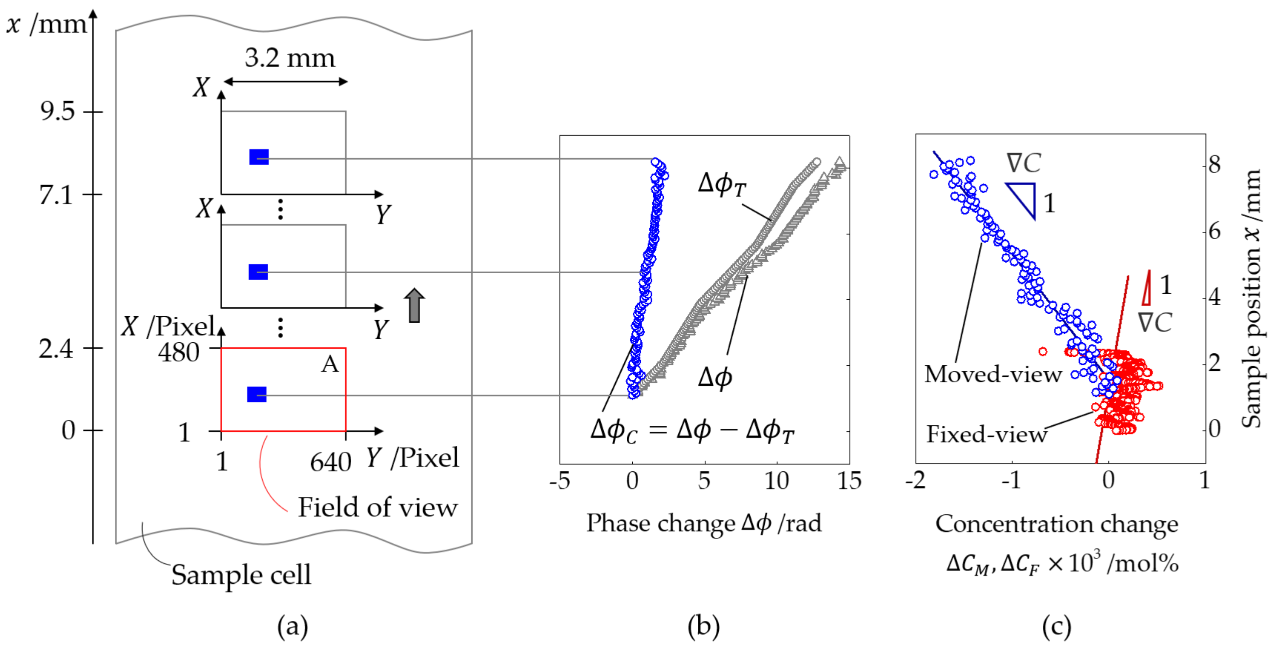


**Fig. 1** The model of the field of view in the moved view analysis and an example of experimental analysis corresponding to it. As the example, the results under the condition of $T_c = 318$ K and $\Delta T_{\mathrm{app}} = 10$ K at $(X, Y) = (221$ Pixel, $175$ Pixel$)$ are shown. (a)The size of the field of view and moving distance, (b) $\Delta\phi$ vs $x$ by the moved-view analysis, and (c) $\Delta C$ vs $x$. In the fixed-view analysis, $X$ was varied in the range 1-480 Pixel, $Y$ was 175 Pixel.

## 3. Results

**Figure 2** shows $S_T$ obtained by each analysis method. Although the $S_T$ in the same experimental run by the fixed-view analysis varied between positive and negative, all $S_T$ values were uniformly obtained as negative values by moved-view analysis. The standard deviations of $S_T$ for some experimental runs by fixed-view analysis were extremely large, but otherwise the standard deviations were generally smaller than by moved-view analysis. The similar trend was observed in the measurements with varied $\Delta T_{\mathrm{app}}$.

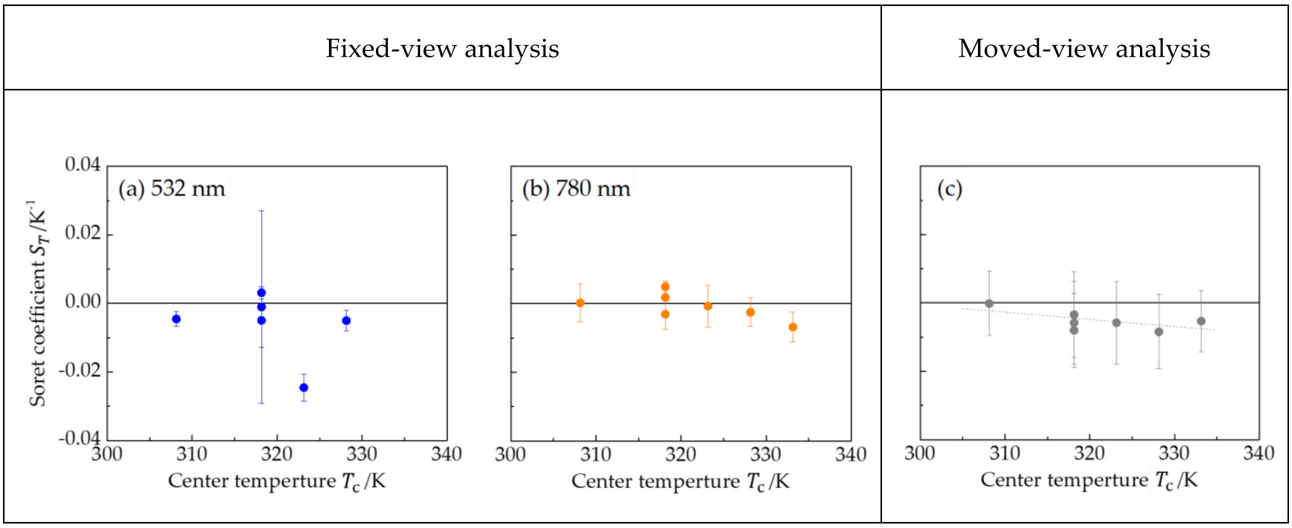


**Fig. 2.** $S_T$ vs $T_C$ by each method. $\Delta T_{\mathrm{app}}$ was 10 K, three runs were plotted at 318 K. The error bars are the standard deviations. The dashed line in (c) is the results of a linear fit to the data points by moved-view analysis for a visual aid.

## 4. Discussion

When the linear approximation was applied for the distribution of $\Delta C$, $\nabla C$ was varied by periodic noise against the distribution of $\Delta C$ in the fixed-view analysis. On the other hand, the moved-view analysis had wider observation range and dealt with the larger $\Delta C$ than the fixed-view analysis. Therefore, in the moved-view analysis, the effect of noise was smaller and $\nabla C$ was determined to have the same sign. Also, the temperature dependence of $S_T$ by the fixed-view analysis waved, but the result of the moved-view analysis suggested $S_T$ decreased monotonically with $T_c$.

## 5. Conclusion

The moved-view analysis enabled us to obtain $S_T$ uniformly with negative sign, while the fixed-view analysis showed positive values in same experimental runs. This is because $\nabla C$ by the moved-view analysis was hardly affected by periodic noise against the distribution of $\Delta C$ due to the wider observation field and the larger $\Delta C$. In addition, it was suggested that $S_T$ decreased monotonically with $T_c$ by the result of the moved-view analysis.

## References


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