Evaluation of Contact Resistance of Silver-Loaded Epoxy with Aluminized Backplane of Silicon Microstrip Sensors

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***Abstract*-Some modules of the ATLAS silicon strip detector (SCT) exhibited a significantly higher effective bias resistance than we had expected. About 20 % of the barrel modules, for instance, showed such a resistance of 40 kΩ or higher.**

We have tried to identify causes of this high resistance as well as to find a remedy if necessary. As for the SCT modules, the bias connection is made with silver-loaded epoxy to the aluminized backplane of the silicon sensors.

It was identified that the contact of the silver-loaded epoxy to the surface of the aluminized backplane sometimes provoked the high resistance. Fortunately, however, it automatically cures in practice by applying a usual bias voltage, to become harmlessly small of a few ten ohms.

I. Introduction

Many modules of silicon strip detectors (SCT), 2112 for the barrel and 1976 for the endcaps, were fabricated and assembled as a central tracker of ATLAS for a LHC experiment [1].

While testing the modules after assembled in cylinders (barrel) and disks (endcaps), some modules exhibited a significantly higher effective bias resistance than we had expected [2]. They were spotted as checking continuities of cablings and connections by applying a small forward voltage to the modules. In fact about 20 % of the barrel modules, for instance, showed such a resistance of 40 kΩ or higher, as high as a few hundred kΩ, in comparison with an expectation of about 11 kΩ which was an overall resistance of the biasing circuit (see Fig. 3).

Concerns were raised particularly about a voltage drop to an applied bias voltage after an exposure of a high radiation dose which would induce a high leakage current of the modules.

II. SCT Barrel Module and Bias Connection

The SCT barrel module [3] is made of four sensors of 64 mm x 64 mm each, a pair of two are glued on a TPG baseboard on top and bottom. A Cu/Polyimide flex-circuit-based hybrid is wrapped around the sensor-baseboard sandwich.

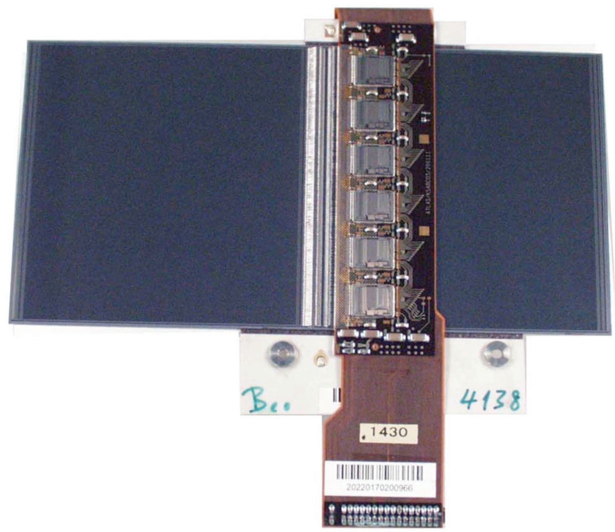

Fig. 1. ATLAS SCT barrel module

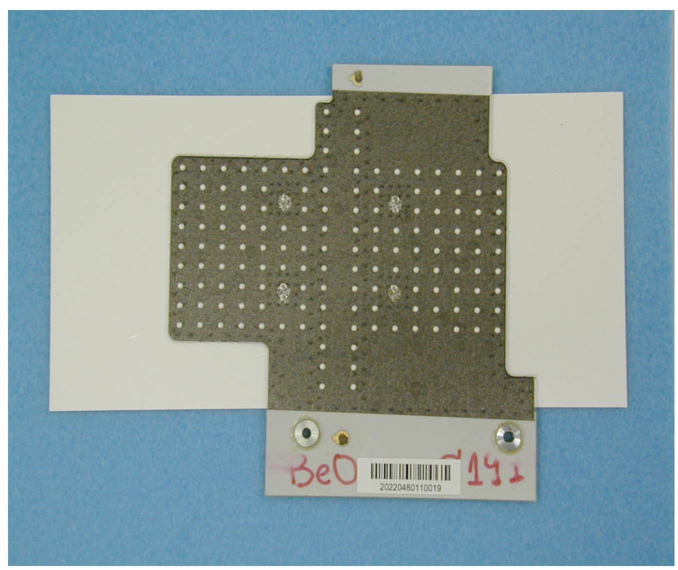

Fig. 2. Glue pattern on the baseboard. Four large dots are silver loaded epoxy to make electrical contact with the sensor backplanes

The sensors are a conventional p-strip in n-bulk with a backside metallization of aluminum. The bias connections to

Manuscript received November 4, 2007.

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the sensor backside are made through the TPG baseboard by means of a silver loaded epoxy adhesive. Fig. 1 shows the completed barrel SCT module, while Fig. 2 shows a glue process of the sensors and baseboard. White dots on the black baseboard are adhesives. The large four dots are silver-loaded epoxy to make electrical contacts with a pair of the sensors to be attached on top of the baseboard. Incidentally the many

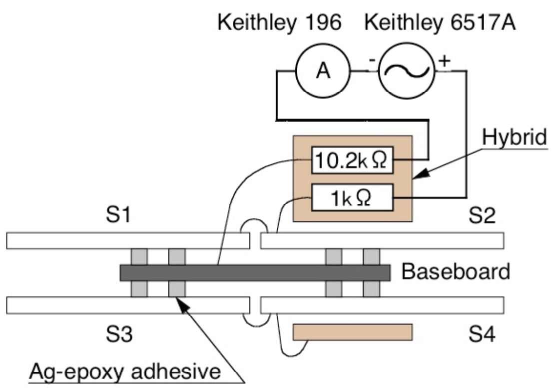

Fig. 3. Setup for continuity measurements
Biasing scheme to sensors in SCT barrel module is illustrated.

small dots are a boron nitride doped epoxy adhesive.

As illustrated in Fig. 3 the bias circuit in the hybrid has a resistance of 11.2 kΩ, which should be registered in the continuity measurements of the modules, if normal.

III. Forward Biasing and Diode Characteristic

A part of complications arose in the resistance measurement due to a diode characteristic of the sensors. In order to measure the bias resistance some small forward voltage was applied to the bias circuit through the hybrid.

Since we concerned an over-current to the sensor, the measurement was tried with a small constant current of 10μA at first, which turned out to be too low a voltage to fully turn on the diode. As a result most of the module exhibited significantly high resistance values.

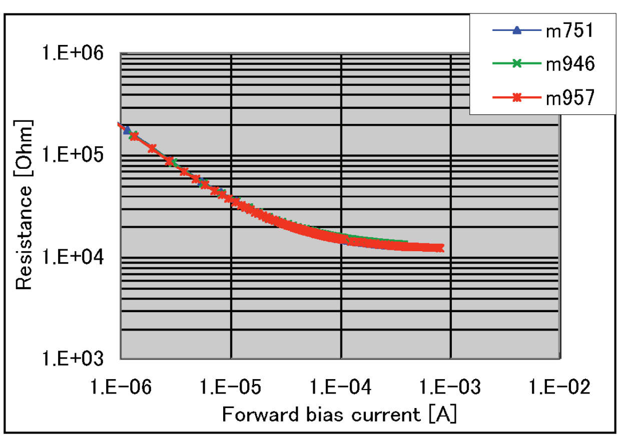

Fig. 4. Module resistance as a function of forward bias current for the normal modules (three modules: m751, m946, and m957)

In fact as we relaxed the current limit up to 1mA, majority of the modules asymptotically reduced the resistance toward the expected 11 kΩ. Typical examples of them are shown in Fig. 4.

In contrast, some modules showed such a peculiar behavior in I-V measurements that the current, initially small, jumped up suddenly to the normal as the applied voltage was raised carefully in an isolated quiet condition. Then once it reached to the normal current it remains the normal thereafter in the repeated measurement as far as it was performed right after the first one. Typical examples are shown in Fig. 5 and 6.

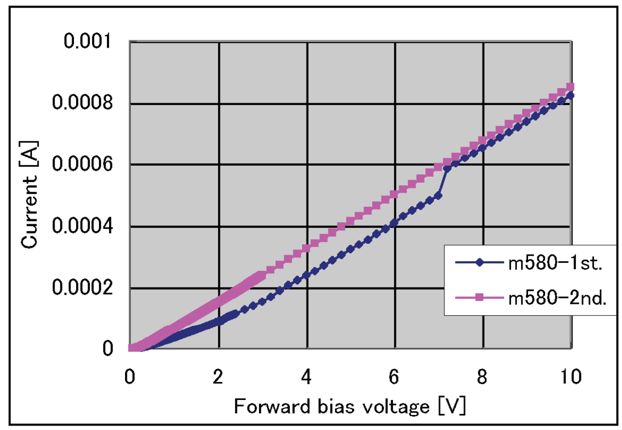

Fig. 5. I-V relation of the high resistance module; There is a current jump in the first measurement at 7 volts. It goes back to normal, however, in the second measurement.

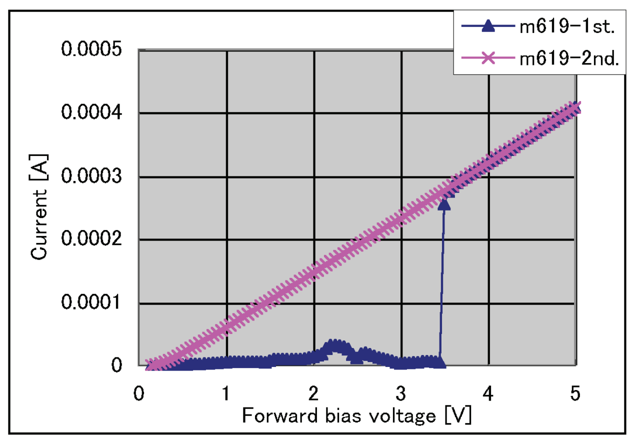

Fig. 6. I-V relation of a high resistance module; initially very high resistance becomes normal at 3.5 volts with an abruptly current jump. However, it behaves normally from the beginning in the second measurement.

IV. Connections with Conductive Adhesive

As we focused on the most suspicious contacts, namely the ones between the aluminized sensor back-plane and the TPG with silver loaded epoxy, the hybrid and the other connections were all bypassed. Then the four sensors of the module were individually measured. Relevant connections in the setup are illustrated in Fig. 7.

The results showed prominent jumping behaviors in I-V curves in the first measurements. Fig. 8 shows an example in which four sensors of the module (m102) behaved rather differently. One sensor (S1) was normal but the other three (S2, S3, and S4) showed a transition from a high resistance to a normal resistance around three and four volts. However, in the second measurements, when performed right after the first ones, the all sensors became normal and behaved smoothly as shown in Fig. 9.

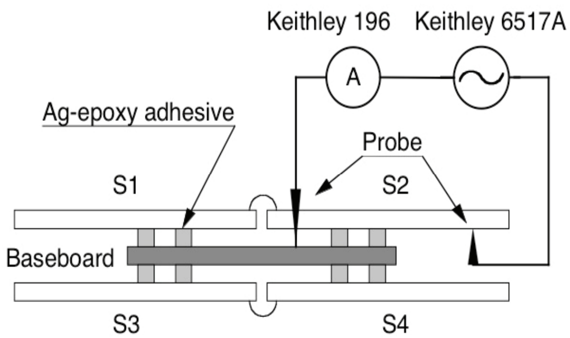

Fig. 7 Setup for the resistance measurement between the sensor backplane and the baseboard

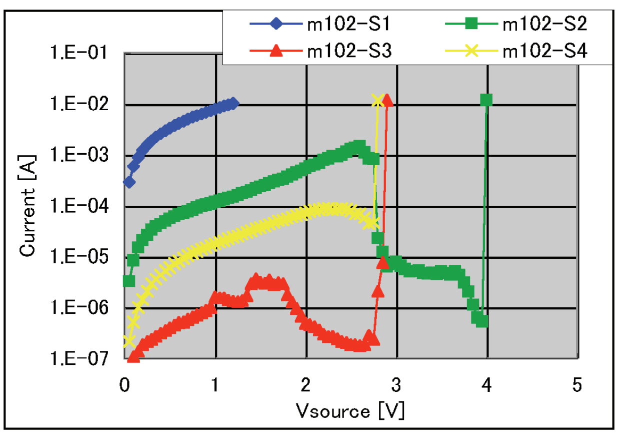

Fig. 8 I-V behavior of the individual sensors in the initial measurements

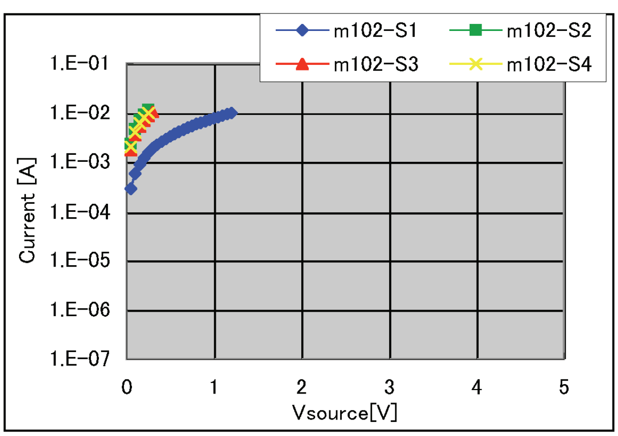

Fig. 9. I-V behavior of the individual sensors in the 2nd measurements

V. STUDIES WITH CONTROLLED SAMPLES

In order to investigate further the contact of the aluminized sensor surface with the silver loaded epoxy, dedicated samples shown in Fig. 10 were prepared. The square plates are pieces of aluminized silicon cut from the actual sensor. A pair of them are glued with a droplet of the silver loaded epoxy placed at the center together with the boron nitride epoxy (four white dots) and 200μm thick spacers placed at the four corners (small squares). Copper leads are glued and wire bonded on the aluminum surface.

Those samples were exposed to various environmental conditions such as high temperature (50 C°) and either nitrogen or air atmosphere during the tests.

As shown in Fig. 11, the measurements show a conspicuous on-off behavior that an initially very high resistive contact becomes conductive of a few ten ohms when an applied voltage reaches at several volts. The highest and the lowest

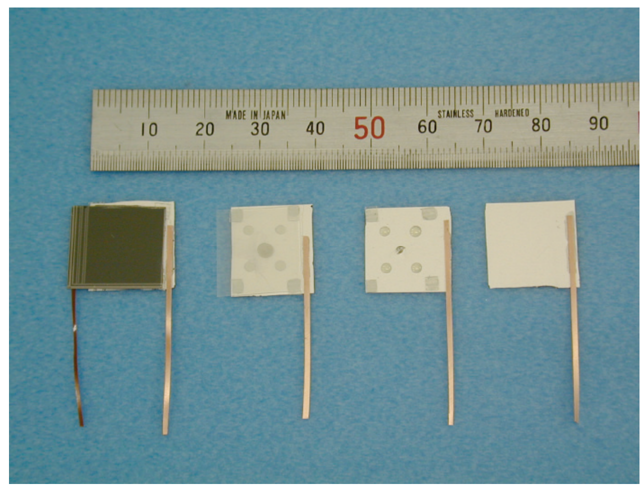

Fig. 10. Controlled samples in fabrication
Far left: completed; Middle two: showing a glue pattern, as applied (right), cured with a thin glass plate for monitoring purpose (left); Far right: Aluminized silicon surface of the sample

resistance values in each measurement, which was taken place once a day or a few days apart, are plotted in this figure. The corresponding voltages at which the transition occurred in the measurements are plotted in Fig. 12. As is prominent in these figures, it usually goes back to a high resistive state in the next measurement performed the day after, though its contact always recovered at some point as the applied voltage increased to several volts.

As a comparison the same samples but used Cu-clad G-10 plates were also measured. The results are shown in Fig. 13. They show smooth behavior though with some variations. No prominent hysteretic behavior nor any significant voltage dependence to the resistance was observed.

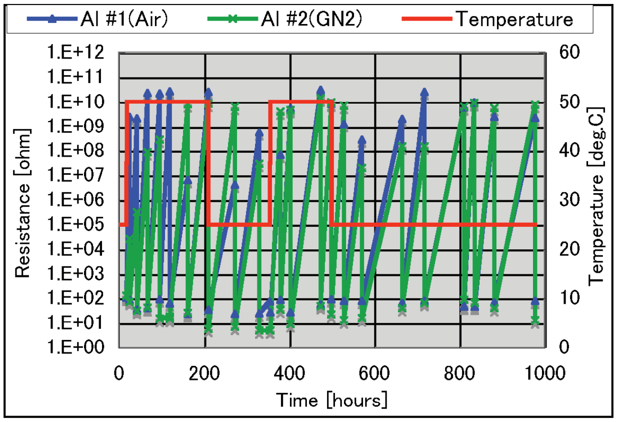

Fig. 11 Long term tests of resistance behavior, initial resistance and final (continuity recovered) ones
Temperature was changed for some periods during the test.

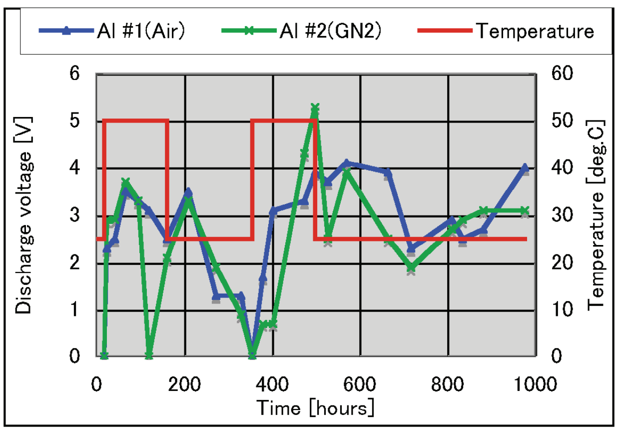

Fig. 12 Long term test: applied voltage at which continuity was recovered; one sample (#1) was kept in air while the other (#2) in nitrogen atmosphere
Temperature was changed for some periods during the test.

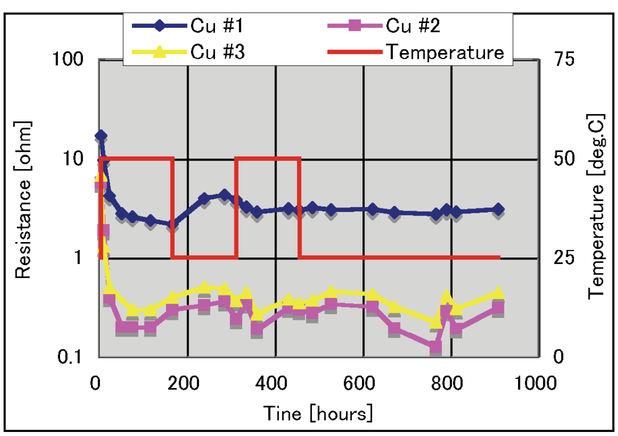

Fig. 13 Copper samples: long term tests of resistance behavior
Temperature was changed for some periods during the test.

VI. CONCLUSIONS

It was identified that the contacts of the silver-loaded epoxy to the surface of the aluminized backplane of the silicon sensor provoked high resistance. The combination of the aluminized silicon surface and the silver-loaded epoxy is to be an inferior choice to establish a secure electric contact.

Fortunately, however, it automatically cured by applying several volts, which is much lower than the usual operating bias voltage of a few hundred volts for the SCT, almost all of the contacts became as small as a few ten ohms.

Therefore we can conclude that this high resistive aspect found in the continuity checking is practically harmless in the SCT operation.

VII. REFERENCES

[1] ATLAS Inner Detector Technical Design Report, Vol. I, ATLAS TDR4, CERN/LHCC 97-16, and Vol. II, ATLAS TDR5, CERN/LHCC 97-17.

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