BL05XU
R&D-ID

1. Introduction

In BL05XU, small-angle X-ray scattering (SAXS) and wide-angle X-ray diffraction (WAXD) measurements are performed at the experimental hutch. In optical hutches, we have installed and tested new optics [1] specifically for the utilization of high-energy X-rays and performed some pilot experiments.

2. Recent activities

2-1. SAXS

In the experimental hutch, it was necessary to remove the flange from the optical bench to switch from the SAXS setup to the WAXD setup. In FY2020, we separated the flange from the optical bench and integrated it with a vacuum tube. This improvement has made it possible to flip up the flange with the vacuum tube and more smoothly and quickly switch from the SAXS to the WAXD setup (see Fig. 1).

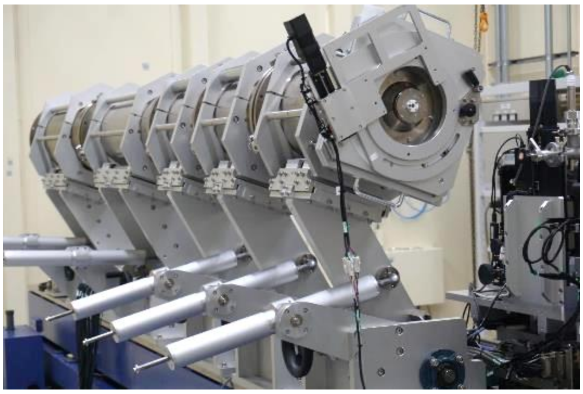

Fig. 1. WAXD setup with all the vacuum tubes and the flange flipped up.

2-2. High-energy test bench

One of the most important characteristics of SPring-8 is the production capability of high-photon-energy X-rays with the 8 GeV storage ring. In FY2020, we installed a new monochromator to provide a high-flux high-energy X-ray beam in optical hutch 1 (OH1) at BL05XU (Fig. 2). The monochromator consists of two multilayer mirrors with 150 Cr/C layers and a d-spacing of 3.33 nm. We obtained a beam with a mean photon energy of 100 keV and an energy band width of 0.93% using the double multilayer monochromator (DMM) for the 19th harmonics of undulator radiation with the 1st harmonics of 5.26 keV (Fig. 3). The spectrum of X-rays from the DMM matched the calculated

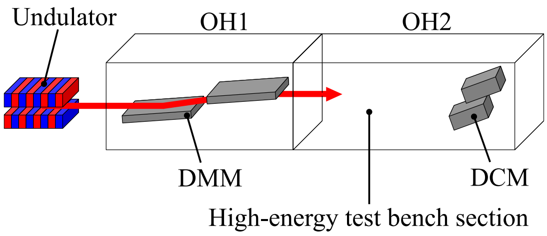

Fig. 2. Schematic of OH1 and OH2 at BL05XU.

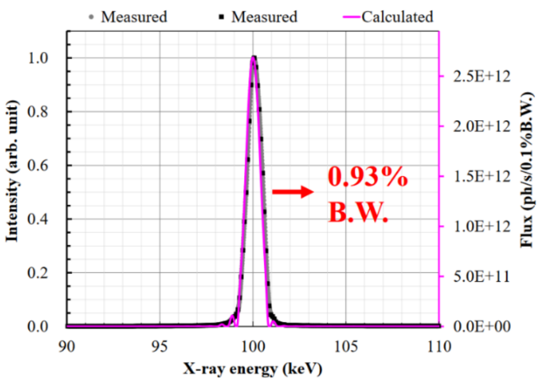

Fig. 3. Spectrum of X-rays from the DMM.

spectrum. The total flux of X-rays from the DMM reached 1.3×10^{13} photons/s.

We prepared an atmospheric section with a length of about 4 m upstream of the double-crystal monochromator (DCM) in optical hatch 2 (OH2) to perform pilot experiments with the high-flux high-energy X-rays from the DMM. As one of these experiments, we performed nondestructive orientation mapping by a scanning three-dimensional X-ray diffraction (3DXRD) method [2] for a solder joint of an electronic component, that is, a printed circuit board (PCB) extracted from a computer peripheral. A mapped area (or field of view (FOV)) was set for one side of the solder joints for the chip resistor on the PCB, as schematically shown in Fig. 4(a). We obtained two-dimensional cross-sectional orientation maps without the need to cut the sample, as shown in Figs. 4(b)–4(d) with a measurement time of about one hour. The microstructure consisting of coarse grains with a size larger than 100 μm was reconstructed in the solder fillet. From the map of kernel averaged misorientation (KAM), it is found that the coarse grains are connected with low-angle grain boundaries (Fig. 4(e)). These features are consistent with microstructures often seen for solder fillets in solder joints for electronic chip components on a PCB.

In the scanning 3DXRD method, diffracted beams from individual grains are detected as diffraction spots on an area detector. The detected diffraction spots are assigned to each grain using multigrain indexing. The number of detected diffraction spots, N, from a grain in the FOV is important in the scanning 3DXRD method, because $N'=N/M$ corresponds to the confidence index of orientation microscopy (OM) with electron

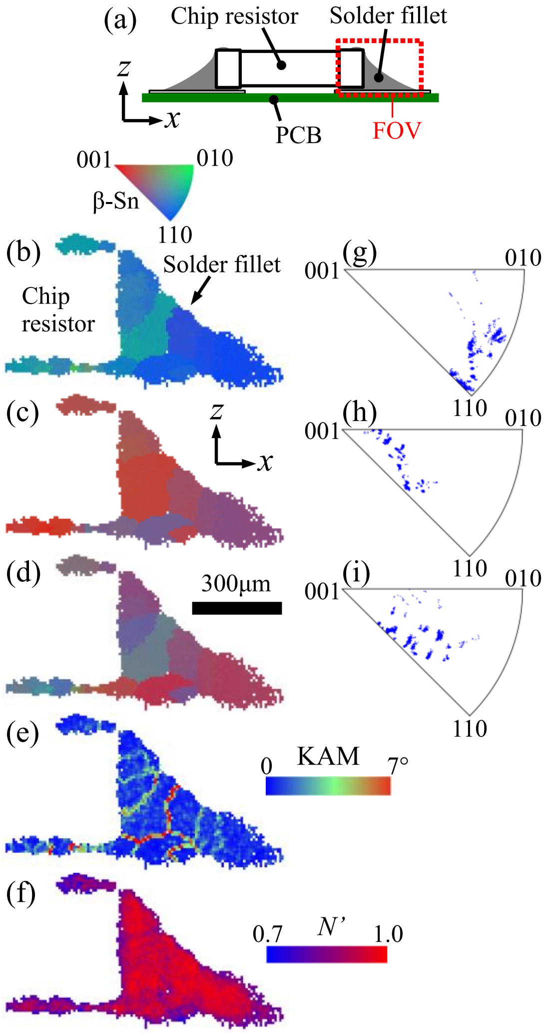

Fig. 4. Nondestructive orientation mapping of a solder joint for an electronic chip component on PCB. (a) Schematic of the sample and the field of view (FOV) of orientation mapping. The maps of orientation represented by the inverse pole figures of the (b) x-, (c) y- and (d) z-axes, (e) KAM, and (f) N'. The inverse pole figures of the (g) x-, (h) y-, and (i) z-axes, where xyz is the sample coordinate system shown in (a).

backscatter diffraction (EBSD), where M is the theoretically expected number of diffraction spots from the grain. Figure 4(f) shows the map of the normalized number of detected diffraction spots, N'. It is found that almost all of the diffraction spots were detected for the coarse grains in the solder fillet, because the evaluated N' of ~1 indicates that all of the expected diffraction spots for each grain were detected. This result suggests that the measurement time can be reduced if we use an area detector with a higher frame rate.

The degradation of solder joints for electronic components on the PCB, which was mainly due to the difference in the linear coefficient of thermal expansion between the solder and the PCB, has long been a serious problem in electronics industries. It has been known from EBSD-OM studies that intergranular and intragranular misorientations and grain refinement increase owing to the thermal-mechanical fatigue of the solder. However, the cross sectioning necessary for EBSD-OM has prevent us from elucidating the mechanisms of the thermal-mechanical fatigue of solder joints, because we cannot trace the fatigue process with such destructive microscopy. In the present study, we achieved nondestructive OM for a solder joint on a PCB using the high-energy test bench, which will allow us to trace the fatigue process and clarify fatigue failure mechanisms. The availability of nondestructive microscopies with high-flux high-energy X-rays will facilitate the resolution of issues in industries.

Taiki Hoshino[*1] and Yujiro Hayashi[*2]

[*1] SR Imaging Instrumentation Team, Physical and Chemical Research Infrastructure Group, Advanced Photon Technology Division, RIKEN SPring-8 Center

[*2] SR Materials Science Instrumentation Team, Physical and Chemical Research Infrastructure Group, Advanced Photon Technology Division, RIKEN SPring-8 Center

References:

[1] Yumoto, H. et al. (2020). *Proc. SPIE* **11492**, 114920I.

[2] Hayashi, Y. et al. (2019). *Science* **366**, 1492–1496.