

ITk Pixel Module Production

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Abstract

My primary contribution here was to assemble the silicon pixel tracker modules to be used in the ATLAS Phase 2 experiment. This involves reception checks, which include visual inspections and metrology measurements. This is followed by the assembly stage by applying epoxy hardener. After all of the procedure is finished, the quality check will be held, and re-tuned to work properly.

Some new tools arrived from KEK, so the reception test of them were also done. We made some assembly using dummy Si or glass tiles as a test.

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1 Introduction

1.1 About ATLAS ITk

The ATLAS detector is a multi-purpose detector set up at LHC. When the collision event occurs, the particles go through many types of detectors installed in ATLAS. The inner tracker (ITk) is one of those detectors, which is placed closest to the collision point. It is a set of Si pixel and stripe detector, which is used to track the particles generated in the collision. By tracing the particle, we will be able to know the momentum of it, and it will lead to the identification of the particle.

LHC is planned to have a long shutdown from 2026, to get an upgrade to High-Luminosity (HL-LHC). During this long shut-down, ATLAS is also upgraded. I worked on the upgrade of the Si pixel detector, which is used in the upgraded ATLAS detector. In the figure 1, the red ones are the Si pixels. My work here was to do the assembly of the modules, to put bare modules (BM) and flexible circuit (flex) together by using glue.

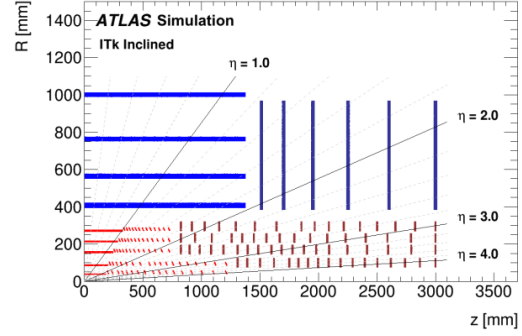


Figure 1: layout of ITk cited from [1]

1.2 Bare Modules

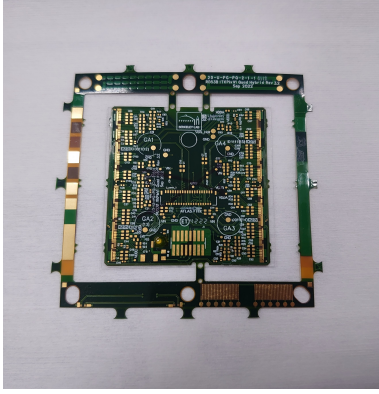


Figure 2: Top side of flex

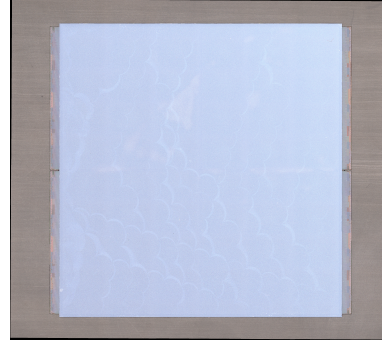


Figure 3: Top side of BM

The bare module is made by 2 parts, the Si sensor and the front-ends (FE). Si sensor is the main part of this detector. This sensor will be applied with high voltage during the run. When a particle fly through the sensor, some electron-hole pairs are generated. Those electrons and holes then move to anodes or cathodes, and it creates current. We take the current as a signal of particle passing.

The current generated by the event will go to next area, the FEs. FE is an ASIC, which is designed to read out the signal. Si sensor and FEs are connected with metal bumps, so the signal current can go through.

1.3 Flexible Circuit

After the signal is read out in FE, it goes to the flex passing the wire bonded point. The flex plays a role of transferring the signal and power. It sends a signal to and from BM to outer DAQ, while it distribute the power given from the external power source to BM.

2 Reception Tests

The reception test is held when new BMs arrive at CERN. We check in this test if the new BMs are within the specifications or not.

2.1 Visual Inspection

In this test, the BMs are visually checked by using the Hirox microscope. Large defects, such as scratches and broken BMs are found in this inspection.



Figure 4: Scratches found in inspection

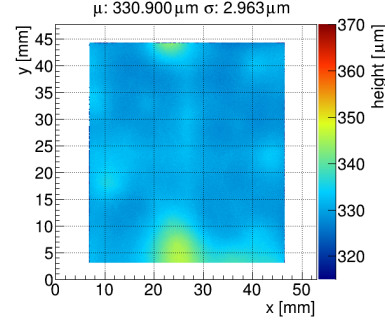


Figure 5: Height of bare module

2.2 Metrology

After the visual inspection, the metrology scan are done. We use Keyence VR-5000 to do the scan. By taking the metrology, we will be able to know tiny difference in height. We will be able to know if there were some dusts between Si tile and FEs.

Since this scanner scans the module optically using the triangular method, we can't take precise metrology of surface which is highly reflective.

2.3 IV Measurement

Si sensor is the sensor which detect particles by current. This current is made by the electron-hole pair generated in depletion layer. The size of this layer changes when the applied voltage change. There will be more pair created if there's larger depletion area, leading to the increase of current intensity. So it is important for us to know how strong the leakage current is when the voltage is applied.

In this test, we first put the BM on the stage, which enables us to move the BM precisely. Then we put 2 needles to designated place, one needle to pad 11 in FE, and the other onto the Si sensor. So we run the measurement 4 times for pad 11 on each FEs. During the scan, the voltage will be applied between two needles, and measures the current. The voltage will change gradually, and relations between the voltage and the current will be earned.

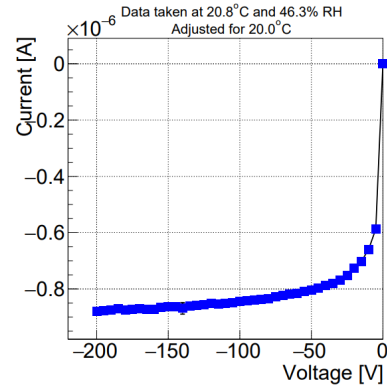


Figure 6: Leakage current measured by IV measurement

2.4 ID Check

After all reception tests are done, the IDs written on the Si sensor and FEs are checked visually. By the comparison with ATLAS ITk Database, it is checked if the components are assembled in the correct order.

For the Si sensors, they are written in binary numbers. The numbers correspond to the ID, and the wafer number. Meanwhile, FEs are identified by 4 quaternary numbers. The first two numbers indicate the row number, and the last two shows the column number of the Si wafer.

During the checks performed, some mismatches were identified, and this helped in improving in the bookkeeping procedures.



Figure 7: ID on the Si sensor

3 Assembly

After the reception tests, BMs and flexes will be put together with the glue to become the completed module. The glue used is Araldite, which starts to harden when two resins are mixed. Since it doesn't contain water or

other organic solvents, the height between the tile and FEs won't change after the cure.

3.1 Before Assembly Checklist

We have some procedure to do before the assembly. Taking the metrology of components are one of them. We want the thickness of flex and BM before the assembly, so that we will be able to know the height of the glue after curing.

Since we also want to know the weight of the glue, we weigh the components before the assembly. There is a hole on the flex for applying high voltage on the Si sensor, so we put some protection using kapton tape during the assembly. The weighing must be done after the tape is put on the flex.

3.2 Assembly

After all of the checklist has been completed, the 2 components will be placed on the jig with the vacuum applied. Then the 2 jigs will be mated without glue to adjust the height. In this mating, the glue gap is set to $35\text{ }\mu\text{m}$. This will be the target glue height after the cure.

After the jig height setting is done, we take apart the jig to put the glue on the flex. We have to mix the glue, since it doesn't start curing unless the two glues are mixed together. When the glue is mixed, we put the stencil on the jig, and the glue is also put on the stencil. We use spatula to apply the glue on the flex.

3.3 After Assembly

When the glue is cured for more than 8 hours, the module will be weighed and the metrology is taken. Then, the modules are sent to wire-bonding. After it is returned from the wire-bonding, the modules are put in the module carrier, and delivered to fast QC.

4 Fast Quality Check

The module is now built, and the last procedure is to run a fast QC on it. The QC is made by roughly 3 scans, digital, analog, and tuning. Even though the modules are made in very precise procedures, there are still some differences between each samples. We have to make a configuration for each module, by checking if each pixels works.

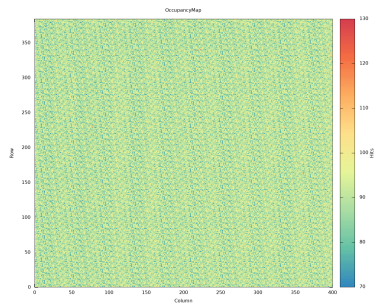


Figure 8: Digital Scan using default config

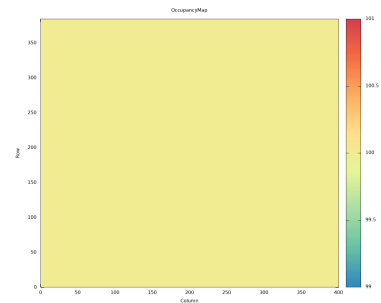


Figure 9: Digital Scan using changed config

Over the course of my summer studentship, I have done fast QC for 10 digital modules, which has glass tile instead of the sensor, these were prepared to be distributed to other groups to allow multiple studies to be carried out.

5 Test of New Tools

In addition, we had done some tests of new assembly tools arrived at CERN. This is a different type of module assembly used at KEK. The test of this module was done by doing the assembly.

In this tool, the spacing of glue is done by spacers. Since the tools we were using had a micrometer, it is much more an important issue for us to have precise measurements for the thickness of both flex and BM while doing an assembly with KEK tools. Therefore, even though we take back-side metrology of the flex, we also take some measurements by our hand using manual micrometer. We use 4 pick-up points on the flex as the point of manual measurements, which is the blank area remained for transporting module by vacuum. After the measurements, the height setting will be calculated.

The procedure after setting the glue height is the same as usual tools.

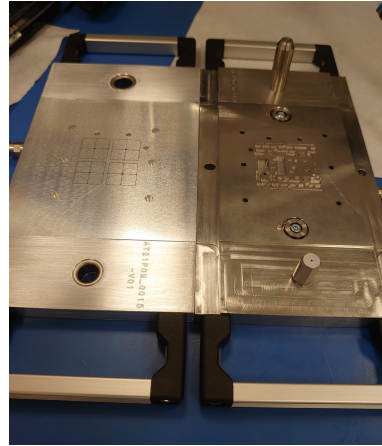


Figure 10: Jigs from KEK

References

- [1] Technical Design Report for the ATLAS Inner Tracker Pixel Detector. Technical report, CERN, Geneva, 2017.