Technical Specification

Supply of Edgeless Strip Detectors for the TOTEM Roman Pots

Introduction

This Technical Specification describes the main features of the Edgeless Strip Detectors (ESD) to be employed to equip the TOTEM Roman Pots. The scope of this document concerns the purchase of 200 units of ESDs (considered as the series production) and 200 test units, which will be used to benchmark some of the physical properties of the ESDs and some quality aspects of the production.

The technical specifications are relative to the 2 first batches of the mass production and have been agreed with the contractor after the evaluation of the pre-sieries production delivered at CERN in March 2006. The technical design required for the fabrication of the masks has been already produced by the Contractor and agreed with the CERN TOTEM representative and is available at:
https://edms.cern.ch/file/827948/1/DetectorDesignMassProduction1.dwg

This Technical Specification comprises four sections. The first describes the main geometrical features of the design of the EDS, the second the Optical, Electrical and Mechanical properties of the EDS, the third the Quality Assurance that the Contractor has to guarantee during the production and the fourth the Acceptance Tests to be carried out by TOTEM at the delivery to CERN.

1 Description of the EDS design

The full design of the EDS can be found at:
https://edms.cern.ch/file/827948/1/DetectorDesignMassProduction1.dwg
The following text summarises the full design requirements.

The EDS is made of different regions that can be recognized in the design: the sensitive region occupied by the strips, the biasing region occupied by the biasing electrode and the current terminating structure (CTS), which terminates the current at the cut edge on the "edgeless side", and the outer region occupied by the Voltage Terminating Structure (VTS), which goes up to the cut edge on the other 4 sides. The plot of the EDS follows in the Figure 1.

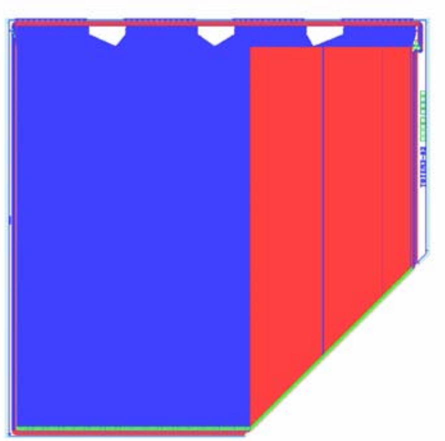

Figure 1 Drawing of the EDS with its carachteristical shape of square with a cut corner.

1.1 Sensitive Region

The sensitive region is occupied by 512 parallel strips (the p^+ implant is 20 µm wide and the superposed AC coupled Al strip is 24 µm wide) oriented with a 45° angle respect to the edgeless side. The strips ending at the edgeless side varies linearly in length from 19285.5 to 33026.5 µm, the others have all the same length of 33026.5 µm. The punch-through distance from the end of the strips to the biasing electrode is 8.5 µm while the distance from the other end of the strips to the CTS is 12.5 µm.

1.2 Biasing Region

The biasing region is made of the Biasing Electrode (BE), which has a rectangular shape and is placed at one strip ending side, opposite to the sensitive cut, and is a deep p+ implant equipped with a metallised bonding pad.
Over a passivating layer covering the BE the Aluminum strips continue from the sensitive region with a pitch adaptation ending with a double bonding pad.

1.3 Current Terminating Structure

The Current Terminating Structure is composed of two separated rings: the Cleanup Ring (CR) and the Current Terminating Ring (CTR) running all around the sensitive region. Both rings are deep p+ implants and each equipped with a metallised wide bonding pad.

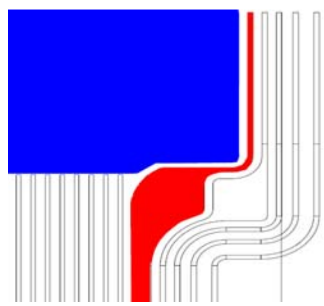

Figure 2 Detail of the CTS at the level of the bonding pads. To evidence the differences the BE is coloured in bleu and the CR in red.

A critical part of the CTR is the Insensitive Width at the Sensitive Edge (IWSE), which is placed between the end of the strips and the cut edge on the so called "Sensitive Edge". The IWSE is occupied only by the CTS. The IWSE is 47.5 µm wide. The distance end strip-CR is 12.5 µm, the CR is 10 µm wide, the distance CR-CTR is 10 µm and the CTR is 15µm wide. On the wafer, before the cut of the EDS, the CTR is followed by the cut groove, a p+ implant which is 30 µm wide.

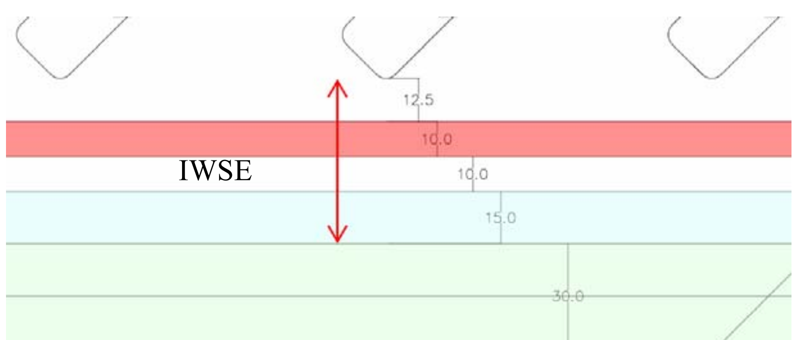

Figure 3 Detail of the IWSE. The CR is in red and the CTR is in blue. The CTR is followed by the cut groove (green).

1.4 Outer Region

All the ESD types will have a series of 3 external U-shaped implants acting as VTS.
All these 3 external U-shaped implants will run continuously around the whole detector apart from the sensitive edge.
Probing pads on these U-shaped implants will be made by window openings in the detector passivation. The openings are made at the level of the strip pitch adapter on the side opposite to the bonding pads of the CTS. An enlargement of the top left corner of the A1-type device is shown in Figure 4.

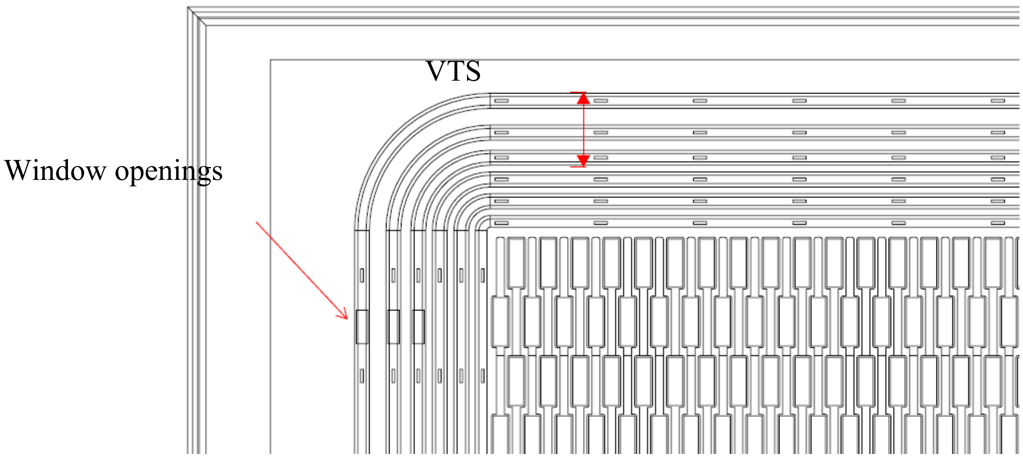

Figure 4 Detail of the TOP RIGHT corner of the EDS, with the VTS and the window openings for probing purposes.

1.5 Contacts, Strip Numbering, Numbering Pads and Alignment Marks.

Each strip is provided of two AC coupled contact pads at the pitch adaptation end and one DC coupled contact pad on the other end.
The strip numbering is present for each adjacent collection of 128 strips. After the pitch adaptation the number is assigned every ten strips and starts with 0 at the first strip of the bunch. The strip corresponding to the number is easily recognised by the absence of metallisation before the bonding pad.

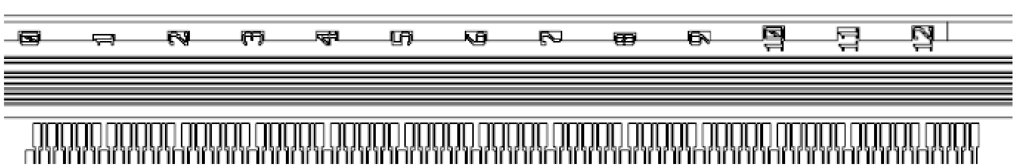

Figure 5 Strip numbering

The numbering pads consist of 8 squared metallic pads aligned to the writing TOTEM3-A2. The complete writing plus pads is centred and aligned. The linear dimension of the numbering pad can be of 0.4 mm, their distance of 0.13 mm. Between the 4^{th} and the 5^{th} a distance of 0.3 mm is advised to ease the reading (see Figure 6).

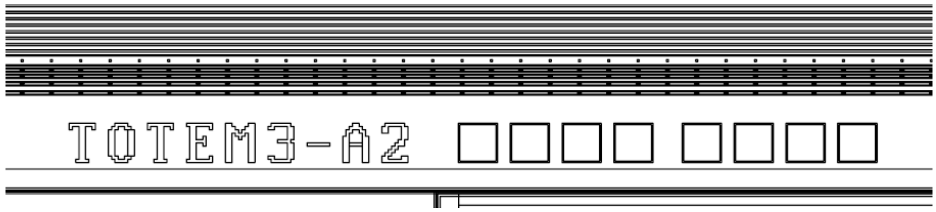

Figure 6 Detector label and numbering pads.

There will be 3 alignment marks per each ESD. They are in the outer region with one of them, the central mark, placed on the axis of the edgeless side and the other two opposed symmetrically with respect to the same axis with the further requirement that two lines passing through the central mark and one of the two other marks have to be orthogonal.

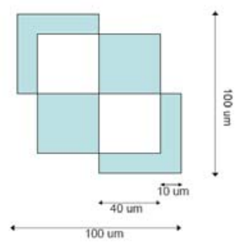

Figure 7 Alignment mark with its dimensions.

1.5.1 Wafer Test Structures

***Miniature detectors*:**

As part of the production also one type of miniature strip detector, one type of miniature edgeless detector and one miniature pad detector per wafer will be delivered to CERN. These devices will be used by TOTEM for routine quality control and future tests of post-irradiation performance.

2 Physical Properties of the EDS

2.1 Mask Requirements

The Contractor shall be responsible for the final mask designs, their procurement and/or their production. Also he shall produce engineering drawings or mask designs and make them available to TOTEM.

- *Number of metallised implanted and read out strips*: 512
- *Read-out implant strip width*: in the range 16µm to 20µm wide, high doped *p*-implants. (As stated above, these are the dimensions in the device).
- *Punch-Through Biasing Electrode*: P+ implanted, capacitively coupled to the *p*-implant strips;
- *Voltage terminating Structure*
- *Current Terminating Structure*
- *Pitch adaptation to F/E electronics (VFAT2 Chip)*
- *Sensitive region to cut edge distance on the "edgeless" side*: <50µm.
- *High Voltage Contact*: Large metallised contactable *n*-layer on back.
- *Read-out*: 144×44µm bond pads, ≥ two rows, daisy-chainable.
- *Probe pad contacts*: Provided to every read-out strip implant at the strip end. Probe pad contact to VTS also provided.
- *Passivation*: Detectors to be passivated on the strip side and un-passivated on the backplane.
- *Identification*: Every 10^{th} strip to be clearly numbered, starting at **0** for the first read out strip. Identification pads to be used for detector labelling and agreed alignment marks required for module optical metrology.

2.2 Detector Mechanical/Optical Properties

- *Quality of cut edges*: Edge chipping to be avoided and all cut edges to be clean and smooth. No chips or cracks should extend inwards by more than 5µm.
- *Thickness:* 300±10 µm for all detectors-
- *Mask alignment tolerances*: ≤3µm misalignment with respect to any other mask. Specific values are the responsibility of the Contractor.

- *Damage and defects:* Device free from scratches and other defects could compromise the detector performance during the lifetime of the experiment.

- *Bond Pads***:** Metal quality, adhesion and bond pad strength to be such as to allow successful uniform bonding to all readout strips of the detector using standard microstrip detector bonding techniques, and without causing degradation in strip quality.

- *Alignment Fiducials***:** All fiducial marks situated between the cut edges and the bias line to be fully visible.

2.3 Detector Electrical Properties

- *Read-out strips***:** Aluminium <15Ω/cm.

- *Interstrip Capacitance***:** Capacitance between a strip and its nearest neighbour on both sides <1.1pF/cm at 150V bias measured at 100 kHz.

- $C_{coupling}$**:** ≥20pF/cm, measured at 1 kHz.

- *Initial Depletion voltage***:** $V_{depletion}$< 50V.

- *Leakage current* normalised to 20°C at 200V measured at the biasing electrode**:** <1μA, and at the CTR: < 2mA **to be verified by Contractor**

- *Leakage current stability***:** Current to increase by no more than 50% during 24 hours in dry air at 150V and stay in the limit of 2μA ***to be verified by TOTEM***.

- *Percentage of good strips (i.e. those conforming to the Technical Specification)***:** A mean of ≥99% good readout strips per detector required in each delivery batch, with no detector having less than 98% of good strips.

  Definition of bad strips (i.e. those not conforming to the Technical Specification):

  Any of the following 3 types of fault will cause a strip to be counted as bad:

  1. *Coupling dielectric***:** Shorts through dielectric with 20V applied between the metal and the substrate.

  2. *Defective metal strips***:** Metal breaks or shorts to neighbours.

  3. *Defective implant strips***:** Implant breaks or shorts to neighbours.

3 Quality Control, Inspection, Acceptance Tests and Data Sheets

3.1 Quality Control, Inspections, Acceptance Tests to be performed by the Contractor

3.1.1 General

The Contractor is required to perform sufficient checks to ensure consistency of processing and to maintain all electrical parameters as previously defined within the specifications. The properties of the polished silicon substrate material used must be tightly controlled.
The Contractor shall be responsible for:

- raw material control (visual inspection);
- ESD acceptance testing, measuring methods;
- labelling;
- data supplied with delivered detectors.

3.1.2 Raw material control

The material in use in the production of the EDS is high resistive silicon wafers by Topsil of property of the TOTEM CERN group, which has the responsibility to provide the Contractor the wafers as they are needed during the production time. The wafers will be shipped to the Contractor in their original packaging. The Contractor has the duty to control their quality before starting the production.

3.1.3 Acceptance Test Measurements

The Contractor is required to perform the following test measurements on every detector, and to supply the measurement results to TOTEM with the delivered detector:

1. Detector IV up to 200V bias, measuring the current in 10V steps as the voltage is raised from 0V up to 200V, with a maximum of a 10 second delay time between steps.
2. Detector CV up to 200V bias for at least one sample per wafer to evaluate the full depletion voltage. The test can be done also on the miniaturized pad detector present in the wafer.

3.1.4 Special Labelling

1. A unique binary-coded decimal identification number (0 to 255) for each detector is to be marked on the detector identification pads by the Contractor. The labelling shall be made with appropriate needle, scratching the metallic surface to define “1” and not doing any scratch on the pad to define the “0”. The scratches shell be done in a way not to damage the detector.
2. Any test structures, diced or undiced, should be supplied with the Contractor’s serial number of the associated wafer clearly marked on the packaging.

3.1.5 Data Supplied by the Contractor

The following data are required from the Contractor for each ESD:
1. The detector's wafer number and the detector identification number.
2. IV data up to 200V bias for the biasing electrode and the CTS.
3. Temperature of IV measurement.
4. Depletion voltage (usually measured by the Contractor using a test diode).

The data are to be provided both on paper and in electronic format.

3.2 Tests carried out by TOTEM

TOTEM will carry out tests on the ESDs. The test procedures to be used throughout the production are described in the section 5.

When a batch is delivered to TOTEM the detector packages will be inspected for damage and stored in an inert atmosphere under TOTEM responsibility.

A visual inspection and an electrical IV measurement will be carried out on all ESDs by TOTEM (see section 5.1). More detailed measurements on a representative sample of delivered detectors using the procedures outlined in 5.2, both to verify the Contractor's claim of quality and to measure additional properties.

The measurements of current made by the Contractor and TOTEM on a given detector and the portion of bad strips must agree to the specification within defined tolerances.

CERN will notify the Contractor in writing of any delivered detectors failing the specifications or performance requirements in TOTEM measurements, or where results differ by more than the agreed tolerances.

4 Packing, Transportation and Delivery of Detectors

Packing and the method of delivery must ensure adequate protection against damage (including theft, loss etc) during handling and transportation.

The detectors are to be individually packed, with their surfaces protected, in envelopes and/or boxes, which are sealed and packed within boxes for transportation. Each individual detector package must be clearly labelled with the identification number of the detector.

The miniature detectors are also to be individually packed, and each package clearly labelled with the identification number of the associated wafer.

The transportation boxes are to be externally labelled with the Packing List showing the delivery batch number and quantities it contains, and clearly identified as fragile.

The Contractor shall carry out whichever customs and other formalities may be necessary for the importation and the shipping of the detectors to CERN.

5 Acceptance Tests to be carried out by TOTEM

The TOTEM Collaboration will check and control the quality of the ESDs to be delivered in accordance with the contractual delivery schedule. There will be two different sets of tests. The first set will be performed on all ESDs delivered in order to check on the basic quality. It will be a visual inspection and an electrical IV measurement on every detector. The second set of tests will be made only on a subset (expected to be 20%). It will consist of a more detailed evaluation of detector characteristics and will be performed as a check on processing consistency and as a verification of the Contractor's tests.

5.1 Tests on every detector

5.1.1 Visual inspection

Objective: To ensure the detector is free from physical defects and scratches.

Procedure: Place the detector on a probe-station chuck and scan it visually using a microscope.

Acceptance: The detector is free from significant scratches and blemishes. The cut edges are straight, clean and free from chipping. No chips or cracks should extend inwards by more than 50μm on all the non sensitive edges. On the sensitive edges the constrains are more strict and the cut can only vary with –5/+10 μm from the IWSE contour which is 47.5 μm from the end of the strips.

5.1.2 IV Curve

Objective: To perform a basic check of detector quality, to cross-check with Contractor data and to ensure there has been no damage during the shipping.

Procedure: This test requires a voltage source/picoammeter (SMU) and is done in a clean environment at 20 °C. The detector backplane is placed on the chuck of a probe-station and the IV characteristic between the bias electrode and the backplane measured using the SMU. The detector bias is applied via the detector backplane with the high impedance terminal of the SMU, the bias electrode is connected to the low impedance terminal and the CTS (Current Terminating ring and Clean-up ring) is grounded via the contact pads. The current is measured in 10V steps from 0V up to 200V.

Acceptance: The detector current should not displays breakdown behaviour in the measured voltage range. Also, the current flowing through the biasing electrode should be less than 1μA when the bias applied is 200V.

5.2 Tests on a detector subset

These tests are a verification of the measurements performed by the Contractor. If any of these tests fail, this is an indication of either a variation in processing and/or a possible failure in the testing procedures of the Contractor. Further samples from the batch should then be tested and contact made immediately with the Contractor.

5.2.1 Detector depletion voltage

Objective: To determine the depletion voltage and verify the Contractor's data.

Procedure: This measurement requires a CV meter and a voltage source. The biasing scheme has to be the same as the one described in the section 5.1.2and the capacity is the one measured between biasing electrode and the backplane. The pulse frequency should be set to 1 kHz and CR in SERIES. The depletion voltage is extracted by plotting the data as $1/C^2$ ($1/nF^2$) vs bias (volts).

Acceptance: Depletion < 50V

5.2.2 Leakage Current Stability

Objective: To check that any variation in leakage current over a 24 hour period is within specifications.

Procedure: With the detector biased as described in 5.1.2, the voltage bias is ramped to 150V and then the current is monitored every 15 minutes over a 24 hour period. During this period the environment temperature and humidity should be monitored.

Acceptance: Current to increase by no more than 50% during 24 hours in dry air at 150V and stay in the limit of 2µA if the environmental temperature and humidity are stable.

5.2.3 Oxide dielectric strength

Objective: Check the AC coupling of each strip and absence of pin-holes between the Al strip and the p+ implant.

Procedure: This test requires a probe station equipped with motorised stages to displace the testing probe and the volt source / picoammeter (SMU). The detector is placed on the chuck of the automatic probe-station, and the external pad of each metal strip is contacted with the testing probe. The voltage (20V) is applied on the backplane and the current flowing through the strip is measured. The current should be less then 1nA to guarantee the good decupling between metal and strip implantation. This test should be made on all the 512 strips of the detector under test.

Detector Acceptance: < 2 % bad strips, where a bad strip has electrical continuity between the strip metal and backplane, strip metal short to neighbour or evidence for metal discontinuity. The whole batch is accepted if the mean number of good strips is ≥99% and no detector falls below 98% good strips.

5.2.4 Strip Integrity

Objective: Check the integrity of the Al and the p+ implant strip by mean of capacitance measurements.

Procedure: This test requires a probe station equipped with motorised stages to displace the testing probe and the CV meter. The detector is placed on the chuck of the automatic probe-station, and the external pad of each metal strip is contacted with the testing probe. The capacity between the Al Strip and the backplane is measured with no bias applied between the two electrodes. The profile of the capacitances measured along the strips should follow the length of the strips.

Detector Acceptance: < 2 % bad strips, where a bad strip shows a capacitance value which is significantly smaller or bigger than the neighbouring value which hints to a broken implant or metallisation of the strip or a shortcut between strips (implant or metallisation).