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# Effect of Contrast Enhancement Prior to Iteration Procedure on Image Correction for Soft X-ray Projection Microscopy

Tatsuo SHIINA[1*], Jamsranjav ERDENETOGTOKH[1], Yasuhito KINJO[2], Atsushi ITO[3]
[1]Graduate School of Advanced Integration Science, Chiba Univ., Chiba-shi, Chiba, 263-8522, Japan
[2]Tokyo Metropolitan Industrial Technol. Res. Inst., Koto-ku, Tokyo 135-0064, Japan
[3]School of Engineering, Tokai Univ., Hiratsuka-shi, Kanagawa, 259-1292, Japan

## Introduction

Projection soft X-ray microscopy has characteristics of easy zooming function, simple optical layout and so on. However the image is blurred by the diffraction of X-rays, leading the spatial resolution to be worse. In this study, the blurred images have been corrected by an iteration procedure, i.e., Fresnel and inverse Fresnel transformations repeated. It was not enough to some images showing too low contrast, especially at high magnification. In the present study, we installed a contrast enhancement method into the blurred observation image to make the diffraction fringes clearer prior to the iteration procedure only.

## Contrast Enhancement

When applying the linear contrast enhancement method which is calculated by formula (1), minimum and maximum values of original gray-scale data in the projection image are assigned to a new set of values so that the full range of available gray-scale values can be utilized. Cross-sectional line graphs before and after contrast enhancement on projection image are illustrated in Fig.1. In this model, diffraction fringe height could be increased by about 2 times as described with arrows in Fig.1.

$$I'(i,j)=\frac{I(i,j)-I_{min}}{I_{max}-I_{min}}\cdot I'_{max} \qquad (1)$$

Two kinds of noise filtering methods were used to avoid unwanted noise enhancement due to the contrast enhancement. The first filter performs a filtering for small noises not exceed 1.06 times of the baseline shown in Fig.1. An average of gray-scales of the image frame was used as baseline. The value of 1.06 was set by an earlier study performed for checking of background noise distribution. The second filter performs a filtering for big noises emanated rapidly and individually.

Results of iteration procedure on the projection images treated previously with contrast enhancement are shown in Table 1 for a latex particle (10 mmϕ) and a chromosome. The gray-scale change due to contrast enhancement and the effect of iteration correction is also illustrated in Fig.2. The contrast enhancement method was effective especially for the correction of the chromosome images, which are not correctable by iteration procedure only. The results suggested that sharpen and deepen the image contrast made enough difference for the iteration correction between the contrast of diffraction fringes and background gray-scale distributions. In the case of a chromosome image which shown in Table 1, the diffraction fringe contrast were enhanced by about 1.7 times as described with blue and green curves on the Fig.2. As a result, latex-particle image observed in any magnification could be corrected, while the chromosome image of the highest magnification of <219 is well corrected. The chromosome image of >219 was still remained as the insufficient result.

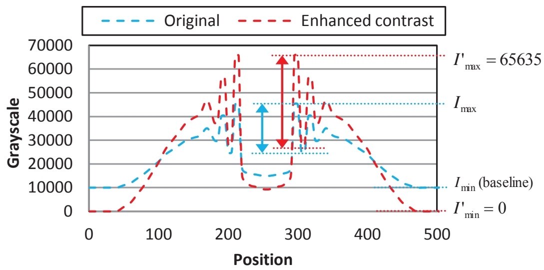
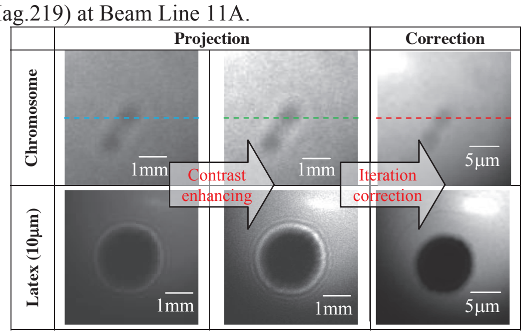



Fig.1 Contrast Enhanced Method.

Table 1 Representative images for contrast enhancement effect (Mag.219) at Beam Line 11A.



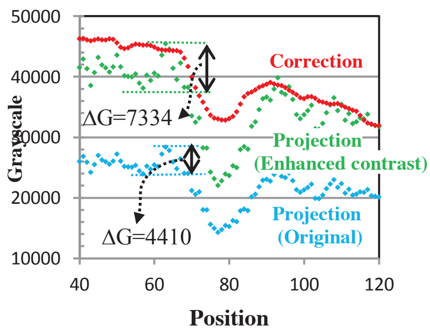




Fig.2 Gray-scale distribution on a line of chromosome image.

## References

[1] T. Shiina et al., PF Activity Report 2013 #31 B 0491(2014)
http://pfwww.kek.jp/acr2013pdf/part_b/pf13b0491.pdf

* shiina@faculty.chiba-u.jp