Unresolvable microstructure analysis using visibility contrast in the X-ray Talbot interferometry

Wataru Yashiro, Sébastien Harasse, Hiroaki Kuwabara, Takashi Yamazaki, and Atsushi Momose
Department of Advanced Materials Science,
Graduate School of Frontier Sciences,
The University of Tokyo,
5-1-5, Kashiwanoha, Kashiwa, Chiba, 277-8561 Japan

Recently X-ray Talbot and Talbot-Lau interferometry (and similar techniques) attract increasing attention because it works with polychromatic and cone beam from a compact laboratory source [1]. In the X-ray Talbot (-Lau) interferometry, we can retrieve two quantitative images, i.e., absorption and differential-phase images, from a series of experimentally obtained moiré images. Pfeiffer *et al.* has proposed another approach to form image contrast, where relative decrease in the visibility of the moiré image is quantified by defining a normalized visibility [2]. They reported that the visibility contrast is formed through the mechanism of small angle X-ray scattering from microstructures with a scale much smaller than the spatial resolution of the imaging system. However, no general formulation of the phenomenon, which is essential for quantitative structure analysis, was provided.

We have shown that the visibility contrast can be generally formulated by autocorrelation function describing spatial fluctuation of wavefront due to the microstructures [3]. Experimentally obtained visibility contrasts due to several samples were successfully explained by the formula. The autocorrelation function is characterized by the Hurst exponent and the correlation length; the Hurst exponent is relevant to the average shape of the microstructures, while the correlation length is interpreted to the averaged size of them. Experimental results supported this interpretation.

Figure 1 (a), (b), and (c) are examples of visibility-contrast images of a chloroprene rubber (CR) sponge, which exhibited uniaxial anisotropy ((a) $\Phi = 0^{\circ}$, (b) $\Phi = 45^{\circ}$, and (c) $\Phi = 90^{\circ}$, Φ being the orientation of the anisotropy axis in the plane perpendicular to the optical axis). Figure 1 (d) shows the dependence of $-\ln(V/V_0)$ on pd at a point, where p is the Talbot order and d is the pitch of the gratings. The results were well fitted by Sinha's model (curves) [3]. From such fittings we showed that the origin of the anisotropy is the anisotropy of the average size of microstructures in the sample.

The experiment was performed at Photon Factory (proposal number: 2009G031). This study was financially supported by Japan Science and Technology Agency (JST).

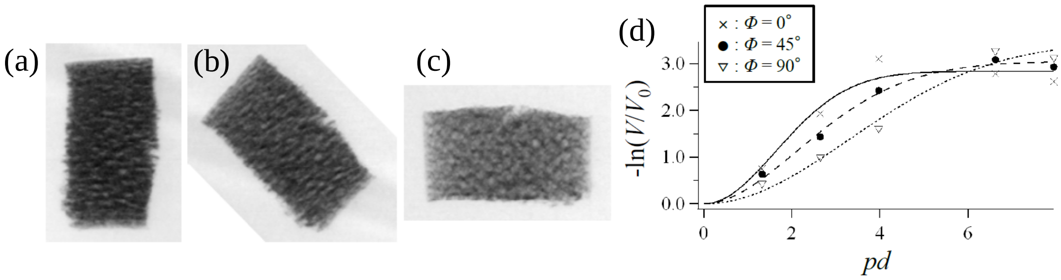

Fig. 1: Orientation-dependence of visibility-contrast images ((a) $\Phi = 0^{\circ}$, (b) $\Phi = 45^{\circ}$, and (c) $\Phi = 90^{\circ}$, where Φ is the orientation of the anisotropy axis around the optical axis) and (d) pd-dependence of $-\ln(V/V_0)$ at a point.

[1] A. Momose *et al.*, *Biomedical Mathematics: Promising Directions in Imaging, Therapy Planning and Inverse Problems*, edited by Y. Censor, M. Jiang, and G. Wang (Medical Physics Publishing, 2008, Madison, Wisconsin, USA).
[2] F. Pfeiffer *et al.*, *Nat. Mat.* **7** (2008) 134.
[3] W. Yashiro *et al.*, *Opt. Exp.* **18** (2010) 16890-16901.