Quality Tests of Double-Sided Silicon Strip Detectors

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Abstract

The quality of the SiO_2 insulator (AC coupling between metal and implanted strips) of double-sided Silicon strip detectors has been studied by using a probe station. Some tests performed on 23 wafers are described and the results are discussed.

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1. Introduction

The main goal of this note is to describe a procedure to investigate the quality of the insulation (coupling capacitance) between the implanted strips and the corresponding metal strips of double-sided silicon strip detector (SSD) and to present some results coming out from this study. These tests were done in the framework of R&D activities devoted to the design of the two outer layers of the Inner Tracking System (ITS) of the ALICE detector [1]. A set of 46 double-sided SSD's has been tested. It should be made clear that these detectors have not been fabricated as candidates for a possible use in the ITS. The statistical meaning of these results is limited, due to the small number of tested detectors. They are, however, relevant and informative in the perspective of the forthcoming test phase following the SSD production for the ALICE ITS.

A short description of the tested SSD's is given. The main characteristics of the probe station used as a test-setup are mentioned. Some statistical results are presented and possible extension of these tests are suggested.

2. Characteristics of the tested double-sided SSD

Two kinds of double-sided SSD's with different structure, both implanted on the same 4'' wafer, 300 μm thick, have been tested. The wafer structure is shown in **Fig.1.** A total of 23 wafers has been examined, hence 46 detectors tested.

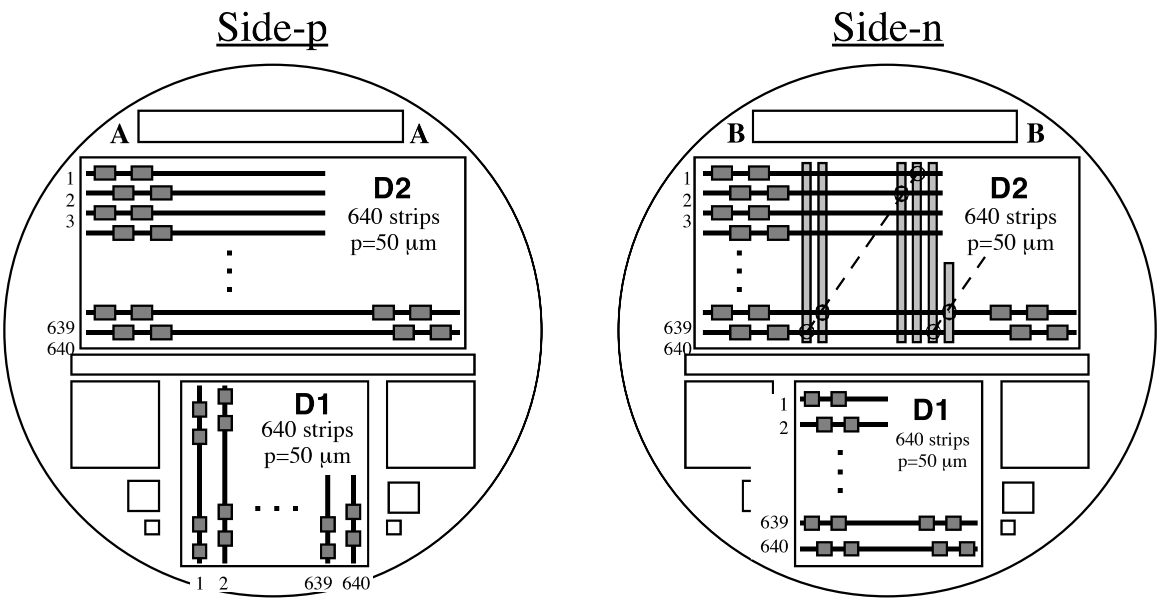


Figure 1: The wafer structure.

The 23 detectors D1 are square shaped (32x32 mm^2) and have 640 readout strips on each side, orthogonally oriented, respectively. The detectors D2 are of rectangular form (64x32 mm^2). They have also 640 metal strips on both sides. In reality, 640 strips have been indeed implanted on the p side, but on the n side there are 1280 implanted strips, connected two by two via a double metal readout scheme [2] (see **Fig.1**). The readout is done by pairs, i.e. 640 metal strips. The pitch of the readout strips is 50 µm for each side of the D1 and D2 detectors.

The wafers are made out of cuts of Silicon pieces with two different crystal orientations : <111> and <100>. Among the 23 tested wafers, 12 are from silicon type <111> and 11 from type <100>.

3. The probe station

A schematic view of the probe station (PS) is shown in **Fig.2**. The different parts, briefly described here after, can be easily identified in the figure. It consists of a 3-D (X, Y, Z) translatable plateau on which the wafer is placed. This plateau may be moved by motors which can be activated manually (with a joystick) or by software with a controller connected, through a serial port, to a computer (PC).

The detector testing is performed by means of two needles insuring the contact between specific spots on the wafer. One of the needle is interdependent on the moving table and has a permanent contact (the common point or the detector’s guard ring). The other one is placed on the PS base and touches the detector pads step by step after each plateau’s translation. The needles are connected to a measuring device (in the present case a Keithley-237) which also provides detector biasing through a « safety » resistor, protecting the detector. At each step, the device allows a measurement which is stored, through a GPIB card, in the computer memory and on hard-disk.

The process may be optically controlled with a binocular (for initial adjustments and accurate examination) supplied by a CCD camera coupled to a TV monitor (for check-up during the tests).

A computer program written in LabVIEW activates the motors, the measuring device, the data acquisition and the data storage, sequentially.

4. The measurements

Recent technical developments offer different coupling designs of the junction strips to the electronics [3-6]. Usually, coupling capacitors are integrated into the detector itself, using 100-200 nm thick SiO_2 as insulator between implanted and metal readout strips. Most recent technologies combine Si-oxide and Si-nitride layers as insulator for the coupling capacitors. In both technologies the occurrence of pinholes in the insulator remains a problem.

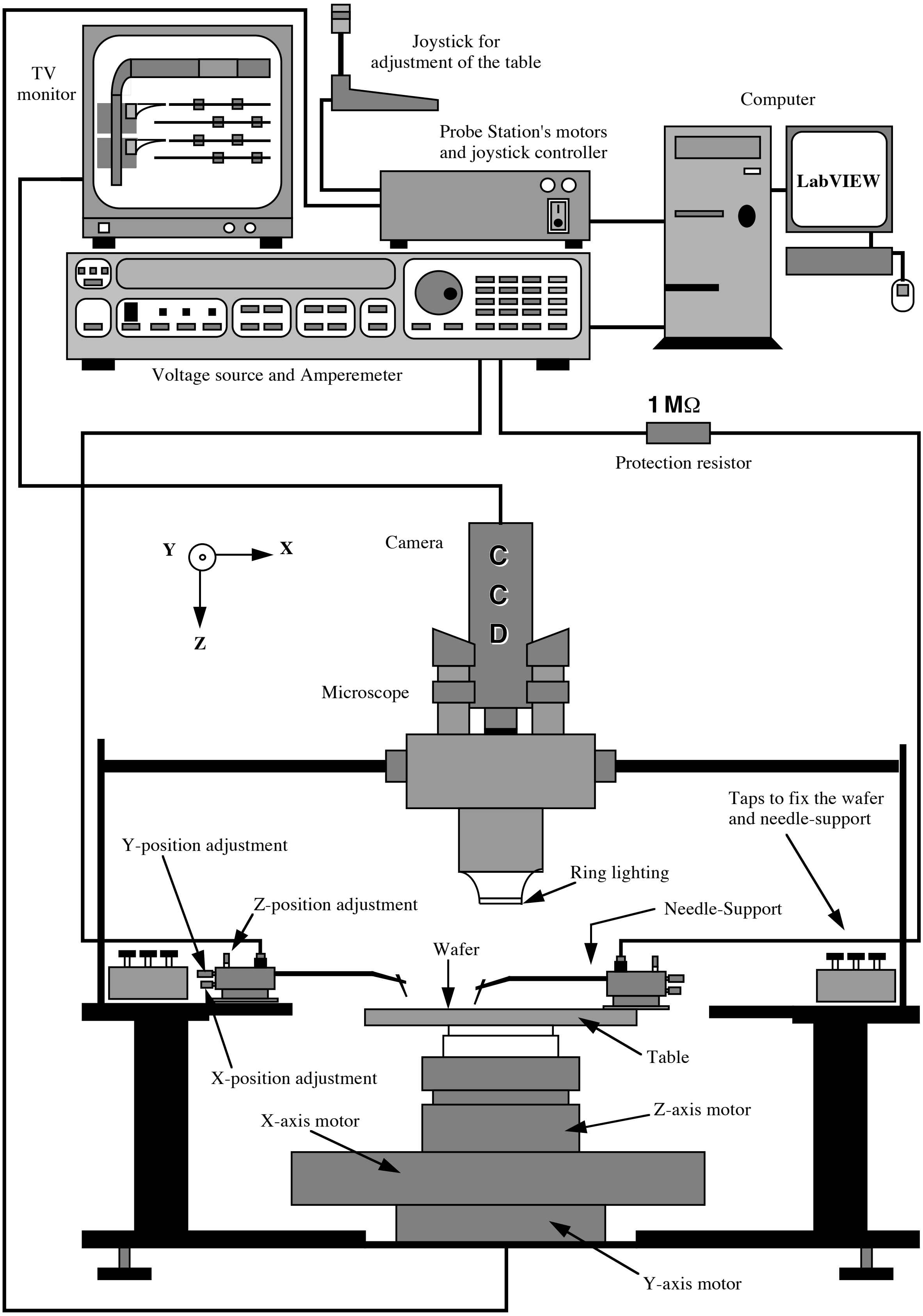


Figure 2: Schematic view of the probe station and measuring devices.

The main purpose of the present tests is to examine the quality of the insulator between implanted and metal readout strips. The schematic view of a double-sided SSD and of its principal equivalent electric scheme is shown in **Fig.3**. It consists of a serial capacitor and a diode.

On the p side of the detector, a specific spot giving access to the detector bulk is purposely made by the manufacturer (the common point). The fixed needle touches this zone while the movable needle contacts successively the different strip pads. On the n side, the fixed needle connects to a specific zone (not covered with SiO_2) on the guard ring.

The measurement consists of polarising in such a way that the diode conducts. Then if the capacitance (insulator) is correct no DC current is measured. Conversely, sizeable current is synonymous with insulator defects, hence damaged (“dead”) strips. Practically, a negative voltage was applied to the common point and the difference of voltage between this point and, sequentially, every strip pad was varied between -8 and -80 volts by -8 volt step. The corresponding current values were registered and stored for each voltage. Of course, in the detector mode, the depletion voltage should be of opposite sign, and its nominal value is expected to be about 80 volts at most. More detail about the description of the tests may be found in Ref.[7].

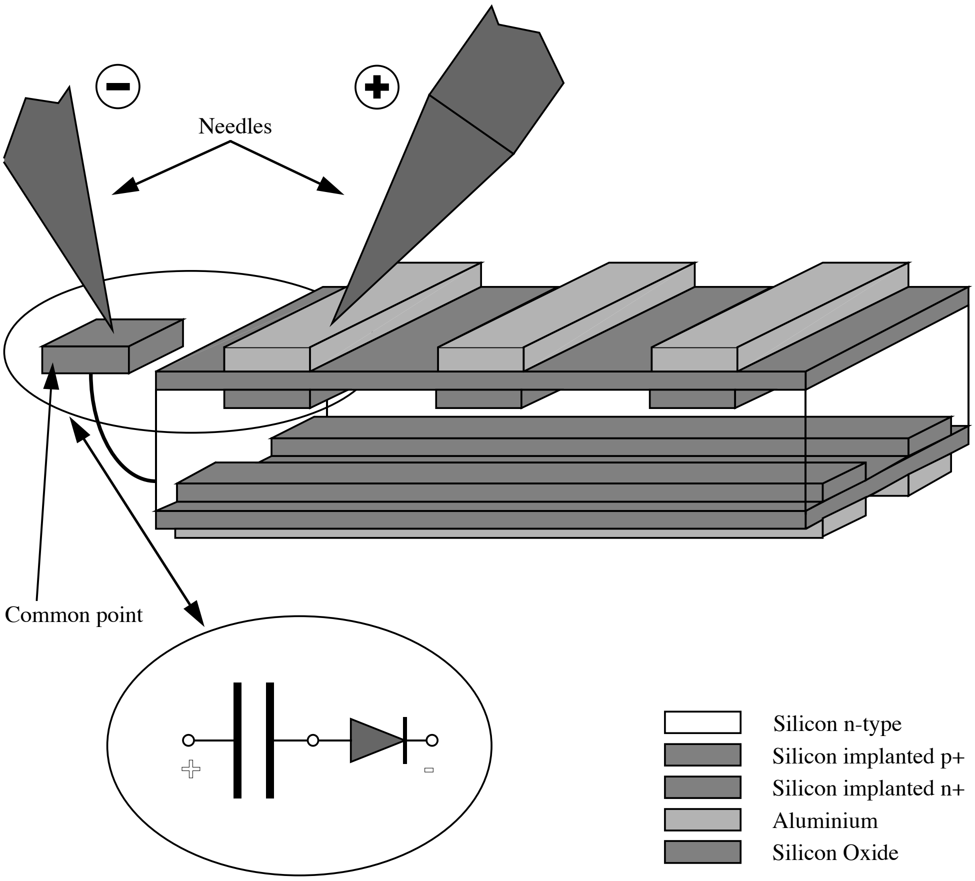


Figure 3: Schematic view of the double-sided SSD and principal equivalent electric scheme of measuring.

5. Results

5.1. Applied voltage effect

We have varied the applied voltage from -8 to -80 volts by -8 volt steps. The percentage of dead strips (number of dead strips integrated over all detectors divided by the total number of strips) versus the voltage is shown in **Fig.4** for the D1 detectors with the <111> structure. The distribution is quite similar for the D2 detectors and for the <100> structure (not shown here). One can see that the number of dead strips increases gently with the voltage. However, it is appreciably larger (~ 8 %) for the n side than for the p side (~ 2.7 %). Let us recall that the nominal depletion voltage in the detection mode is around + 80 V at most.

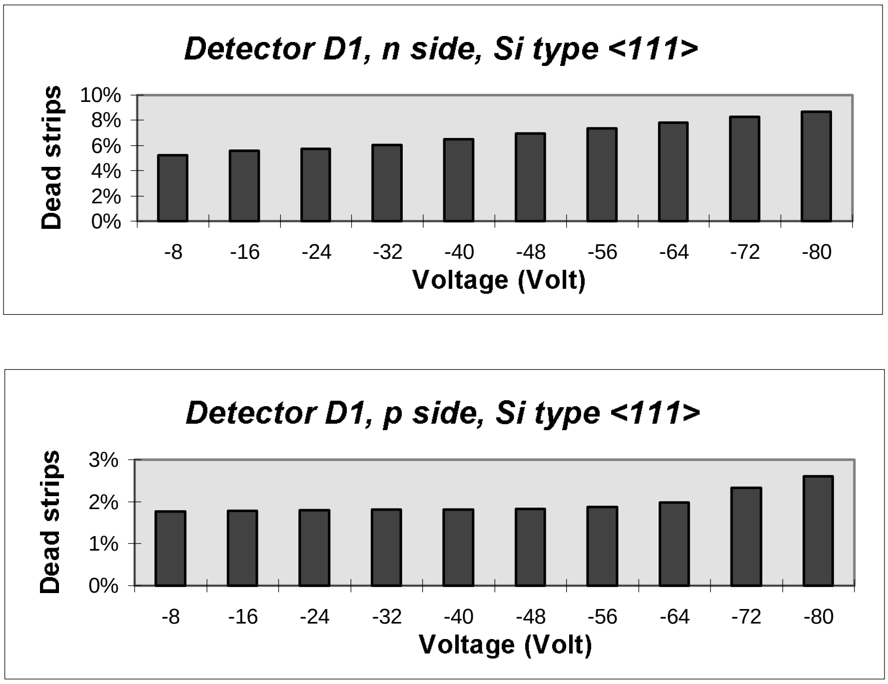


Figure 4: Distribution of the number of dead strips versus the applied voltage. The distributions are integrated over all D1 detectors. It is shown separately for each side and only for wafers with <111> silicon orientation.

5.2. Effect of the cut-orientation of the Silicon-crystal

We have tested two series of SSD with two different cut orientations in the crystal : 11 wafers are of <100> type and 12 of <111> type. The distributions of the number of dead strips, at -80 V, as a function of all the strips are shown in **Fig.5** for the D2 detectors. The distributions are integrated over the 11 and 12 detectors, respectively. In **Fig.5**, the upper two frames are for the p side, and the lower two correspond to the n side. For each side, the <100> and <111> cases are shown. For each case, the total number of dead strips per strip integrated over all detectors is reported as well as the percentage (total number of dead strips/total number of strips) of dead strips.

The percentage of dead strips is roughly 4 times less for <100> than for <111>. This figure is found quite similar for the D1 detectors (not shown here).

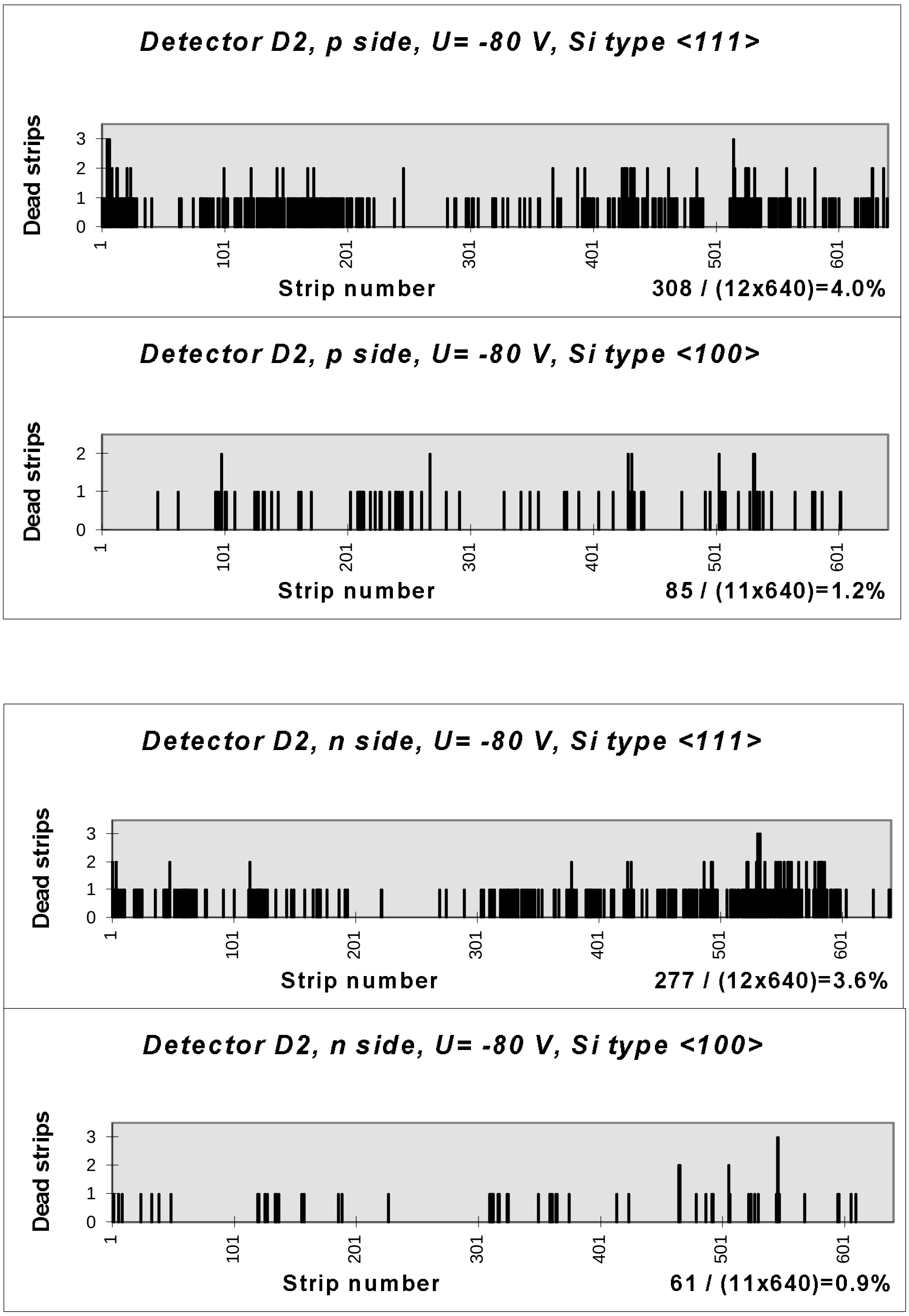
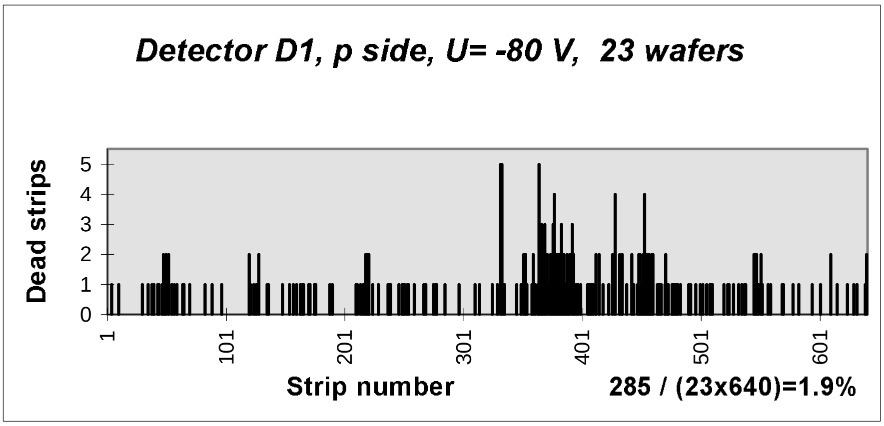


Figure 5: Distribution of the number of dead strips versus the tested strip number for both sides of the D2 detectors. The distributions are integrated over all D2 detectors of a specific type. From top to bottom, are shown the p and n side results. For each side, the <111> and <100> orientations (see text) are reported. All measurements have been performed with an applied voltage of -80 V.

5.3. Strip orientation versus detector position on the wafer

In this paragraph we show again the integrated distributions (see **Fig.6**) of the dead strips as a function of all the strips for the 23 D1 detectors, measured at - 80 V applied voltage. Both detector sides are exhibited. The p side shows a bulk of dead strips over the 350-450 strip range while the n side presents a clear increase of damaged strips near one single extremity of the detectors. If no argumented reasons can be put forth to explain the first effect, a look at **Fig.1** may provide an explanation for the second effect. In **Fig.1**, one observes that the strips of the D1 detectors are oriented differently with respect to the wafer edge for the p and the n side. The dead strips on the n side (in **Fig.6)** are precisely those which are close to the wafer edge. One might speculate that this proximity is responsible for this local increasing of the concentration of dead strips. Conversely, on the p side all the strips are close to the wafer edge but only at one extremity. No comparable effect is observed with the D2 detectors, the fact that they are far from the wafer periphery supports the proposed explanation.



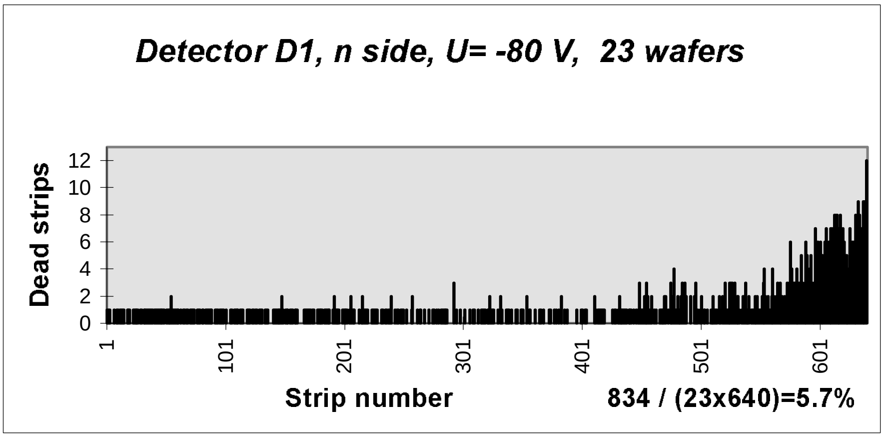


Figure 6: Integrated distributions of the number of dead strips versus the tested strip number for both sides of the D1 detector and for all tested wafers.

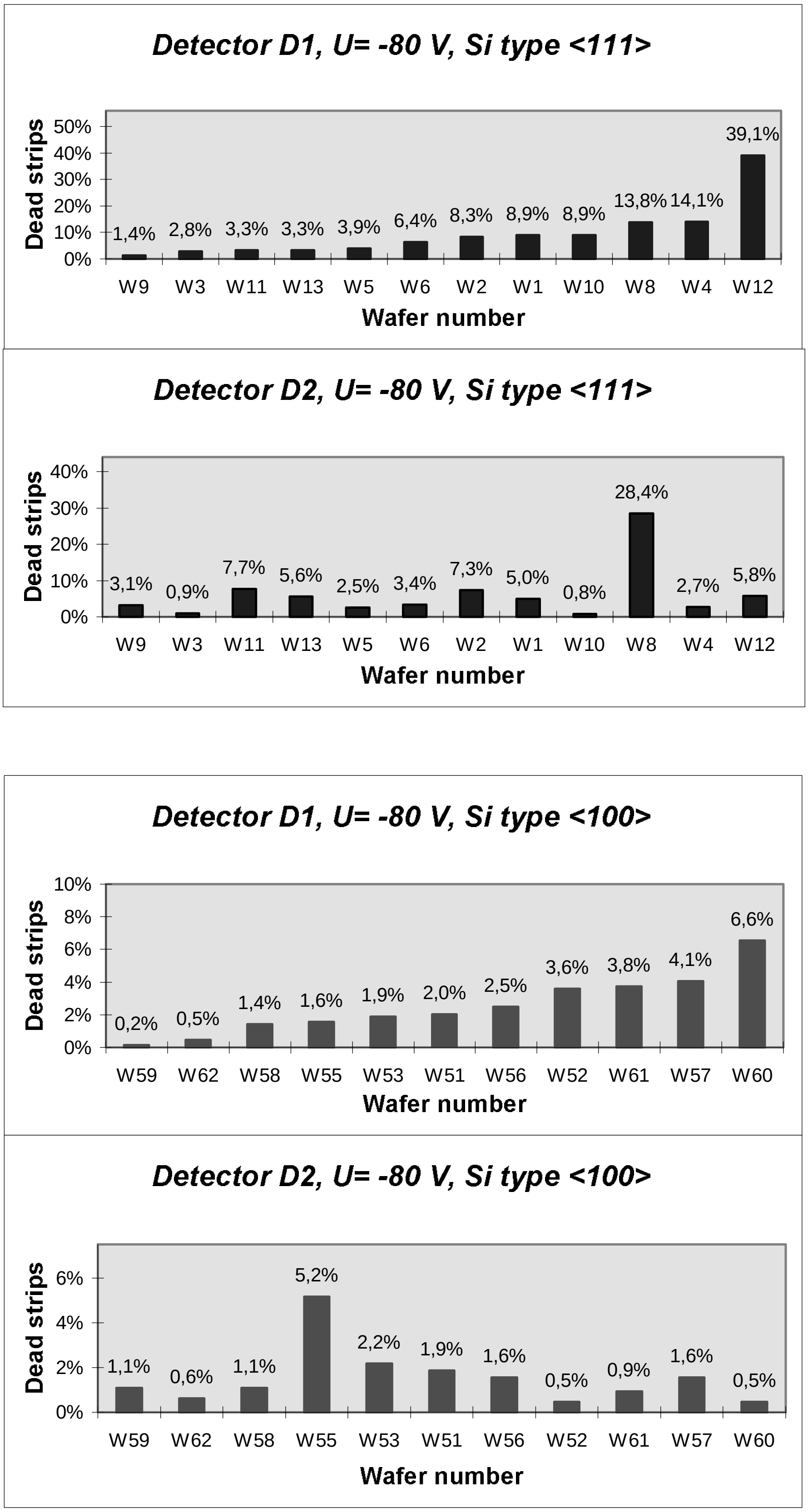


Figure 7: Distribution of the number of dead strips versus the wafer number for detectors D1 and D2, presented separately for different kinds of crystal-cut orientation.

5.4. Global wafer dependence

One may wonder about the dependence of the different effects mentioned above from a wafer to the next.

Fig.7 shows the percentage of dead strips per wafer for the complete set of wafers. The percentages correspond to the worst figure, irrespective of the wafer side. In the figure, the wafers are plotted, in an arbitrary way, as a function of an increasing number of dead strips for the D1 detectors and are identified by W1-W13 for the <111> structure, and by W51-W62 for <100>.

There are clearly no correlation of the quality of coupling capacitors between the D1 and the D2 detectors of a particular wafer and this holds for the two orientation cuts. Beside, the better quality of the <100> structure over the <111> is enlightened in **Fig.7**.

5.5. A statistic evaluation of the tested detectors

One may speculate that, when produced in large quantity, the ALICE SSD's will have to be individually submitted to quick and decisive tests. The insulator measurement described here is a relevant one.

Another important question is the number of detectors to purchase in order to fit the required amount of pieces needed to equip the full two ITS layers.

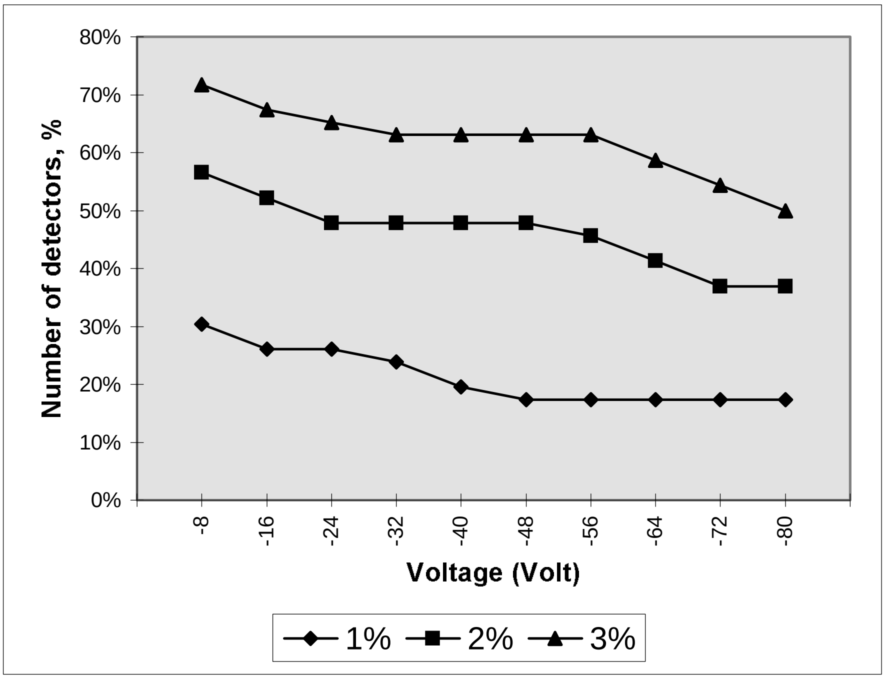


Figure 8: Number of detectors with less than 1%, 2% and 3% of dead strips as a function of the applied voltage.

Some estimate may be infer, for the particular batch of wafers tested here, from **Fig.8**. It shows the percentage of detectors with 1%, 2% and 3% of dead strips (the most pessimistic figure irrespective of the detector side) as a function of the applied voltage.

In the present case, a requirement of 1% of dead strips would imply that only 20% of the detectors would be satisfactory. Still, only 40% would accommodate a 2% dead-strip tolerance. Hence, as many low rates.

Conclusion and Outlook

We have examined the quality of the insulator between the metal and the implanted strips on both side of a batch of 46 double-sided silicon strip detectors not specifically manufactured to be used in the ALICE ITS.

We have observed that the number of dead strips (defects of insulator) increases moderately with the applied voltage. The wafer of <111> silicon type have a substantially larger number of insulator defects than wafers of <100> silicon type. The quality of the insulator is not uniform over different parts of a specific wafer and from a wafer to the next. The most critical zones, where the amount of insulator defects increases, are near the edge of the wafer. Among 46 tested detectors only 8 have a number of dead strips less than 1%, 17 detectors have 2% and 23 less than 3%. Such a rate would be, of course, quite low for a production phase of the ALICE SSD’s.

The present study, although relevant for a quick and decisive quality test of SSD’s, is only partial. It seems quite interesting to quantify the value of the tested AC coupling, also to measure the strip leakage current, the resistance and the capacitance between the neighbouring strips. It is also interesting to check the mechanical continuity of the metal strips. Such tests are already in progress.

Acknowledgements

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