BL24XU
Hyogo ID

1. Introduction

BL24XU is known as the Hyogo ID beamline. It is one of the two beamlines designed by Hyogo Prefecture for industrial applications. It is a branched beamline employing a figure-8 undulator light source, a diamond (220) beam-splitting monochromator for branched line A, and a standard SPring-8 double-crystal monochromator (DCM) for mainstream B. The end-station is specialized for high-resolution structural characterization by microbeams and imaging (Table 1). The BL upgrading of the end-stations and their promotion to industrial users are ongoing in cooperation with the University of Hyogo. In FY2019, a lensless nanoimaging technique using coherent X-rays, called coherent diffraction imaging (CDI), and its scanning variant, ptychography, were opened to users for the first time at SPring-8 [1,2].

Recently, we have attempted to integrate informatics technology and synchrotron radiation analysis. The informatics approach may extract useful features from the measurement data and find a correlation among these features, physical properties, and manufacturing processes of materials. Here, we report its industrial applications as a research topic.

2. Study on structural basis of texture of traditional hand-stretched wheat noodles (*Tenobe Somen*) using synchrotron X-rays and machine learning

Ibonoito Somen is a type of Japanese traditional hand-stretched wheat noodle (*Tenobe Somen*) with a history of about 600 years in the Harima area of Hyogo Prefecture. In the hand stretching process, the careful stretching of the dough and the bundling of several strands of the stretched dough are repeated several times, whereas machine-made noodles are manufactured by cutting sheeted dough. The hand-stretched noodles have characteristic

Table 1. Specifications of the measurement techniques in BL24XU.

Measurement techniques	Structural information	Spatial resolution
Projection/imaging microscope/coherent diffraction imaging (CDI)/CT	2D/3D image Field of view: 1 μm–1 mm Absorption, refraction contrast (projection/imaging microscope) Absorption, phase contrast (CDI), ptychography	10 nm–0.33 μm
Microbeam SAXS/WAXD/XRF	Periodic/aggregation structures of angstrom–several hundred nm Distribution of crystal grains Elemental mapping	0.5–5 μm
Bonse-Hart USAXS	Periodic/aggregation structures of 16 nm–6.5 μm	bulk
Highly parallel microfocus diffraction, bright-field topography	Local strain analysis, dislocation imaging	0.5–30 μm (diffraction), 0.65 μm (topography)
Near-ambient-pressure HAXPES	Chemical state	30 μm

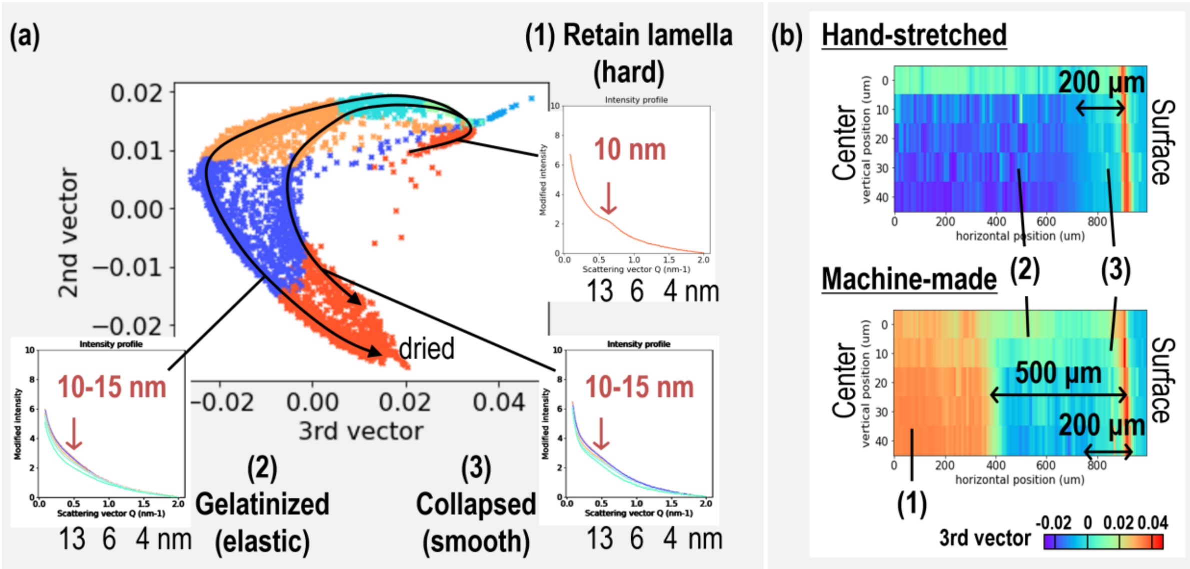

Fig. 1. Distribution of gelatinization state of starches in boiled noodles. (a) Manifold map of local SAXS profiles. (b) Distribution of gelatinization state derived from manifold map.

textures in general: *Koshi* and *Nodogoshi*. However, the structural basis of the texture is still unclear. In collaboration with Mr. Hara Nobutake of Hyogo Prefecture Tenobe Somen Cooperative Association and Prof. Yoshimura Miki and Ms. Nakatani Mayu of University of Hyogo, we investigated the structural basis of the characteristic texture of the hand-stretched noodles [3].

Synchrotron X-ray micro-CT studies of the dried noodles revealed that the hand-stretched noodles have many long pores with a diameter of ~20 μm oriented along the noodles, whereas the machine-made noodles have only disordered pores [1]. The oriented pores are expected to work as water channels to transport heat and water into the noodles during boiling. This result suggests the difference between hand-stretched and machine-made noodles in terms of the distribution of the gelatinization state of starches in boiled noodles.

Thus, we next investigated the heterogeneity of the gelatinization state of starches in boiled noodles by the combinational use of microbeam SAXS mapping and manifold learning, one of the machine learning methods. Slices of the boiled hand-stretched and machine-made noodles were raster-scanned with an X-ray beam focused to a diameter of ~6 μm, and local SAXS profiles were collected. Manifold learning can visualize the distribution of these profiles in the data space with respect to the profile shapes, yielding a map indicating the phase transition pathways of the starches (Fig. 1(a)). From the manifold map, we found two gelatinization pathways with the same initial state located at the upper right quadrant of the map. The SAXS profiles of the initial state have a bump around the scattering vector Q of ~0.4–0.6 nm^{-1}, which originated from the lamellar structures, indicating closeness to the raw state. According to the literature [4,5], the outer pathway is interpreted as gelatinization while retaining the granular shapes, and the other involves the collapse of starches and the formation of smooth gels.

The gelatinization states of the starches derived from the manifold analysis are mapped on the boiled noodle slices as shown in Fig. 1(b). Both the boiled hand-stretched and machine-made noodles were surrounded with smooth gels of ~200 µm thickness formed by the collapse of the starches. However, as expected, the internal structures are different from each other. The interior of the boiled hand-stretched noodles was fully gelatinized and expected to be elastic. In contrast, the starches in the boiled machine-made noodles located more than ~500 µm inside from the surface retained their lamellar structures, suggesting a relatively hard texture. The research group is planning a simulation study to further investigate the relationship between the texture and the layered structures of the boiled noodles revealed in this study.

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