CONTROL COMPLEX FOR A DOUBLE-SIDED MICROSTRIP DETECTOR PRODUCTION AND TESTS

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The controlling system for detector silicon and for a double-sided microstrip detectors (DSMD) characteristics tests is described.
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1. INTRODUCTION

Quality control is the main point for all steps of a microstrip detector design and production. To increase the detector production efficiency control is started from detector silicon characteristics test and it is finished by total control of the good strips yield [1].

2. MEASUREMENTS OF DETECTOR Si CHARACTERISTICS BEFORE AN INGOTS CUTTING

2.1. MEASURING EFFECTIVE LIFETIME OF NONEQUILIBRIUM CHARGE CARRIERS IN SEMICONDUCTOR INGOTS

The technique is used for measuring the distribution nonuniformity of the effective lifetime of nonequilibrium charge carriers (τ_{NCC}) within the semiconductor volume, appearing because of defects and technological peculiarities of producing semiconductor materials.

The effective lifetime τ_{NCC} is measured according to the microwave-cavity photo-modulation technique. The technique is based on analyzing the photoresponse elaxation of the semiconductor under study for a pulsed excitation of the photoconductance.

During the measurement process a semiconductor sample is positioned on the cavity inside which microwave oscillations are excited (Fig. 1). The sample is irradiated with the amplitude-modulated light whose wavelength lies within the range of intrinsic photoconductance of the semiconductor material. The irradiation generates electron-hole pairs in the semiconductor. After the termination of the light pulse the recombination of nonequilibrium charge carriers sets in. The variation of the semiconductor conductivity induces the variation of the cavity quality factor and, consequently, varies the level of the power passing through it. Kinetics of such a variation corresponds to the kinetics of photoconductance. At the output of the measuring instrument a photoresponse signal U is formed and the duration of the signal front drop (equal to the effective τ_{NCC} in the sample under study) to the level U/e is measured.

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At the Kharkov State Technical University of Radio Electronics a measuring device in the form of two units in separate casings has been manufactured (one for measuring wafers and another one for measuring ingots).

The tuning of the measurement regime (at the resonance) is performed manually. The results of measurements are displayed on a digital screen.

The device measures the effective τ_{NCC} in wafers and ingots within the range 10-2000 μs to ±10% accuracy. The range of resistivity values of silicon under study is 0.5-200 kW×cm.

The process of measurements does not require establishing the electric contact with the semiconductor enabling one to avoid special preparation of the sample's surface. The technique makes it possible to perform routine measurements of the τ_{NCC} distribution inside the samples of high resistance detector silicon for monitoring ingots before cutting.

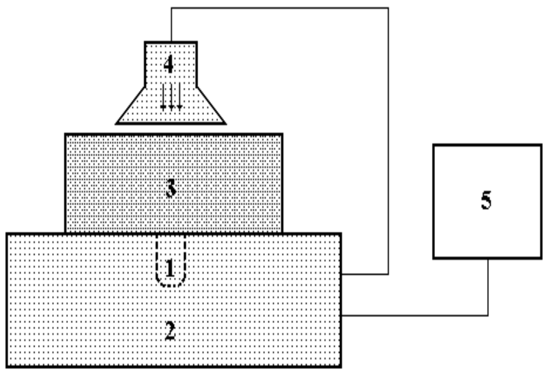

Fig. 1. *Scheme for measuring τ_{NCC}: 1 – the cavity; 2 – the measuring device; 3 – the semiconductor sample; 4 – photodiode; 5 – the oscilloscope.*

2.2. MEASURING THE RESISTIVITY OF HIGH RESISTANCE SILICON

The main objective is to determine the resistivity (ρ) distribution of high resistance detector silicon in ingots.

The measurements are based on a four-probe technique of determining the resistivity of semiconductors [2, 3]. A probe head with four aligned probes with a pitch of S= 0.167 cm is used. The probes are pressed to the semiconductor surface (Fig. 2). A high voltage U_{1-4} is applied across the outermost probes. As a result a current I passes through the semiconductor sample. A potential difference U_{2-3} is measured across the innermost probes. The probe head and a semiconductor sample are placed inside an opaque box. The semiconductor sample is put on a non-conducting table movable along two horizontal axes. The probe head moves along the vertical axis.

The resistivity of the semiconductor (ρ) is determined from the expression:

$$r = 2\pi S U_{2-3} / I$$

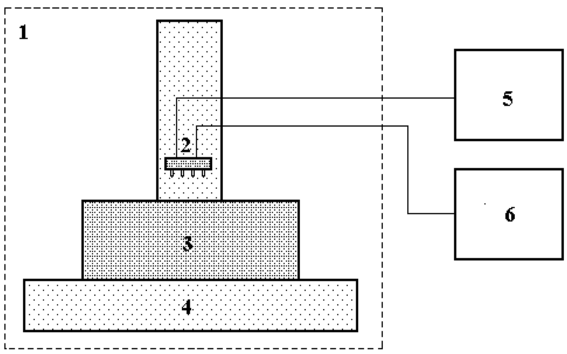

Fig. 2. *Scheme for measuring the resistivity of a semiconductor sample: 1 - the opaque box; 2 - the probe head; 3 – the semiconductor sample; 4 - the non-conducting table; 5 - the power supply; 6 - the voltmeter.*

For increasing the accuracy of measurements a number of conditions are provided:

— before the measurements the surface of the ingot is made free of impurities and partially of the oxide layer;

— the voltage U_{1-4} helps to break down the residue of the oxide layer;

— the internal resistance of the measuring device is $\approx 10^9$ W making the leak currents through potential electrodes negligible;

— the current in the ingot does not exceed 2 μA to prevent heating the silicon volumes being measured;

— varying polarity of the voltage U_{1-4} enables one to restrict the influence of contact phenomena on the result of measurements;

— in order to minimize noise, an autonomous power supply based on galvanic batteries is used.

The technique designed enables one to make routine measurements of detector silicon for monitoring the resistivity distribution of ingots before cutting.

3. TECHNIQUES FOR STATIC CHARACTERISTICS INVESTIGATION OF A DSMD

3.1. PROBE STATION

The station is used to measure the static characteristics of microstrip detectors, photo-diodes and other test structures implanted on a 3- or 4-inch diameter wafer. One can measure the following characteristics:

— current-voltage dependencies of leak currents;

— capacitance and breakdown voltage of capacitors;

— resistance of resistors;

— inter-strip capacitance and resistance.

The measuring station consists of:

— the opaque box;

— microscope;

— coordinate table;

— precise-positioned probes;

— lifting platform for precise-positioned probes;

— a set of measuring instruments;

— mechanical adapter for the measurements of characteristics of DSMD and double-sided test structures on a silicon plate.

3.1.1. The microscope is located on a movable chariot that may be displaced with screws in horizontal directions: 100 mm in one direction and 40 mm in another one.

3.1.2. The coordinate table moves in two directions over 100 mm in the horizontal plane. A chuck with a vacuum lock for a silicon plate is mounted on the table. This chuck may be rotated through 360° around its axis and fixed with a stop-screw.

3.1.3. The precise-positioned probe is a device with four degrees of freedom aimed at providing a reliable electric contact between the contact needle and the contact area on the silicon wafer. The device can move the needle, fixed a rod ~100 mm long, around the vertical axis as well as along straight lines in three mutually orthogonal directions. The rotation is rough and it serves for a preliminary positioning of the needle in front of the contact area or for moving this needle away on readjusting.

Rotation may be made within 360°. The linear displacements are smooth and precise and they provide the contact of the needle with area less than 50×50 μm^2. The horizontal displacements are within 15 mm, and the vertical ones are within 10 mm. The probe is fixed at the platform with a special support possessing a "dove-tail" lock. On this support the probe is displaced in one horizontal direction within 40mm and fixed with a special spring-clamp.

3.1.4. The lifting platform is a solid plate with enough space for 1 to 6 precise-positioned probes on their supports. The platform together with probes may be displaced smoothly by a lever in the vertical direction over a distance up to 5 mm. The lever is equipped with a brake to exclude the self-lowering of the platform.

3.1.5. All mechanisms of the measuring station are mounted on a solid steel platform inside the opaque box. This decreases the amplitudes of possible vibrations and makes the design sufficiently rigid. On installing the plate inside an opaque box, porous resin spacers are placed under the plate for reducing vibrations.

The opaque box cover is removable and balanced with a weight suspended on the line going over the castor. This decreases shocks accompanying opening and closing the box.

3.2. MECHANICAL ADAPTER

The adapter is used for providing the measurements of characteristics of double-side detectors and test structures on a silicon wafer before its cutting. The adapter possesses two inner (own) precise-positioned probes providing the displacement of contacting needles to any point on the semi-circle 100 mm in diameter located in the horizontal plane (Fig. 3). By design the pro(Fig. 1)bes are on chariots displaced in two horizontal directions with the help of a pair of screw. On the chariot a rotatable circle is mounted so that with the help of a worm gear we may rotate the needle-holding rod through any angle in a horizontal plane to provide a rough positioning of the needle close to the required one. Via linear displacements of the chariot the needle is displaced precisely to the required contact area. The device provides for smooth and precise lowering or lifting of the needle. This motion is performed ~3 mm above the plate surface.

The silicon wafer is positioned in a special seat consisting of two dielectric rings one of which is rigidly fixed in a basic frame of the adapter and another one is free serving for pressing the silicon plate to the first ring. Six pressing springs are located over the circumference of the metallic ring fixed to the basic frame with two clamps. The clamps are of a "slot-washer" type enabling the quick removal and installation of this ring when the silicon wafer is changed for another one. The silicon plate is installed from the side opposite to the needle holders. From this side the total area of the plate is accessible for establishing contacts with external probes with precise positioning.

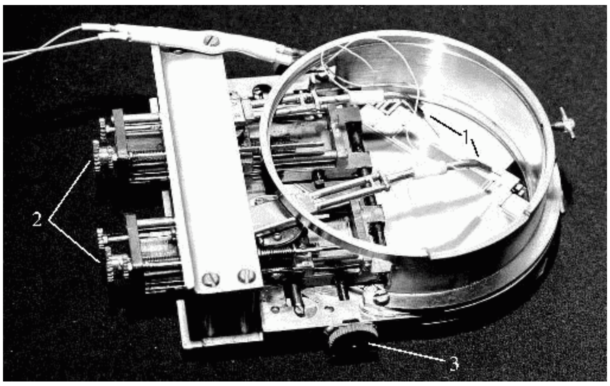

Fig. 3. *The mechanical adapter for static characteristics measurements of double-sided microstrip detectors. 1- two microposition probes; 2, 3- the control handles of the probes.*

The adapter described above is made in two modifications regarding its installation into the static probe station. The first modification concerns the way in which the adapter is installed on the chuck of the coordinate table and fixed with special screws. The contacts with internal probes may be made under the microscope of the measuring station as well as under another similar microscope.

This compact adapter may be used as separated equipment for simplified measurements of characteristics of a double-sided microstrip detector for example at production (Fig. 4). However, during installation of the adapter into the static probe station, the contact may be broken due to unavoidable shocks.

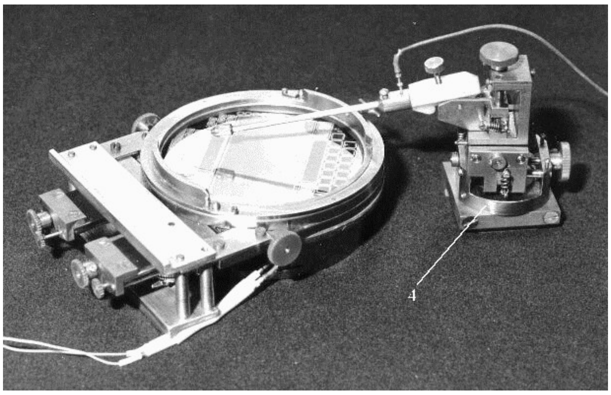

Fig. 4. *The overturned adapter and separated microposition probe (4) prepared for simplified measurements of a double-sided microstrip detector characteristics.*

The second modification (Fig. 5)concerns the way for a steady installation of the adapter on the coordinate table of the static probe station instead of the chuck. The adapter is turned over in special cone bearings without removing it from the coordinate table. The operation with external and internal probes is accomplished under the microscope of the measuring station.

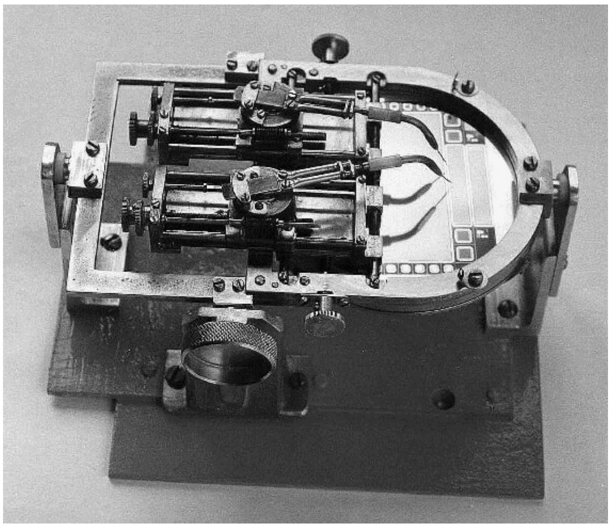

Fig. 5. *The second modification of the mechanical adapter for conditions of static probe stations using.*

The adapter is fixed with a special screw in two horizontal positions. This provides a stable state of the adapter for measuring and frees the device of unnecessary shocks.

The contact needles of internal probes of the adapter are removed in the absence of the silicon wafer in the seat, because the plate surface may be damaged (Fig. 6,7). The needle holder containing a new needle has to be adjusted after a silicon wafer dummy made of duraluminum is installed in the nest. This enables one not to damage neither the plate nor the needle.

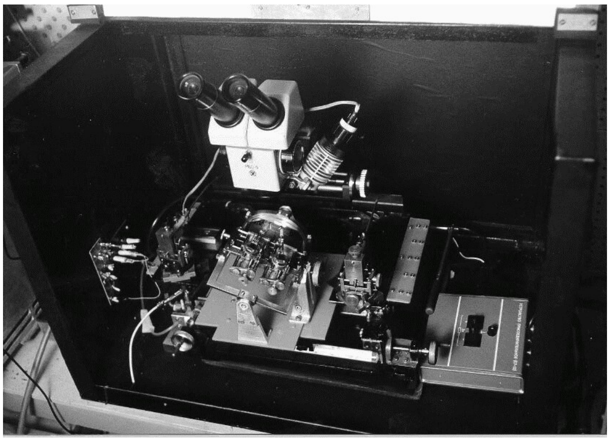

Fig. 6. *The second modification of the mechanical adapter with rotation give possibility for quick changing of the detector side (the adapter is in rotation).*

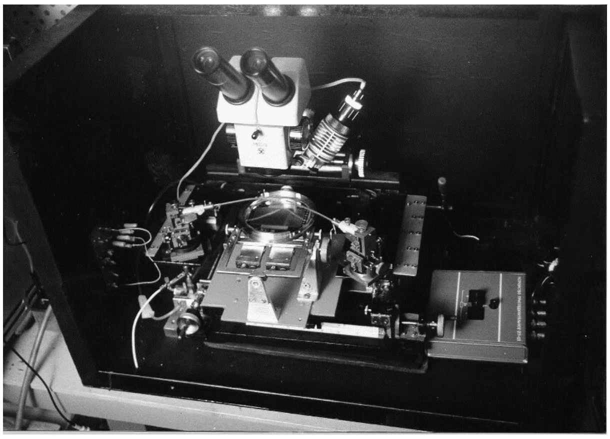

Fig. 7. *Measurements using the mechanical adapter. The wafer is in the adapter. The probes of the static probe station are visible on the wafer.*

4. AUTOMATIC BENCH FOR MEASURING THE YIELD OF GOOD DSMD

In order to check the detector suitability one should perform a large number of standard measurements at separate strips. Performing these measurements automatically, one can reduce the test period substantially and avoid possible operator's errors. To this end, a bench is developed intended for automatic measuring the DSMD parameters (Fig. 8). The bench permits one to monitor the capacitance of coupling capacitors and yield of good capacitors automatically.

The bench consists of a semi-automatic probe station, an instrument measuring capacity, a CAMAC crate and a computer. The probe station enables one to move the object table with the detector in the horizontal plane within the field 80×80 mm with the step multiple of 25 μm and 10 μm along the coordinates X and Y, respectively. The station also lifts or lowers the object table with the detector providing the contact of the detector with a stationary probe with precise positioning. The probe has been described above. The detector is fixed on the table with vacuum lock. The object table

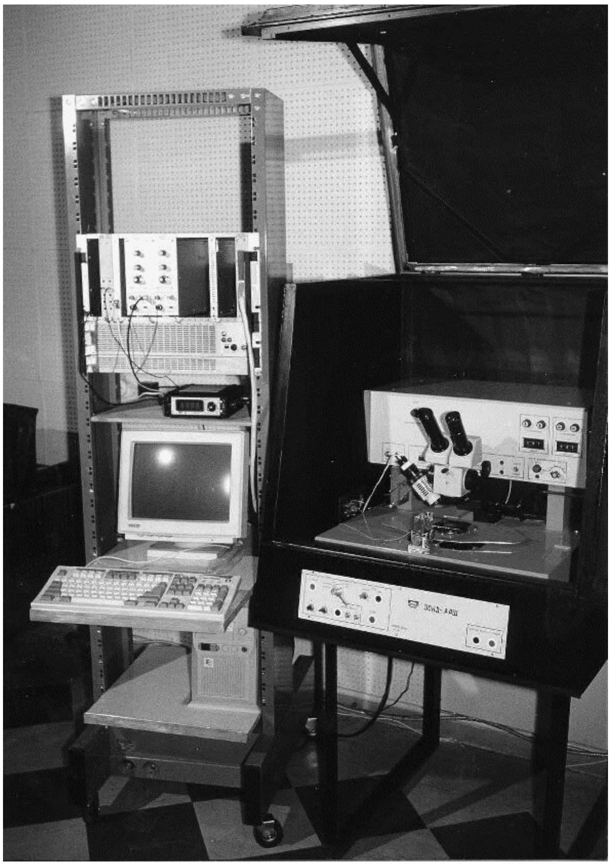

Fig 8. *Automatic bench for measuring DSMD coupling capacitors.*

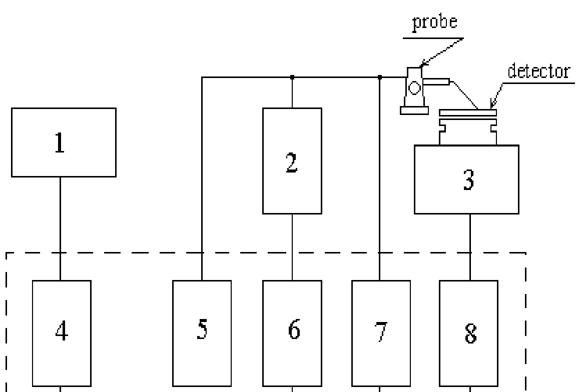

Fig. 9. *Block-diagram of the automatic bench: 1 - computer; 2 - capacitance meter; 3 - probe station; 4 - controller; 5 - supply unit; 6-7 are analog-to-digital converters; 8 - control unit.*

may be rotated around its axis and fixed. The probe station is placed inside an opaque box. Fig. 9 presents the block-diagram of the bench.

In order to test a detector, one should measure the voltage drop across coupling capacitors of every strip and their capacitance when a test voltage is applied via the needle of a precise-positioned probe. The electric scheme of measurements is depicted in Fig. 10.

The bench operates as follows:

— the detector is fixed on the movable object table and is displaced under the needle of a precise-positioned probe;

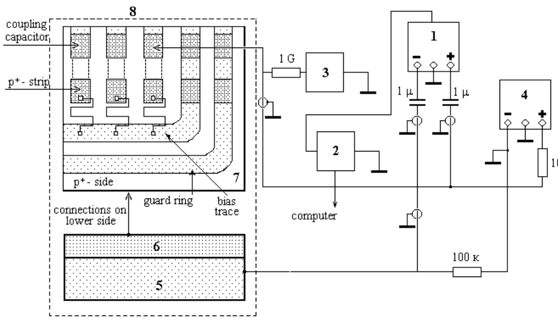

Fig. 10. *Electric scheme for measuring capacitance of coupling capacitors: 1 - capacitance meter; 2-3 - analog–to-digital converters; 4 - power supply; 5 - object table; 6 - aluminum foil; 7 - micro–strip detector (MSD); 8 - opaque box.*

— the object table is lifted and the probe is installed on the first strip;

— the opaque box is closed and the computer initiates the measurement program.

On initiation the program requires introduction of some parameters:

— the number of steps without measurements (this parameter enables one to move to any area of the detector and start measurements there);

— admissible deviation of the capacitance from the normal value in %;

— name of the file where the results of measurements are saved.

The program performs the following operations:

— table (detector) lifting;

— readout from both analog-to-digital converters;

— displaying a strip number, capacitance value of the coupling capacitor and voltage drop across it on the screen;

— table lowering;

— displacing along a prescribed direction with a prescribed step.

Then the cycle is repeated.

There are two versions of the program differing in the algorithm of determining the value of the normal capacitance of a capacitor:

1. The version when an operator determines the value of the normal capacitance.

2. Automatic determination of the normal capacitance value.

With the first version the program measures the first capacitor, displays its capacitance and voltage drop across it and asks, "Can this value be regarded as normal?" After "Yes", the program automatically measures other capacitors comparing their capacitance with this value.

With the second version the program automatically measures all capacitors, chooses the most frequently obtained capacitance value and takes it as normal. Then the program analyzes all measurements and measures again those strips for which the capacitance values of coupling capacitors are above or below the admissible deviation.

If the bench registers a zero capacitance (it is possible only if the probe is not in contact with the detector) the program terminates the measurements and gives a sound signal. After correcting the probe installation, there is an option to proceed with automatic measurements from the same location. An option exists for terminating the bench operation at any time.

The automatic bench has been employed for making a set of measurements on 750-strip MSD and its workability has been demonstrated. The bench measures one side of detector (750 strips) [4, 5] during from 7 to 10 minutes. The time depends on the number of broken capacitors.

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