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Construction of the ATLAS semi-conductor tracker (SCT) barrel modules in Japan

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Abstract

We have developed a semi-automated assembly system and constructed 124 silicon microstrip modules so far for the ATLAS SCT barrel. This article describes the assembly procedure, evaluations of precisions and the module survey results. A precision of ~2 μm is achievable with this assembly system.

Keywords: SCT; Precision module assembly; Silicon microstrip detector

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1. Introduction

ATLAS semi-conductor tracker (SCT) [1,2] is composed of four barrel layers and nine forward discs at each end, covering the pseudorapidity range from −2.5 to 2.5. We, ATLAS Silicon Japan Group, assemble the third layer of the barrel SCT. The third barrel is made of about 600 modules, each of which consists of four $64 \times 64\,\mathrm{mm}^2$ silicon microstrip sensors glued back to back on a TPG baseboard with a stereo-angle of 40 mrad (Fig. 1). A flexible Kapton-based hybrid, which is backed with a carbon fiber, bridges over the silicon sensors. For high-precision tracking, strip coordinates have to be known with an accuracy of 10 μm in the direction perpendicular to strips (Y direction), and 25 μm in the direction parallel to strips (X direction). Because finite accuracy of the stereo-angle also deteriorates the resolution, we assemble the modules with the following precisions:

- 5 μm in deviation of centroids in Y of outer and inner sensor pairs (midyf),
- 10 μm in deviation of centroids in X of outer and inner sensor pairs (midxf),
- 0.13 mrad in stereo-angle (stereo/2).

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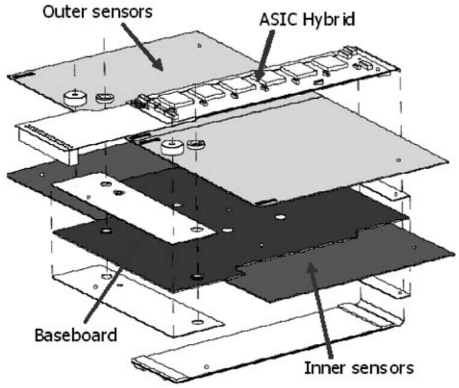

Fig. 1. SCT barrel module consists of four silicon microstrip sensors glued back to back with a stereo-angle of 40 mrad.

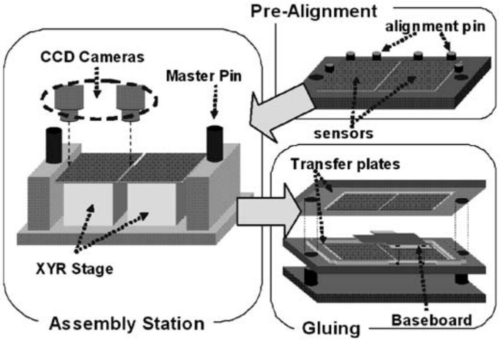

Fig. 2. Illustration of the sensors alignment steps and jigs. The details of this system are given in Ref. [4].

The parameter names in parentheses are parts of 24 which we measure in our module metrology survey [3].

We have developed an assembly system and constructed 124 modules so far. We describe the details of the system and module survey results.

2. Assembly process and jigs

The assembly steps and required times are:

(A) align outer sensor pair (~ 1 h);
(B) align inner sensor pair (~ 1 h);
(C) apply adhesive (BN filled EP-2011) to the baseboard and align the sensor pairs (>4 h);
(D) metrology survey (~ 1 h);
(E) glue the ASIC hybrid (>4 h);
(F) wire-bond between sensor pair and between sensors and ASIC hybrid (~ 4 h);
(G) metrology survey (~ 1 h).

The glue curing after steps (C) and (E) requires at least 4 h. We have multiple three sets of jigs needed for these steps so that we produce two modules per day.

Fig. 2 illustrates the steps from (A) to (C). Details of Step (A) are:

(A1) Two sensors are put on the pre-alignment jig, and aligned to a few 10 μm by pushing sensors against alignment pins. The sensors are vacuum chucked to a transfer plate.
(A2) Transfer the sensors on the assembly station.
(A3) Align sensors precisely using CCD cameras and XYR stages. The CCD cameras can pattern-recognize the sensor fiducial marks, the positions being feedback to piezos to fine adjust the XYR stages.
(A4) Place a transfer plate on the sensors. It is essential to turn off the vacuum of the assembly station prior to turning on the vacuum chuck of the transfer plate.
(A5) Measure the sensor position again, through holes made in the transfer plate for this purpose. If the sensors slip at (A4), repeat from (A3) again.

Step (B) is identical to the above.

The alignment between the two sensor pairs relies on the two master pins of the assembly station, the master pins having an angle of 20 mrad with respect to the strip direction. The two sensor pairs and baseboard are glued in Step (C) using another pair of pins which enables movement. The alignment parameters in Steps (A) and (B) are adjusted after the results of module survey described in Section 4.

3. Precision of assembly system

Achievable precision depends on CCD camera resolution, stage stability and master pins accuracy. The CCD pattern-recognition determines the sensor fiducial marks within an accuracy of ±1 pixel, which is ±0.074 μm. The base of the assembly station is moved by servo-motors to less than 1 μm linearity over the full module length. The individual XYR stage is controlled by piezos. The voltages to the piezos are adjusted until the measured and set positions agree to less than 0.7 μm. The hysteresis characteristic of piezos can be neglected in this computer-controlled feedback procedure. The jigs have temperature-dependent deformation. We measured this effect to be less than ±0.5 μm/°: The assembly room is controlled to 25±1°. The master pin and hole are mated via a linear bearing system. The measured repeatability of the linear bearing system is about ±2 μm.

Finally, the overall assembly precision of about ±3 μm should be achievable in midyf, that is after all the most critical parameter to achieve.

4. Metrology survey method and results

Modules metrology survey is performed with Mitutoyo Quick Vision Pro250. This machine can survey modules three-dimensionally with contrast edge detection, pattern recognition and focusing. The machine has a system of one CCD camera and one stage. We improved the stage linearity and corrected for a shift of optical axis of the CCD camera when its magnification changed. Finally, the survey precision is ∼1 μm in *X* and *Y*, and <10 μm in *Z*.

The module precision is expressed in terms of 13 parameters in *XY* and 11 parameters in *Z*. We discuss two (“midfy” and “stereo/2”) *XY* parameters and one (“optMaxZ”) *Z* obtained from 124 modules. The parameter “optMaxZ” is the maximum deviation in *Z* from a “standard” module profile. Note that “midxf” is less critical and easier to achieve compared to “midyf”.

Fig. 3 shows the histograms of “optMaxZ” and “stereo/2”. The “standard” shape for “optMaxZ” is an average *Z*-profile determined from the first five modules. The mean value is shifted by ∼0.02 mm because of this limited number of modules. Since the distribution is narrow, “optMaxZ” should be well within the specification if we use the “standard” shape re-calculated when the production is completed.

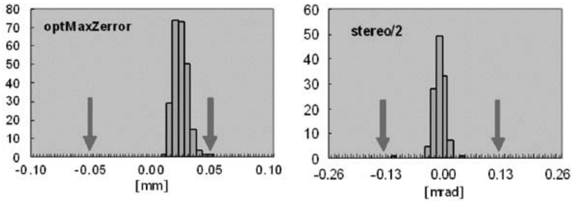

Fig. 3. Histograms of “optMaxZ” and “stereo/2” for 124 modules. Arrows are tolerance limits.

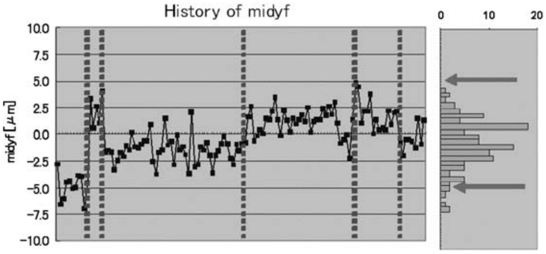

Fig. 4. History and histogram of “midyf” for 124 modules. Arrows are tolerance limits.

If “stereo/2” (“midyf” or “midxf”) is not well controlled, some coordinate calibration would be required for individual module. The “stereo/2” distribution is well inside the specification.

Fig. 4 shows the history and histogram of “midyf”. In the history, broken lines show when the assembly parameter which tunes “midyf” is adjusted. We find that “midyf” is stable to ∼2 μm in each period, and after repeating the survey and parameter adjustment, “midyf” has become accurate to 2 μm, about zero for recent modules.

5. Summary

We, ATLAS Silicon Japan Group, are assembling SCT modules for the third barrel layer. Our module assembly system has an excellent accuracy that fulfills the SCT requirements. From the results of first 124 modules, the assembly system has proved that it can control “midyf”, most critical parameter, to ∼2 μm.

We will produce 700 modules by autumn 2003.

References

[1] ATLAS Inner Detector Technical Design Report, CERN/LHCC/97-16 and CERN/LHCC/97-17, 1997.

[2] Y. Unno, Nucl. Instr. and Meth. A 453 (2000) 109.

[3] ATLAS SCT Barrel Module FDR, SCT-BM-FDR, 2001.

[4] T. Kohriki, et al., Module assembly jigs and assembly steps of the barrel modules, http://jsdhp1.kek.jp/~unno/si_mod/Jigs/Massembly01May.pdf.