Development of Hybrid Structure for
the ATLAS barrel Silicon Microstrip Tracker

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representing
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Hybrid of the barrel ATLAS SCT

- ABCD3T chips (12 x 128 ch)
- glass pitch-adaptor (2 x 6 x 128 ch)
- connector
- carbon-carbon bridge (underneath)
- flexible Cu/PI circuit
ATLAS Barrel SCT

radius  # modules
300 mm  384
373 mm  480
447 mm  576
520 mm  672

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Total  2112 modules

8448 sensors
34.4 m^2
Module components

- Si sensor
- TPG1700 epoxy-coated
- Carbon-carbon bridges
- ABCD chips
- pitch adaptor
- Cu/PI flex circuit
- BeO facing
- Slotted washer
- Datum washer
Barrel module parameters

- **Sensors**: 63.56 x 63.96 mm², p-in-n, single-sided
- **Strip directions**: ±20 mrad
- **Operating temperature**: -7°C
- **Total chip power**: 6.0 W nom., 8.1 W max.
- **Thermal runaway heat flux**: > 240 µW/mm² at 0°C
- **Mechanical precisions**:
  - back-to-back: < 5 µm (in-plane lateral), < 10 µm (in-plane longitudinal), < 50 µm (out-of-plane)
  - Fixation point: < 30 µm (in-plane)
- **Radiation length**: < 1.2% X₀
Cross section of the module

Flow paths of heat
Carbon-carbon reinforcing bridge

- **Guide holes** (φ0.8)
- **Openings of parylene coating** by laser 0.88J/cm² x 120 shots (for thermal electrical contacts)
- **Surface roughing by laser** (for gluing)
- **Carbon-carbon w/uni-directional fibers**
- **All surfaces coated by 10μm thick Parylene (GVD)**
Carbon-carbon material

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal conductivity (∥ fiber)</td>
<td>700 ± 20  W/mK</td>
</tr>
<tr>
<td>(⊥ fiber)</td>
<td>35 ± 5   W/mK</td>
</tr>
<tr>
<td>Density</td>
<td>1.9 g/cm³</td>
</tr>
<tr>
<td>Young’s modulus (∥ fiber)</td>
<td>294 GPa</td>
</tr>
<tr>
<td>Tensile strength (∥ fiber)</td>
<td>294 Mpa</td>
</tr>
<tr>
<td>Thermal expansion coeff. (∥ fiber)</td>
<td>-0.8 ppm/C</td>
</tr>
<tr>
<td>(⊥ fiber)</td>
<td>10 ppm/C</td>
</tr>
<tr>
<td>Resistivity (∥ fiber)</td>
<td>2.5 x 10⁻⁶ Ωm</td>
</tr>
</tbody>
</table>
Layer structure of Cu/Polyimide flex circuit

- **Polyimide**
- **Copper**
- **adhesive**
- **solder resist**

**Connector**

**Front side**

**Back side**

**via hole**

**thru hole**

<table>
<thead>
<tr>
<th>Layer</th>
<th>Thickness (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1 MASK</td>
<td>20</td>
</tr>
<tr>
<td>L1</td>
<td>20</td>
</tr>
<tr>
<td>L2</td>
<td>37</td>
</tr>
<tr>
<td>L3</td>
<td>25</td>
</tr>
<tr>
<td>L4</td>
<td>49</td>
</tr>
<tr>
<td>L4 COVER</td>
<td>25</td>
</tr>
<tr>
<td>L4 COVER</td>
<td>37</td>
</tr>
<tr>
<td>L4 COVER</td>
<td>37</td>
</tr>
<tr>
<td>L4 COVER</td>
<td>20</td>
</tr>
<tr>
<td>L4 COVER</td>
<td>46</td>
</tr>
<tr>
<td><strong>Total thickness</strong></td>
<td><strong>279</strong></td>
</tr>
<tr>
<td><strong>Cable part</strong></td>
<td><strong>149</strong></td>
</tr>
</tbody>
</table>

07/11/2001 IEEE NS San Diego
Layout of the flexible circuits: top to bottom
Assembly of Hybrid

1. apply glue dots
2. place components
3. cure half day
4. apply solder flux
5. place solder balls (.4\(\phi\))

Soldering (by hand or laser), wash and remove protection sheets

Mounting passive components with a robot

Electrical check (R and C) via the connector

Heat cycle, 3 hours

-30 \(\degree\) C to 60 \(\degree\) C

Electrical check (R, C) and flatness check using a 3D metrology machine

Deliver to module assembly sites (Japan, UK, Scandinavia and US)

Align pitch adaptors with a microscope and glue

Cure @ 4 atom, 125 \(\degree\) C, 2 hours

Attach protection films
Glue & cure press for Cu/polyimide flex and CC bridge

Curing at 125°C for 2 hrs
Module assembly

Fixtures at the Japanese module assembly site
Module of the ATLAS barrel SCT

Si strip sensor
(64 x 64 mm²)

Hybrid structure

TPG baseboard & BeO facings
Simulated thermal profile with $Q_{\text{chip}}=6\text{W}$

bulk heat generation ($\mu\text{W/mm}^2@0^\circ\text{C}$)
Gain

60 mV/fC

ENC

1400 e

Channel # (1-1536)
Mean Noise Occupancy, all channels
module 20220170100018, measured warm

1 fC
Median charge and S/N vs bias voltage
(mod 3 was irradiated to $3 \times 10^{14}$ p/cm$^2$.)
Summary of Electrical Performance

For non-irradiated modules:

- noise ~ 1350e at ~0°C, S/N > 14
- noise occupancy ~10^{-5} at 1 fC threshold
- threshold uniformity < 4 mV (~0.08fC)
- timewalk : ~ 3 ns

For irradiated modules:

- noise ~ 2050e at ~0°C, S/N ~ 10
- noise occupancy ~ 3x10^{-5} at 1 fC threshold
- threshold uniformity < 12 mV
Conclusions

• A hybrid structure with Cu/polyimide flexible circuits with reinforcing Carbon-carbon bridges was successfully developed at KEK/Tsukuba, for the ATLAS barrel SCT module.

• All electrical performance (with ABCD3T), mechanical precision and thermal property, including radiation hardness, satisfy the severe LHC requirements.

• Ready for mass production.