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結晶成長過程の解明に向けた三次元干渉計および屈折率マッチングセルの開発
Development of 3-D interferometer and refractive index matching cell for crystal growth

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It is known that the crystal growth mechanism in the solution changes as the supersaturation increases. When the crystal is growing in the supersaturating solution, the solute concentration at an interface between crystal and solution is smaller than that of the bulk solution because the crystal grows by incorporating solute in a solution. Since local concentration distribution at the interface can cause instability of the form on the crystal surface, determination of the concrete concentration distribution at the interface is important to discuss the mechanism of the crystal growth. Therefore, to discuss the relation between the crystal growth mechanism and growth rate of the crystal, it is necessary to measure the concentration around the crystal-liquid interface, not of the bulk.

There are many reports concerning measurement of the concentration field, but many of them are two-dimensional (2-D) observations, namely, the object is observed only from one direction. The information obtained by the 2-D observations is integrated along the direction of the observation, so the local information, e.g., concentration distribution around the crystal-liquid interface, is not obtained.

To improve the disadvantage on the 2-D observation, a method of computer tomography (CT) has been adopted by some authors. By using the CT method, one can reconstruct the information of the three-dimensional (3-D) concentration field around the growing crystal based on 2-D observations obtained from several directions (3-D observation). Previous works of 3-D observations revealed the 3-D structure of solute convection around the growing crystal. However, there are quite a few observations of the concentration field at the interface between crystal and solution..

In the present study, we carried out 3-D observation to measure the 3-D concentration field very close to the crystal-liquid interface growing in solution quantitatively. We newly developed microscopic Mach-Zehnder interferometer.

For quantitative 3-D measurement of concentration field, we developed a 3-D microscopic Mach-Zehnder interferometer. 3-D observations can provide us the concentration distribution at an interface between the growing crystal and solution with high magnification and high sensitivity.

For the application of the 3-D observation by using our Mach-Zehnder interferometer, we measured the concentration field around a protein crystal growing in a solution. The growth rate of the protein crystal is quite low, so the decrease of concentration in solution should be much smaller. The interference fringes obtained are straight, but curved slightly only at a very narrow area close to crystal surface. In spite of the very small movements of the interference fringes, we successfully reconstructed the 3-D concentration field around the growing protein crystal.

To use the 3-D observation of the concentration field at a rough interface or the interface in early stages of crystal growth, it is important to raise the spatial resolution of 3-D microscopic Mach-Zehnder interferometer further. The spatial resolution of the 3-D observation depends on the number of view angles. As the number of the view angles, namely the number of the images of 2-D concentration field, increases, resolution of reconstructed 3-D concentration field image gets better.

To get many 2-D images, we prepared cylindrical growth cell. Usually, cylindrical cell is not able to use for the interferometer because the curvature of the cell bends the light beam. We will overcome this problem by using the refractive index matching method.

To avoid bending of the light beam, we put the matching liquid around the cylindrical cell. This liquid removes refraction and reflection of the light on the wall of the cylindrical cell so that the beam can pass through the cell straightly.