7th CLHCP 2021/11/25

Performance of 15x15 full-size IHEP-IME LGAD sensor

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Introduction

High Granularity Timing Detector:

The High Luminosity Large Hadrons Collider (HL-LHC) will be started in 2027 and the instantaneous luminosity of the HL-LHC will by far increase. As the luminosity increase, the number of collisions in each bunch crossing (pile-up) increases. To separate collisions in limited space, the High Granularity Timing Detector (HGTD) project was proposed aiming at 30~50 ps time resolution per track.

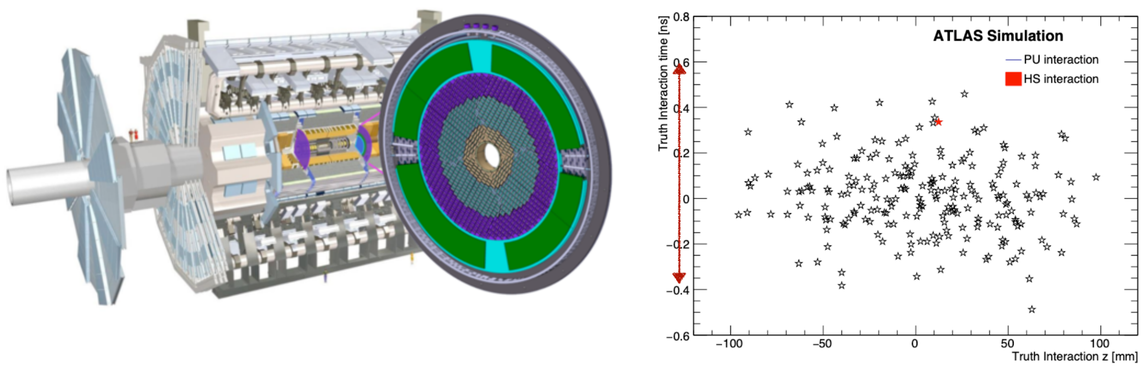

Figure 1. HGTD detection

Low Gain Avalanche Detector:

Low gain avalanche detector (LGAD) will be used as the sensing technology to provide fast signals in response to the charged particles for a time resolution per hit of about 35 ps at the start and 70 ps at the end of HGTD lifetime . Compared with the PiN junction, the LGAD sensors have a highly doped p+ layer, where the multiplication of charged particles occurs. It will be operated the high voltage at -30°C to reach good resolution. Currently, many vendors have produced the LGAD sensors, such as HPK, FBK, CNM. The sensors are segmented into 1.3x1.3 mm^2 pads, with a total of 15x15 pads per sensor. The sensor will be bump bonded to the module then mounted on the detector wheel.

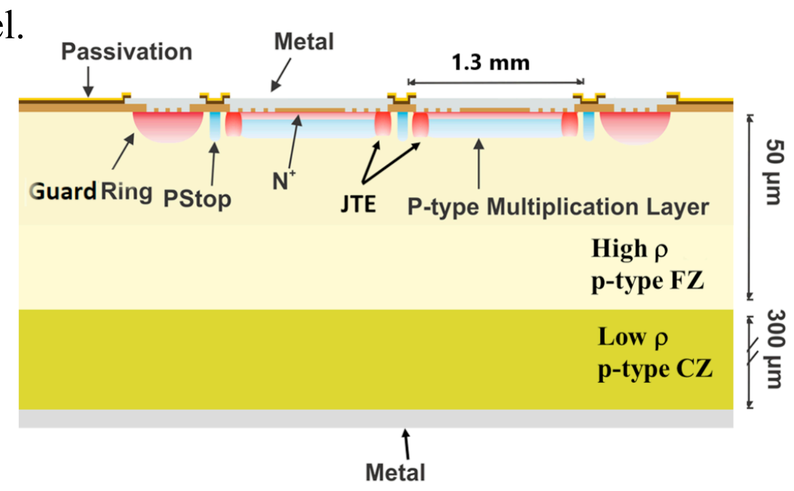

Figure 2. Cross section of a 2x2 LGAD sensor

IHEP-IME LGAD

IHEP-IME:

IHEP has been working on the design of LGAD sensor since 2018. IHEP-IME LGAD sensors are designed by IHEP, fabricated by the Institute of Microelectronics of Chinese Academic of Science (IME) for the HGTD project.

So far two versions of IHEP-IME LGAD have been produced. IHEP-IMEv1 submitted in May 2020, finished in September 2020, with 4 wafers. Eight wafers of IHEP-IMEv2 LGAD sensors finished in June 2021. In addition, the third version production is ongoing now. Figure 3 shows the pictures of two versions IHEP-IME 8 inch wafers. In the second version, there were in total 26 full size sensor per wafer.

Figure 4 shows the design layout of the two versions. Single pad, 2x2, 5x5 and also 15x15 sensors (only in v2) with different structure parameters were produced. Additionally, each wafer was separated into four quadrants. In each quadrant, boron concentration, N implantation energy or carbon dose are varied.

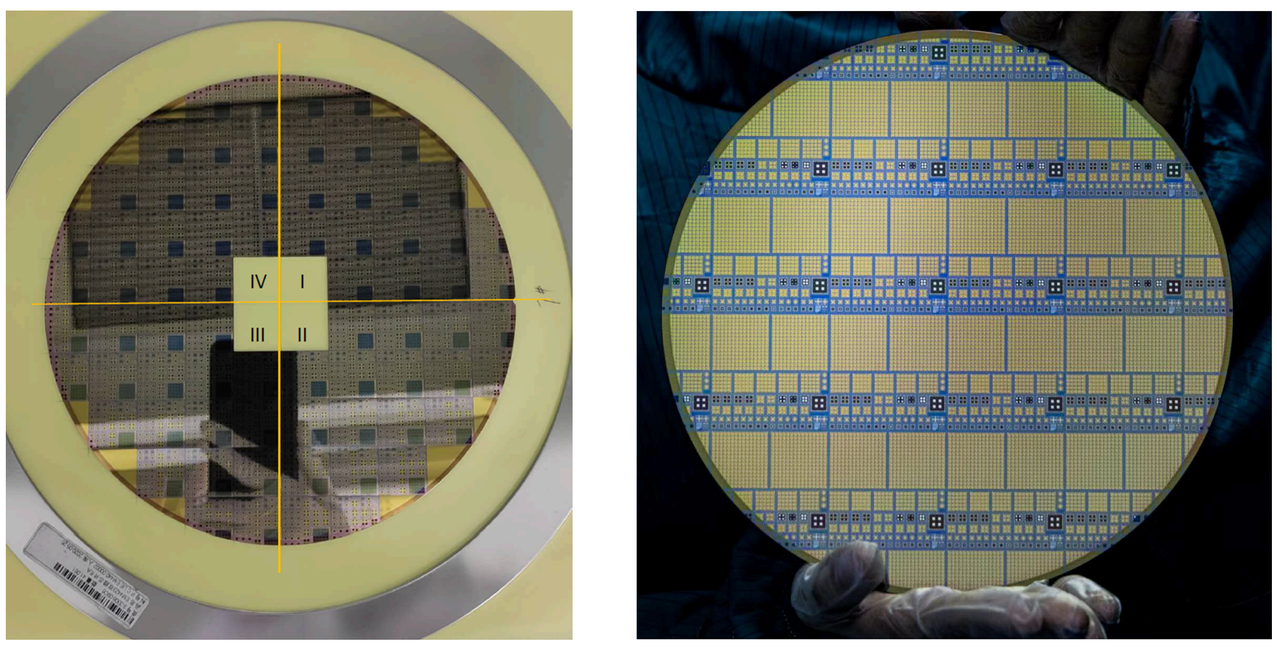

Figure 3. Wafers of IHEP-IMEv1(left) and IHEP-IMEv2 (right)

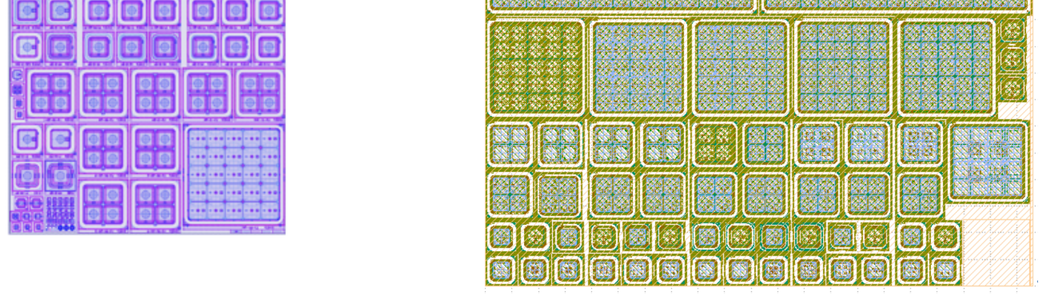

Figure 4. Layout of IHEP-IMEv1(left) and IHEP-IMEv2 (right)

Large array sensor test

Large array sensor can be tested with a probe card system (Figure 5), where the probe card is fixed on the probe station by a holder. The probe card is connected to a switcher that can select one pad so that the current of the pad can be measured while all the other pad and the guard ring are grounded. Figure 6 shows an example the IHEP-IMEv1 5x5 leakage current test results with the probe card.

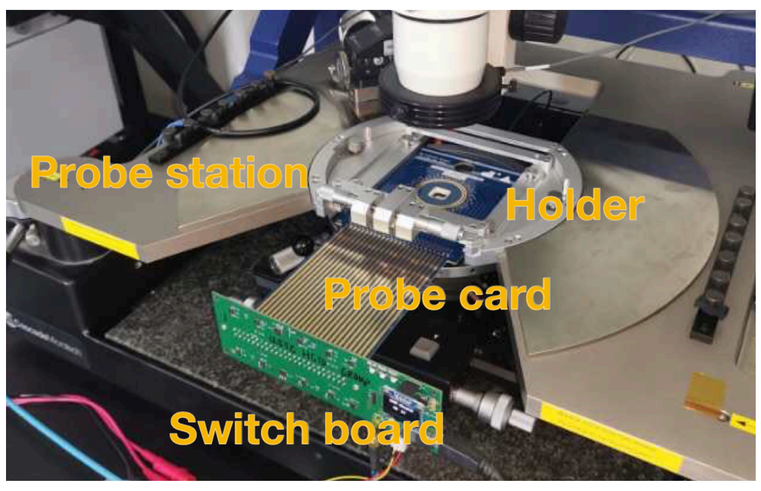

Figure 5. Probe card test set up

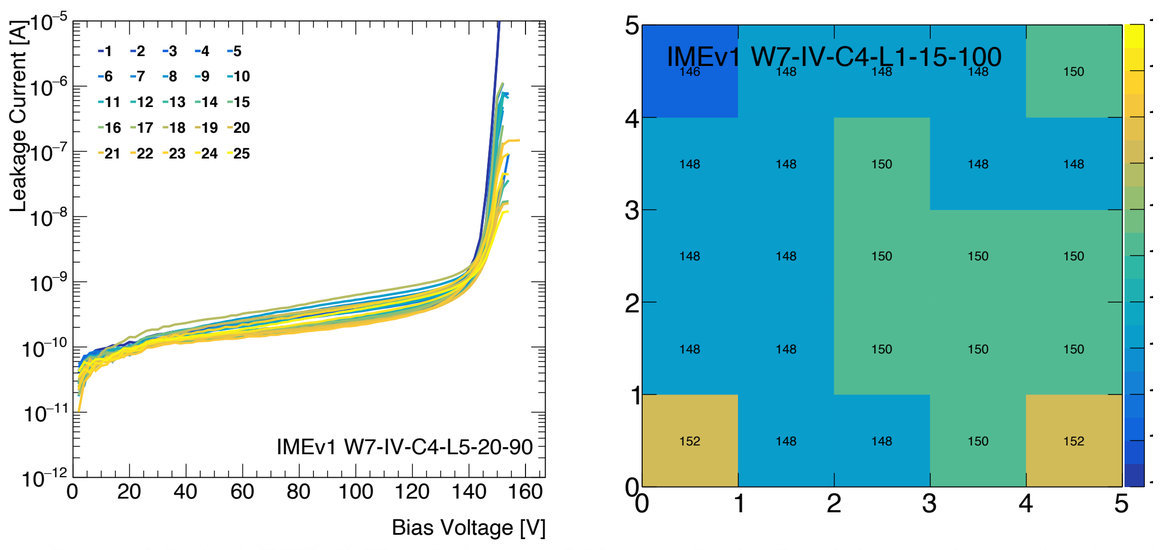

Figure 6. Left: A IHEP-IMEv1 5x5 sensor I-V curve. Right: Breakdown voltage of each pad of the sensor

Large array sensor can also be tested with an automatic probe station. The automatic probe station can move the probe/chuck automatically. Many IHEP-IMEv2 15x15 sensors from a full wafer were tested with an automatic probe station with other pads and GR floating. Figure 7 is a typical 15x15 results.

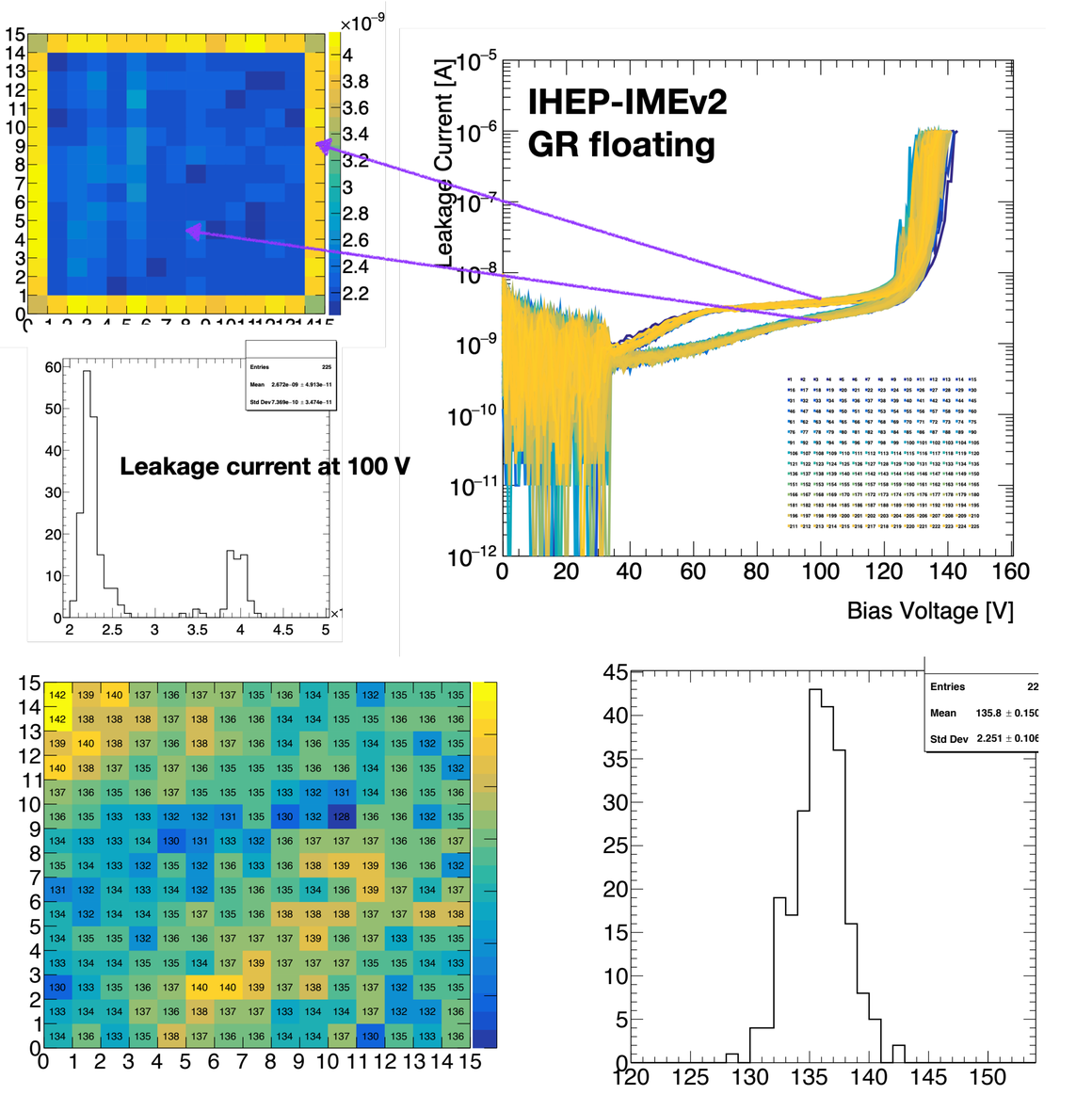

Figure 7. A typical IHEP-IMEv2 15x15 sensor I-V curve and its breakdown voltage distribution

Figure 8 is the breakdown voltage distribution of all 15x15 sensor pads from a full wafer. The pad yield of IHEP-IMEv2 large array sensors is larger than 99.3%.

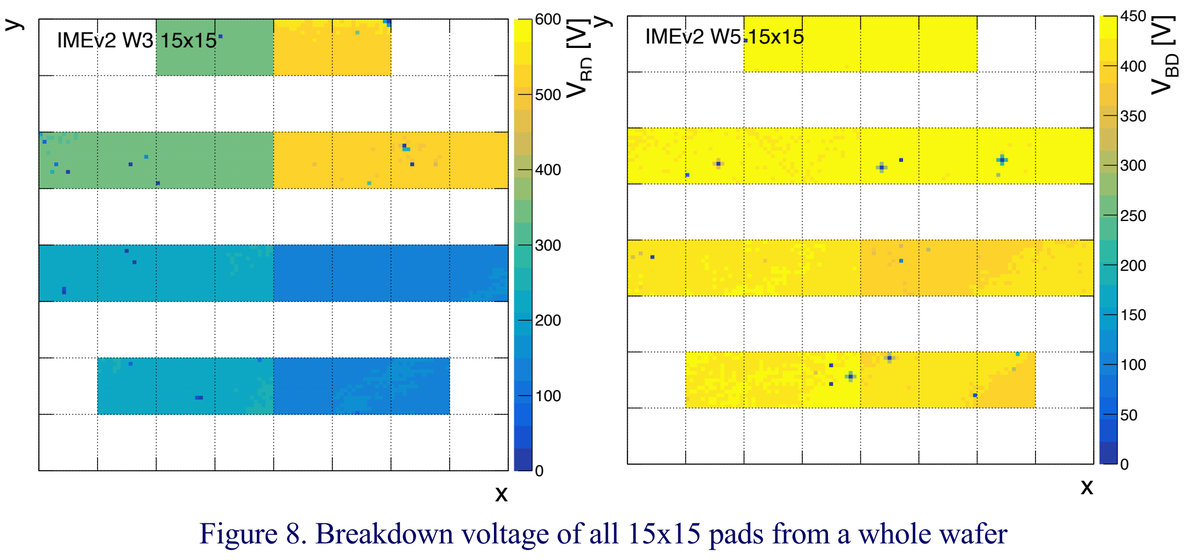

Figure 8. Breakdown voltage of all 15x15 pads from a whole wafer

Summary

IHEP-IME LGAD large array sensors showed good uniformity before irradiation and can satisfy the HGTD sensor requirements.

The yield is expected to be improved in further iterations.

IHEP-IME sensor show very promising performance both before and after irradiation please check the poster of Kewei and upcoming talk of Zhaomei.