A Custom Probe Station for Microstrip Detector
Quality Assurance of the CBM Experiment

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Abstract. The double-sided silicon microstrip sensors with $58\mu m$ pitch are the main building blocks of the Silicon Tracking System (STS) — the central detector of the Compressed Baryonic Matter (CBM) Experiment. The STS will employ about 1200 such sensors arranged on eight tracking stations. Electrical characterization of the sensors is necessary to ensure their compliance with the specifications. For this purpose a custom probe station is being developed at Tübingen University. One of the main requirements is a high accuracy and a repeatability better than $1\mu m$ to allow an automatic, successive positioning on all 1024 pads of a sensor, as well as a positioning range in accordance with the size of STS sensors. The probe station is controlled via dedicated software developed at Tübingen University. It allows to inspect the required $\sim 10\%$ of the sensors on the series production stage with characterization time 4-5 hours per one double-sided sensor. The construction of the probe station and first measurements are discussed in this paper.

1. Introduction
The CBM experiment at FAIR will investigate the properties of nuclear matter under extreme temperatures and densities created in ultrarelativistic heavy-ion collisions. Figure 1 shows the CBM detector configuration for hadron and electron measurements. Its core detector — the Silicon Tracking System [1] inside the dipole magnet — will allow to reconstruct charged particle tracks with high precision and determine their momentum. The detection of rare probes requires the STS to be capable to measure at interaction rates of up to 10 MHz for Au-Au collisions. The track multiplicity will reach up to 700 within the detector aperture covering the polar angle $2.5^0$ and $25^0$ which corresponds to a rapidity range from mid rapidity to close to beam rapidity. The high track density as well as stringent requirements for the momentum resolution (around $1\%$ at $p \geq 1 GeV/c$) require a setup with high granularity and low material budget. Therefore front-end read-out electronics, cooling and mechanical infrastructure are located outside of the detector acceptance.

2. Microstrip Sensors for the CBM Silicon Tracking System
The STS will be constructed of 8 detection layers entirely covered by silicon microstrip sensors [1]. Figure 2 shows the concept design of the STS. About 1200 sensors will be mounted on lightweight carbon structures and the signal will be routed to the FEE by ultra-thin cables. Sensors of
Figure 1. CBM SIS100 experimental setup for hadron and electron measurements. The STS is placed inside the dipole magnet. Downstream are the RICH, TRD and TOF detectors, and calorimeters. The MUCH detector can be moved into the acceptance after the RICH is removed.

4 different sizes have been chosen for different areas of the detection layers to keep the maximum strip occupancy at the level of few percent. Thus, short strips are chosen close to the beam pipe where the particles densities are highest. All sensors have the same width and number of strips but differ in the lengths of strips. The main sensor parameters are:

- n-type silicon
- thickness: $285/320 \pm 15 \mu m$ (vendor dependent)
- double-sided segmentation
- 1024 strips per side of $58 \mu m$ pitch, strip width $\sim 18 \mu m$
- strip lengths: $2/4/6/12 cm$
- strip angle w.r.t. vertical edge: 7.5 degree (p-side), 0 degree (n-side)
- AC coupled read-out
- 2nd metal read-out routing lines interconnecting the AC layers of the corner strips
- outer dimensions: $6.2 cm$ width; $2.2, 4.2, 6.2$ and $12.4 cm$ height.

The prototype sensors have been produced by two companies: CiS, Erfurt [2], Germany and Hamamatsu Photonics, Japan [3]. Figure 3 shows the microscope view of a recently produced prototype sensor and figure 4 represents a simplified model of the silicon microstrip sensor as an extended network of capacitors and resistors (omitted for simplicity) which is used for determination of strip parameters.

3. Electrical Quality Assurance of Silicon Microstrip Sensors

The complicated fabrication technology of double-sided microstrip sensors and the large-scale sensor production demands a reliable and efficient quality assurance (QA) program for the CBM-STS sensors to guarantee the expected operation of the whole detector system. The electrical QA program for sensors consists of:

- **Basic tests:** IV, CV curves for every received sensor.
Subset tests: pinholes in coupling capacitors, strip metal and implant shorts and opens, strip leakage current — on ∼ 10% of the sensors which pass the basic tests.

Specific tests: coupling and interstrip capacitances, polysilicon resistors — on a small fraction of sensors to measure in much more details electrical parameters.

To perform all those tests two quality test centers are being equipped in GSI Detector Laboratory and at University of Tuebingen, respectively. Both centers have the same set of the measurement instrumentation: SourceMeter Keithley 2410, Picoammeter Keithley 6487, LCR-Meter QuadTech 7600, Switching matrix Keithley 708B.

Current-voltage (IV) and capacitance-voltage (CV) measurements are the first and simple estimation of the sensor quality. This measurements describe the sensor as a single entity and allow to extract full depletion voltage ($V_{FD}$), bulk capacitance ($C_{bulk}$) and leakage current ($I_{leakage}$) at full depletion voltage. Figure 6 shows the CV characteristic plotted in a double logarithmic scale for the sensor labeled as CBM06C6-w18. $C_{bulk}$ measured between backplane and bias ring by LCR meter with $C_s - R_s$ function at 1 kHz frequency. Full depletion for most of the tested prototype sensors is reached at $\approx 70$ V and the capacitance saturates at $\approx 1.2 \text{ nF}$.
For strip-by-strip characterization a custom made, automated probe station has been developed and set up in the clean room at University of Tuebingen [4], while commercial wafer prober (Suss PA300PS) is employed at GSI [5]. In addition to high accuracy of positioning and repeatability (< 1μm) the custom made probe station provides large travel range of both chuck positioning and optical systems that allows to contact needles to pads at opposite corners of the silicon sensor. This feature makes it possible to perform some specific tests like probing of the 2nd metal lines on the sensors’ p-side. Figure 5 shows the concept design of the custom probe station. A switching scheme has been implemented to allow acquisition of several electrical parameters at each step. Instruments (HV-source, Amp-meter, LCR-meter) are connected via a switching matrix to the needles which contact the sensor to perform different measurements. For each test the switching matrix has to be reconfigured.

![Figure 5. Concept design of the custom probe station. The microstrip sensor is held by the custom vacuum chuck. The box is closed during the measurements.](image)

LabVIEW based [6] software provides automation for all kind of measurements. Its stepping procedure for subset tests probes every strip of the sensor in order to check the capacitor dielectric for pinholes, to look for strip metal and implant shorts and opens and to determine the coupling capacitance of the readout strip. Figure 7 shows the results of one of the subset test — pinhole check performed on the CBM06C6-w18 sensor. The current through the capacitor for most of the strips is much less than 1 nA, i.e. no pinholes are present. The group of the strips reveals a twice higher value of current than normal which is due to metal shorts between pairs of strips. This measurement has been done by contacting the strip’s DC and AC pads with two needles and measuring the current after the test voltage of 10 V is applied. A source of the revealed defective strips is a scratch on the sensor surface. Such kind of defect degrades the spatial resolution of the system and has to be determined. Further specific tests (e.g. interstrip capacitance, posysilicon resistance, coupling capacitor breakdown) have also been implemented.

A time estimate for the complete testing protocol (consisting of 4 QA tests) is 4-5 hours per sensor. The specification requires < 1 % bad strips on every sensor to be accepted for module assembling. We define bad strip as a strip with at least one of the electrical parameters outside the specified cuts. Current prototype sensors fulfill this requirement [7].
Conclusions
A quality assurance program with detailed characterization procedures has been developed for CBM-STS microstrip sensors. For this purpose the custom made high precision probe station has been set-up at the University of Tuebingen. Prototype sensors for CBM experiment were successfully tested using this probe station — the results are in compliance with CBM detectors specifications. The probe station allows to inspect required $\sim 10\%$ of the sensors on series production stage. Characterization of one double-sided sensor with 1024 strips on every side takes $\approx 5$ hours.

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