KHARKIV TEST PLATFORM FOR RESEARCH AND DEVELOPMENT OF Si SPECTROMETRIC PLANAR DETECTORS AND DETECTORS ARRAYS FOR MEDICAL APPLICATION

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A universal test platform for research and development of planar radiation detectors for use in medicine has been created having the possibility of obtaining complete information about the characteristics of the detector before creating a detecting module with specialized electronics. 5 jobs were created with the ability to perform the following work: measurement of the electrophysical characteristics of individual detectors and selected detection elements of the matrices based on the station with manual movement of microprobes; determination of the yield of suitable detector elements of matrices using a test station with automated microprobe movement and automated collection and processing of electrophysical measurement data; measurement of the energy resolution (ER) of individual silicon detectors, "scintillator-silicon photosensor" type detectors and measurement of the ER of selected matrix elements before creating a detection module with specialized electronics.

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INTRODUCTION

The Kharkiv test platform is created on the basis of 25-year experience of KIPT group in research, development, creation, and operation of multichannel silicon microstrip detectors in high energy physics experiment [1 - 7]. In the Kharkiv test platform (Fig. 1) for development of spectrometric detectors the following potential platform performances were planned and realized:

- Measurement of electrophysical characteristics of individual detectors and separate detecting elements of detector arrays;
- Measurement of the yield of the operable detecting elements of detector arrays;
- Measurement of energy resolution of individual silicon detectors, combined "silicon photosensor-scintillator" detectors and separate detecting elements of detector arrays before the creation of the detecting module with multichannel read-out electronics;
- Possibility of detector modules assembly, including assembly of multichannel modules on the basis of detectors arrays and multichannel read-out electronics;
- Possibility of thermal treatment of detectors and detecting modules.

For providing above performances the following facilities of the test platform were created:

- A test station with the automated movement of microprobes and the automated storage and processing of measurement data;
- A test station with manual movement of microprobes and with visual registration of measurement data;
- A special spectrometer system for energy resolution measurement of individual silicon detectors, individual combined "silicon photosensor-scintillator" detectors and separate detecting elements of detector arrays before the creation of the detecting module with multichannel read-out electronics;
- Zone for detecting modules assemblage, including assembly of multichannel modules on the basis of detector arrays and multichannel read-out electronics with possibilities of thermal processing of detecting modules.

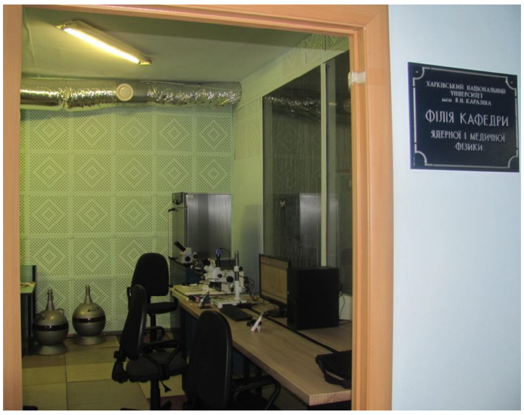

Fig. 1. Entrance to the room of the Kharkiv test platform for research and development of Si spectrometric planar detectors and detectors arrays for medical application

1. AUTOMATED TEST STATION

The test station with the automated movement of microprobes and the automated storage and processing of measurement data designed for the measurement of the detector electrophysical characteristics and the yield of operable detecting elements in detector arrays.

The automated test station was created on the basis of the microstep probe station ZOND-A4III which was employed previously in the USSR for testing the chips of integrated electronics (Fig. 2).

During the creation of test station with the automated movement of microprobes and the automated storage and processing of measurement data the following main R&D were carried out:

- The microstep probe station ZOND-A4III device was housed in a light-tight box;
- Mechanical movements of the object stage of the probe station ZOND-A4III were automated;
- An interface board for matching the signals of the input-output (I/O) register and probe station ZOND-A4III was developed;

• A commutation device was developed and manufactured intended for the computerized connection of the measuring schemes in the process of automated testing of silicon multichannel arrays for the determination of the yield of operable detecting elements;

• Programs for storage and processing data of measurements were developed;

• Testing of the simultaneous automated movement of the object stage of the microprobe station and the automated measurement and storage of the measurement data was carried out.

Fig. 2. General view of the automated test station with the automated movement of microprobes and the automated storage and processing of measurement data of detector electrophysical characteristics

Automation of the mechanical movements of the object stage of the probe station ZOND-A4III. The probe station ZOND-A4III allows to move the tested detector array located on the object stage in two directions and provides connection to contact needles by lifting and lowering the object stage.

The object stage is moved with stepper motors. Stepper motors are connected to the pulse generating circuits of the probe station. The stepper motors' schemes are controlled by pulses formed in the output register of the USB-based 24-channel digital I/O device. A special matching board was developed for matching the signals of the I/O register and the probe station ZOND-A4III.

In order to control the register of "USB-based 24-channel digital I/O device" to the computer USB port a corresponding driver and a Universal Library (UL) of low level programs was installed. A library of programs realizing interaction functions with programs of low level of UL library and the test program for checking the control of the test station in the step-by-step mode were developed. Delays in the formation of the operating pulses and for stable operation of stepping motors were selected. The functions of the step-by-step movement in X and Y axes in both directions and functions of lifting and lowering of the object stage were realized. The check of the control system of the test station within the developed test program was carried out.

Commutation facility for the automated test station. A commutation facility is intended for automatic connection of measuring circuits during testing of electrophysical characteristics of silicon multichannel arrays and silicon planar detectors in order to determine the yield of operable detecting elements. The commutation facility is governed by a personal computer by means of specially developed program operating via I/O registers of USB 1024-LS bus connected to USB port of the personal computer. Keithly 6487 Picoammeter/Voltage Source and 895 BK Precision LCR Meter are connected to the commutation facility for the automated measurement operation.

For creation of the commutation facility a schematic diagram has been developed, as well as the printed-circuit board were developed and manufactured (Fig. 3).

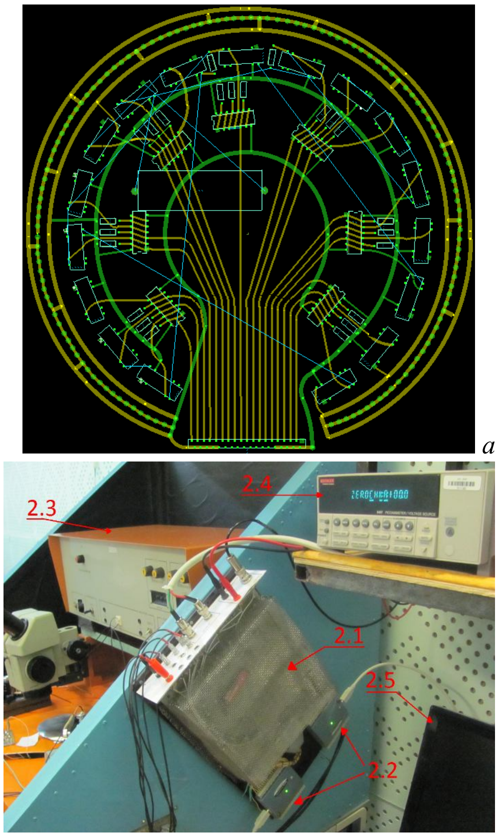

Fig. 3. Commutation device: commutation device board for Meder DIP05-1C90-51D relays (a). Commutation device mounted on the light-tight case of automated test station (2.1); 2.2 – USB 1024-LS input-output registers; 2.3 – microstepping device; 2.4 – meters; 2.5 – computer display (b)

For commutation implementation the printed-circuit board was equipped with the Meder DIP05-1C90-51D relays. For reduction of dielectric losses in a material for printed-circuit boards the boards have been manufactured from a foil-coated Teflon plate. They were made using specially developed photo masks. The manufactured and soldered board was mounted on a chassis to which the input-output registers also were attached, as well as a panel with sockets for connection to measuring devices and probes.

The investigation of a possible influence of the commutation device on the results of detector parameters measurement was carried out by their comparison with results of measurements carried out directly, without the commutation device (Table).

Results of measurements of the S6 detector parameters obtained with the use of the commutation device and measured directly for comparison are given in Table. U is the depletion voltage applied to the detector; I_{a0} – the leakage current of the detector active region, and I_{gr} – the leakage current of the detector guard ring.

Measurements of S6 Si-detector

With the commutation device			Directly	
U(V)	I_{a0} (pA)	I_{gr} (pA)	I_{a0} (pA)	I_{gr} (pA)
10	10.5	288	8.3	279
20	9.5	330	7.5	320
30	9.5	370	7.57	359
40	9.5	401	7.68	392
50	9.5	427	7.66	421
60	9.5	452	7.72	448

It is obvious that the difference in results of measurements with the use of the switchboard and of the same detector directly is insignificant.

Fig. 4 presents the results of three passes of measurements of the leakage current of a multichannel silicon array using the microstepping device which provided connection to contact windows sized 60×100 μm.

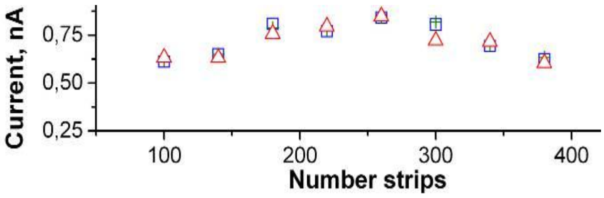

Fig. 4. Trial measurement of the leakage current of Si matrix elements at automated test station with the use of the commutating device and microstepping device of the automated test station

Each step is equivalent to 4100 μm or 40 strips. There are observed a stable contact at operation of the microstepping device and good repeatability of results of the leakage current measurements of the array elements.

2. THE TEST STATION WITH MANUAL MOVEMENT OF THE OBJECT STAGE

The test station with manual movement of the detector object stage and with visual registration of measurement data of detector electro-physical characteristics was modernized and mounted in the Kharkiv platform. It allows providing necessary measurements of detector electro-physical characteristics and will be very useful to users starting to study detectors and carrying out measurements. The general view of test station with manual movement of the object stage and visual recording of measurements data is shown in Fig. 5.

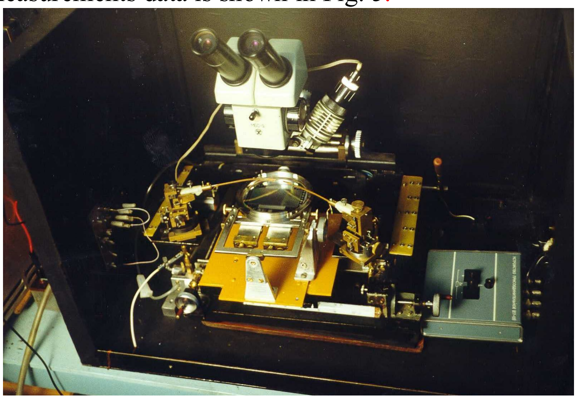

Fig. 5. A general view of the test station with manual movement of the detector object stage and with visual registration of measurements data

3. SPECIAL SPECTROMETER SYSTEM

The platform for the development of silicon uncooled detectors should have a possibility to measure the energy resolution of one-channel uncooled detectors, combined "silicon photosensor-scintillator" detectors and separated detecting elements of two-dimensional arrays. Therefore for such measurements the specialized one-channel spectrometer (Fig. 6) was developed and fabricated for platform by "Department of Radiation Physics and Multichannel Track Detectors" of NSC KIPT (https://www.kipt.kharkov.ua/ihepnp/files/physvypr.html).

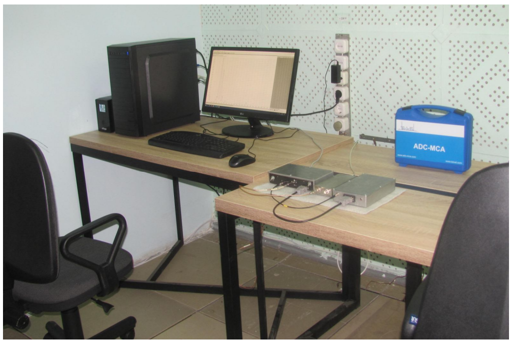

Fig. 6. A general view of a specialized spectrometer and special box (rightmost) for holding and connecting of non-encapsulated detectors

One-channel Si detectors, combined "scintillator- Si photosensor" detectors and two-dimensional arrays are placed in special box for measurements (Fig. 7).

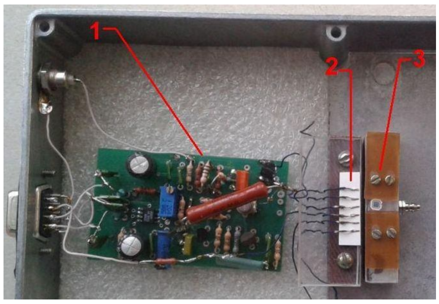

Fig. 7. Special box with preamplifier (1) for energy resolution measurements of non encapsulated detectors

For connection of non encapsulated silicon detector (3) to the preliminary amplifier (1) the transitional dielectric plate with intermediate contacts, already connected to the preamplifier (2), is provided.

The contact pads of the non-encapsulated silicon detector fixed in the holder in immediate proximity to the transitional plate are connected to the plate contacts by bridges made of 18 or 25 μm aluminum wire by ultrasonic microwelding. Special box is connected to the spectrometer mainframe by a cable.

The spectrometer includes, besides the special box for holding the investigated non-encapsulated detecting element, spectrometric amplifier, spectrometric ADC, connected to computer or notebook, and a power supply unit (DC/DC converter). The voltage from the computer USB-interface (+5 B) is used as a primary power supply that ensures the autonomy of the spectrometer.

The spectrometer with box allows measuring detector energy resolution before the creation of module with specialized readout electronics while developing the detectors.

4. ZONE FOR ASSEMBLING AND THERMAL PROCESSING OF DETECTING MODULES

A zone for assembling and thermal processing of detecting modules on the base of single-channel detectors, of detector arrays with single-channel and multichannel read-out electronics was created accounting the experience of the team from NSC KIPT [8, 9] as well as the experience of foreign research centers. The general view of the created assemblage and thermal processing zone is shown in Fig. 8.

Fig. 8. Detector modules assembling and thermal processing zone

The main components of detecting modules are non-encapsulated silicon sensors and silicon elements of read-out electronics which are extremely sensitive to mechanical damage and chemical pollution. The size of the elements is of order of micrometers that demands the use of the equipment and tools designed for the assembly of microelectronics items which provides sparing modes of tiny objects processing. Employed materials and technological processes must also rule out chemical, mechanical and thermal damage.

The assembling and thermal processing zone includes the microwelding installation US.IMM-1 (equipment used in the former USSR for a microelectronics production) as well as the new equipment, namely a KONUS CRYSTAL PRO stereo microscope, a digital video camera Levenhuk M800 Plus, a Performus III dispenser with the MIKROS microportioning device, a Memmert UF-50 thermocase (Figs. 9-12), a vacuum pump N022AN.18IP20, an ultrasonic bath PS-08A, a personal computer (not shown).

Fig. 9. The microwelding installation US.IMM-1 (equipment used in the former USSR)

Fig. 10. KONUS CRYSTAL PRO stereo microscope with digital video camera Levenhuk M800 Plus

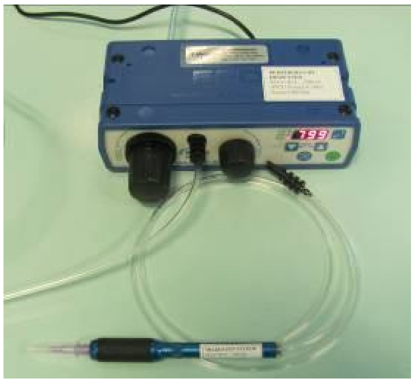

Fig. 11. Performus III dispenser with the MIKROS microportioning device

Fig. 12. Memmert UF-50 thermocase

In addition, the following materials and tools are used to ensure the development and manufacture of various detecting devices based on silicon planar detectors:

- An aluminum wire for microwelding of the BWALALSI1%18MY and BWALALCR%25MY type in diameter of 18 and 25 μm from Heraeus Co;
- Microwelding tools for US welding of the specified wire of the FP45A-W-1515-L-CM and FP30A-W-2020-L-CM type from Small Precision Tools Co;
- Tips and syringes of various size for Performus III dispenser for application of glue in microdoses;
- A number of high-purity dielectric and conducting glutinous materials which do not worsen the characteristics of silicon detectors, including Epo-Tek H70S, Epo-Tek H20S, and Epo-Tek 930-4 from Epoxy Technology and Elastosil Solar 2202 from Wacker Chemie AG.

The created assemblage and thermal processing zone allows to carry out the following operations:

- Ultrasonic microwelding of wire leads of 18 and 25 μm diameter to silicon crystals, printed boards and other components of detector modules;
- Gluing of tiny parts of modules using epoxy and silicone glutinous materials;
- Heat treatment of components and assembly parts of detector modules with temperature up to 300ºC;
- Visual inspection of assembled objects, both with an optical microscope, and with a video camera for the computer screening with the magnification up to 180×;
- Cleaning of components of the module and tools in an ultrasonic bath;
- Encapsulation of detecting modules.

CONCLUSIONS

The universal platform for research and development of planar radiation detectors for use in medicine has been created and tested on real operations of investigation and creation of detecting modules.

The platform allows to carry out a full cycle of detectors R@D, assemblage and thermal processing operations in the manufacture of one- and multichannel detecting devices on the basis of silicon planar detectors.

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ХАРЬКОВСКАЯ ТЕСТОВАЯ ПЛАТФОРМА ДЛЯ ИССЛЕДОВАНИЙ И РАЗРАБОТКИ СПЕКТРОМЕТРИЧЕСКИХ ПЛАНАРНЫХ Si-ДЕТЕКТОРОВ И ДЕТЕКТОРНЫХ МАТРИЦ ДЛЯ МЕДИЦИНСКОГО ПРИМЕНЕНИЯ

А.А. Каплий, С.К. Киприч, Н.И. Маслов, В.Д. Овчинник, С.М. Потин, И.Н. Шляхов, М.Ю. Шулика, Г.П. Васильев, В.И. Яловенко

Создана универсальная тестовая платформа для исследований и разработки планарных детекторов излучения для использования в медицине с возможностью получения полной информации о характеристиках детектора и матриц детекторов для создания детектирующего модуля со специализированной электроникой. Созданы 5 рабочих мест с возможностью выполнения следующих работ: измерение электрофизических характеристик отдельных детекторов и выбранных детектирующих элементов матриц на основе станции с ручным перемещением микрозондов; определение выхода годных детекторных элементов матриц с использованием тестовой станции с автоматизированным перемещением микрозондов и автоматизированным накоплением и обработкой данных электрофизических измерений; измерение энергетического разрешения (ЭР) отдельных кремниевых детекторов, детекторов типа «сцинтиллятор-кремниевый фотосенсор» и измерение ЭР выбранных элементов матриц для создания детектирующего модуля со специализированной электроникой.

ХАРКІВСЬКА ТЕСТОВА ПЛАТФОРМА ДЛЯ ДОСЛІДЖЕНЬ І РОЗРОБКИ СПЕКТРОМЕТРИЧНИХ ПЛАНАРНИХ Si-ДЕТЕКТОРІВ І ДЕТЕКТОРНИХ МАТРИЦЬ ДЛЯ МЕДИЧНОГО ЗАСТОСУВАННЯ

О.А. Каплій, С.К. Кіпріч, М.І. Маслов, В.Д. Овчинник, С.М. Потін, І.Н. Шляхов, М.Ю. Шуліка, Г.П. Васильєв, В.І. Яловенко

Створена універсальна тестова платформа для досліджень і розробки планарних детекторів випромінювання для використань в медицині з можливістю отримання повної інформації про характеристики детектора та матриці детекторів до створення детектуючого модуля зі спеціалізованою електронікою. Створено 5 робочих місць з можливістю виконання наступних робіт: вимірювання електрофізичних характеристик окремих детекторів і обраних детектуючих елементів матриць на основі станції з ручним переміщенням мікрозондів; визначення виходу придатних детекторних елементів матриць з використанням тестової станції з автоматизованим переміщенням мікрозондів і автоматизованим накопиченням і обробкою даних електрофізичних вимірювань; вимірювання енергетичної роздільної здатності (ЕРЗ) окремих кремнієвих детекторів, детекторів типу «сцинтилятор-кремнієвий фотосенсор» і вимір ЕРЗ обраних елементів матриць до створення детектуючого модуля зі спеціалізованою електронікою.