

PL-2.2

Single Crystal Diamond Radiation Detector

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We have reported on the growth of single-crystal diamond and its application to radiation detectors. This time, we report on the measurement of an imager with a photon-charge counting read out integrated circuit (ROIC) connected to a single-crystal diamond. The single crystal diamond was 3.0 x 3.0mm x 0.5mm thick. The bump connection area of our test ROIC is a 3.2mm x 3.2mm area with 40 x 40 pixels pads with 80 μ m pitch. Silver-based bumps were formed on short-crystal diamond using a super inkjet printer and bumped to the ROIC using flip chip bonders. The imaging experiment was conducted by irradiating X-rays at 90 kV and 0.2 mA at 30cm distance. The results showed that the X-ray transmission image with a clear contrast between the area shielded by 2 mm thick lead and the unshielded area was captured, demonstrating a prototype single-crystal diamond-type X-ray imager.

CVD growth single-crystal diamond was used for the semiconductor detector. The crystal was 3 mm x 3 mm x 0.5 mm in size. The plate electrode was formed by sputtering a thin indium film. The other side had no electrode formed before stacking, but was connected to the ROIC by contact with the silver paste formed on the ROIC side during stacking. 40 \times 40 electrodes were arranged at a pitch of 80 μ m for the ROIC, and the maximum crystal size was 3.2 mm \times 3.2 mm. However, due to the small crystal size, the detection area is 3.0 mm x 3.0 mm and 38 x 38 pixels. For the connection to the crystal, silver paste bumps were formed on the electrodes of the ROIC using a SIJ-S050 super inkjet printer manufactured by SIJ-Technology, Inc. The readout architecture of the ROIC was designed by our group [3],[4] and the transistor-level circuitry was designed by Brookman Technology, Inc. (now TOPPAN Inc.) and fabricated in a TSMC (Taiwan Semiconductor Manufacturing Company Limited) 0.13- μ m standard CMOS process. Figure 1 shows the assembled diamond imager and its stacked structure.

The ROIC was operated in electron collection mode. A bias voltage of -500 V was applied to the plate electrodes. the frame rate of the ROIC was 200 Hz. 10 seconds (2,000 frames) were taken and the counts were summed to obtain one image. an x-ray tube with a tube voltage of 100 kV was used as the x-ray source. the distance from the tube to the detector was 20 cm. A 3 mm x 3 mm lead plate with a thickness of 1 mm was used as the X-ray shield. The shielding body was shaped like a Japanese character. The shielding was placed between the X-ray tube and the detector, 5 mm away from the detector.

It was confirmed that X-rays were detected as expected when X-rays were irradiated with and without the shielding. Next, a shielding was placed in front of the detector and the shielding was imaged. As shown in Figure 2, the shape of the shielding was obtained as an image.

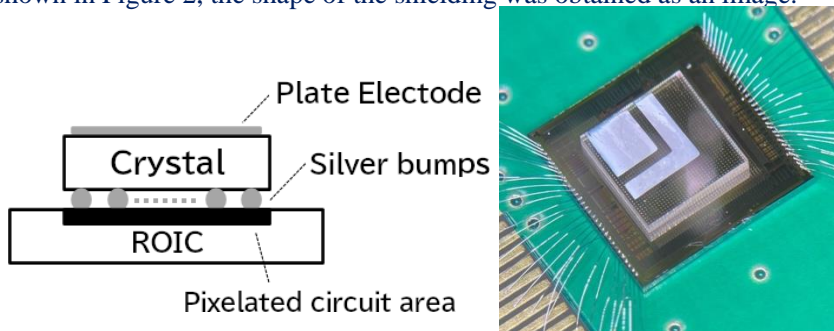


Fig. 1. Schematic diagram of diamond detector(L) and picture (R).



Fig. 2. X-ray imaging result with a lead-object of イ (Japanese character)

References

1. K.Takagi, et al., "Readout Architecture Based on a Novel Photon- Counting and Energy Integrating processing for X-ray imaging." IEEE Transactions on Radiation and Plasma Medical Sciences (2020).
2. K. Takagi, et al., "Study of an X-ray/Gamma Ray Photon Counting Circuit Based on Charge Injection." Sensors and Materials 30.7 (2018): 1611- 1616.