Time-resolved synchrotron PXRD of additive manufacturing process using a hybrid-photon-counting EIGER2 CdTe detector

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Monitoring of melting and solidification dynamics during additive manufacturing often requires elaborate experimental setups that feature high temporal resolution and a relatively wide 2θ coverage. This can be achieved by combining high energy X-rays at a synchrotron source with a wide detector. In order to capture the dynamics of melting and solidification of Ti alloys, the BL3W1 beamline of the Beijing Synchrotron Radiation Facility (P.R.o.C) used an EIGER2 X CdTe 1M-W hybrid photon counting (HPC) detector [1], with quantum efficiency of about 68% at the employed photon energy of 51.2 keV. In particular, the Lines-ROI feature of the detector was adjusted to read out 2068 × 256 pixels in 8-bit mode, with an effective time resolution of approximately 110 µs (8-bit mode) at a frame rate of 9 kHz. This unambiguously resolved the fast phase transformations (α→β→α) during the additive manufacturing process (see Figure).

The novel Lines-ROI readout implemented in several EIGER2 detectors [2] is a feature that allows increasing the frame rate and adjust the time resolution to the phase transformation dynamics. It achieves frame rates beyond what is possible in full-frame readout (2.25 kHz in 16-bit and 4.5 kHz in 8-bit readout), continuously and deadtime-free up to 98 kHz frame rate by reducing the readout area to a selectable number of central pixel lines. This brings advanced performance and flexibility to time-resolved scattering experiments, especially for the characterization of irreversible processes such as additive manufacturing. In the presented case, frame rate >20 kHz of the EIGER2 CdTe 1M-W detector could not be exploited due to the limited X-ray flux. However, the current proof-of-principle experiment highlights the potential of EIGER2 detectors in the coming 4th generation synchrotron facilities, especially in time-resolved experiments, carried out at high X-ray energies.

An outlook is given on the PILATUS4 CdTe detector currently under development, a high-energy HPC detector with large active area suitable to cover large solid angle for maximizing the integrated diffraction, while offering even higher frame rates than the EIGER2 detector series.

Figure 1. Capturing the fast melting and solidification dynamics of Ti alloys during additive manufacturing. Left: Schematic rendering of the in-situ additive manufacturing setup implemented at BL3W1 of Beijing Synchrotron Radiation Facility. Right: The 9 kHz time-resolved diffraction patterns of Ti alloy during a laser melting of 1 ms with laser on at τ = 0 ms.
