SILICON MICROSTRIP DETECTORS R&D AT UB/EPPG AND IMT BUCHAREST AND COLLABORATION WITH INFN ITALY

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Abstract

The purpose of this paper is to present an overview of the results obtained at Bucharest by UB/EPPG, in close relation with IMT, in the field of R&D and experiments on silicon microstrip detectors. Some contribution of Romanian peoples working at INFN in different international projects are also presented, in the framework of this collaboration.

- Talk presented at INFN Pisa -
Silicon Microstrip Detectors R&D at UB/EPPG and IMT Bucharest and Collaboration with INFN Italy

1. Introduction

The purpose of this paper is to present a general overview of the common R&D efforts made at the University of Bucharest (UB) Experimental Physical Particle Group (EPPG) and the Institute of Microtechnology Bucharest (IMT) in the framework of their collaboration with different research groups from Instituto Nazionale di Fisica Nucleare (INFN) Italy [1].

The paper is structured in two main parts. The first part is an overview of the results obtained at Bucharest by UB/EPPG, in close relation with IMT, in the field of R&D and experiments on silicon microstrip detectors. The second part presents some contribution of Romanian peoples working at INFN, in the framework of this collaboration. Some final conclusions are drawn at the end.

2. R&D Activities at Bucharest

2.1. First trial

Our activity in the field of radiation sensors dates back to 1991, when Prof. Samuel Ting, chief of the L3 Experiment at CERN, followed the invitation of Prof. Alexandru Mihul (Romanian EPPG leader), to come at Bucharest.

Proofs of our capability to design and manufacture large structures on 4” silicon wafers with resolution of 5μm, were required also from Prof. Spillantini (INFN Florence) to whom we show during his visit in Bucharest our first microstrip detector (see Fig. 1) realised on low resistivity silicon wafers.

Fig. 1. First design and manufacturing of silicon microstrip detectors at Bucharest.
At that time, a common R&D efforts was started by the laboratories and industries interested in participation in HEP experiments: EPPG with Prof. Alexandru Mihul, IMT with Dr. Cristian Gingu, Microelectronica S.A. with Dr. Mihai Dinale.

2.2. First prototype

With the gratitude of Prof. Samuel Ting and Prof. Roberto Battiston, the L3 group at CERN and Perugia provided few high resistivity 4" wafers and necessary design geometry requirements to design and manufacture a prototype silicon microstrip detector. In this framework, a real silicon microstrip detector prototype was produced and tested at Bucharest for the first time. It was intended as an element of a detector system situated in front of the electromagnetic calorimeter for the L3 experiment, in an e+e- crossed beam of about 60 GeV.

The main design parameters of this detector are the following (see Fig. 2):

- 4 inch silicon wafer;
- 64 radial strips;
- strip shape is trapezoidal;
- strip radial opening is 0.375°;
- strip length is 78mm;
- interstrip gap is 100µm;
- inner radius is 74.5mm;
- outer radius is 155.5mm;
- total active angle covered is 24°;
- all the strips are surrounded by a floating guard ring of the same type as the substrate;
- the detector active area is 37.57cm².

To manufacture this detector, on high resistivity silicon, we develop our own processing technology. After processing, I-V and C-V strips characteristics were measured in different biasing configurations and in different laboratories (Bucharest, CERN, JNIR Dubna. We did also an experimental data modelling for parameter extraction of strip capacitance, interstrip capacitance and average effective impurity concentration. Then nuclear tests were performed at the Faculty of Physics, Bucharest University, on a standard spectrometric chain using a ²⁴¹Am α-particle source. The results of this work are presented in [2], [3].

2.3. Test Chip Design

A test chip was designed, 'in house' with the aim to improve the broad variation of the leakage current, by investigating the effect of different layout design and technological processes. The principal features of this test chip are:

- microstrip- and pad-type detection structures;
- multiple guard rings option (separate mask);
• AC or DC coupled strips (3 contact masks);
• pad and microstrip diodes with different areas/perimeter ratio;
• special test structures for technological process control;
• possibility to combine different optional masks.

The design was complete using SL2000 IC design software from Microelectronica S.A. Bucharest, but because of the lack of resources it was not yet put into silicon.

2.4. A Microstrip Gas Chamber Plate Design

A mask plate was designed (with the assistance of EPPG, Prof. Tatiana Angelescu) and manufactured (IMT) with the aim to be assembled in a Microstrip Gas Chamber (see Fig. 3). Main characteristics of this design are:

• borosilicate glass substrate;
• chromium metalisation 900Å thickness;
• X-Y particle co-ordinate design;
• strip pitch 200µm;
• total number of channels 150;
• detection active area 12 cm²;
• anode width 10µm;
• cathode width 80µm.

Fig. 3. Microstrip Gas Chamber Plate

2.5. A Second Prototype

Design, mask making and wafer processing were done at IMT and Microelectronica Bucharest in a co-operation with SEA Spa Roma, Italy, for a new prototype of silicon microstrip detectors [4]. Starting from the Italian’s detector design requirements and high resistivity silicon wafers, we did the layout, working masks and technology processes (see Fig. 4). We processed 30 high resistivity wafers, in 5 technological variants. Rough I-V and C-V measurements gave us, on some wafers, leakage currents densities down to 10nA/cm². This work is in progress.

Fig. 4. Design, mask making and wafer processing at Bucharest in a co-operation with SEA Spa Roma, Italy.
2.6. Development of Double Face Wafer Processing Technology

Considering a requirement made by the CMS group of Pisa, Prof. Guido Tonelli, and the UB/EPPG, we developed at IMT a technique for double side silicon wafer processing, using single side alignment - exposure machines.

The basic idea is to realize, on both wafer’s faces, some registered alignment marks, prior to detectors’ processing [5]. If this is done, a double face lithography can be reduced at two single face lithography processes, using this registered alignment marks.

Our procedure necessitates the construction of two additional masks, which contain only these initial double face alignment marks. These masks have to be part of the detector’s mask set. Anyhow, in some cases, we can still match the alignment masks with customer masks’ set.

We used this procedure to manufacture double side microstrip detectors for mechanical tests in the CMS and CDF-ISL Experiments.

2.7. Microstrip Detectors Manufactured at IMT for Mechanical Tests in INFN Experiments

Starting from 1996 we manufactured at IMT different microstrip detectors (single side SS or double side DS, on 4” silicon wafers) for mechanical tests applications:

- for CMS Barrel at INFN Pisa: 50 SS + 50 DS (1996);
- for CMS Barrel at INFN Perugia and Bari: 200+300 SS (1996);
- for CMS Forward at INFN Florence: 40+40 SS (1997);
- for CMS Barrel at INFN Bari: 130 SS (1997);

We also made for FNAL Chicago two test structure for automatic bonding machines’ tests: design, mask making and 100 wafer processing (1997).

![Fig. 5. SMD for mechanical tests produced at IMT for INFN experiments.](image-url)
3. R&D Activities of UB/EPPG and IMT in INFN Italy

3.1. Collaboration in the SMD Project

Our collaboration with the L3 Silicon Microvertex Detector is mainly related to the Perugia Group and is co-ordinated by Prof. Roberto Battiston and Prof. Alexandru Mihul. It started in 1994, with an activity related to SMD half-ladder manufacturing in INFN’s clean room from Perugia. The ‘starting’ romanian team was composed of Dr. Cristian Gingu from IMT and Dr. Vasile Postolache from Microelectronica S.A. First, during the training period with Dr. Michele Pauluzzi, we learned to operate specific machines (CMMs, K&S) and the ladders’ assembling technology [6], making two real half ladders. Then, we assembled our self other 12 half ladders.

During the manufacturing process, great care is being devoted by the Romanian team to perform very precise measurements of the ladder components and their relative positions [7]. The measured experimental data were analysed and parameters variation tendencies at different manufacturing process moments were investigated. Range variation of and correlation between different parameters were derived. Some improvements of HLS manufacturing process control were finally proposed [8],[9].

The Romanian team composed by Dr. Maria Ionica and Dr. Cristian Gingu participate in the clean room facility of INFN Perugia at the assembling work of different detector types, for the R&D Test Beam Experiment of L3 in Summer 1994 [10]. Special contribution was related to the metrology of the first 64cm long silicon detector. We studied the linearity of the readout channel and characterised three error sources [11].

Figure 6. SMD half ladder assembling at INFN Perugia

Figure 7. The first 64cm long Si ladder assembling at INFN Perugia.
3.2. Collaboration in the AMS Project

A prototype of the AMS detector will be on board of the DISCOVERY shuttle flight, launched May 28th, 1998. The final AMS detector will be on board of the International Space Station Alpha (ISSA) in 2002. The goal of the AMS is the search for extra-galactic anti-matter, dark matter and the study of cosmic rays. This will be achieved thanks to a data-taking period of 3 to 5 years.

The Alpha Magnetic Spectrometer AMS is a state-of-the-art particle physics detector containing a large permanent magnet that will be designed, constructed, and tested by an international team organized under DOE and NASA. The international partners of AMS are from Finland, Germany, Italy, P.R.China, Romania, Russia, Switzerland and USA.

*Romania* has contributed in the production of the AMS ground system.

Assembling and electrical characterisation activities were done at the clean rooms facilities of INFN Perugia by a Romanian team, co-ordinated by *Prof. Alexandru Mihul* (EPPG) and *Prof. Michele Pauluzzi*, responsible for the assembling work of AMS (INFN Perugia). *Nicoleta Dinu* (IPRS), *Maria Ionica* (IMT), *Romeo Ionica* (UB), *Raluca Iorgulescu* (IMT), *Vasile Postolache* (Microelectronica), *Florentina Velcea* (Microelectronica) composed the Romanian team.

![Figure 8. AMS work by Romanian team at INFN Perugia](image-url)
3.3. Collaboration in the CMS Project

Assembling and electrical characterisation activities for the CMS project were done at the clean rooms facilities of INFN Pisa, Perugia, Florence and Bari by the following romanian team, co-ordinated by Prof. Alexandru Mihul (UB): Nicoleta Dinu (IPRS), Cristian Gingu (IMT), Otilia Militaru (IAP), Vasile Postolache (Microelectronica), Mihaela Preda (IAP).

The visits of Prof. Guido Tonelli from INFN and University of Pisa, Chief of the Silicon Detector Tracker for the CMS Experiment and Prof. Ettore Focardi from INFN and University of Florence, responsible for the Forward Silicon Tracker of CMS) was received at UB EPPG and IMT, Romania.

Barrel and Forward dummy detectors manufactured at IMT Bucharest were mechanically measured using Coordinate Measuring Machines. The purpose of these measurements was to verify the cut quality by investigating: cut linearity, cut verticality, cut length and registration of detector’s layout into the cut lines [5]. Measurements programs were wrote and some measurement set-up improvements were proposed [12].

Using dummy detectors produced at Bucharest, the barrel and forward prototypes for the CMS Milestone ’97 were realized at the clean room facility of Pisa [13].

A barrel detector module is fabricated by coupling together two half-ladders joint by stiff carbon elements. We built at INFN Pisa 40 mechanical modules and 8 functional modules. Other modules were built at INFN Bari and Perugia. Wheel assembly was done using a large DEA Brown&Sharp CMM at INFN Pisa.
4. Conclusion

A general overview of the common R&D efforts made at the UB EPPG and IMT, in the framework of their collaboration with INFN Italy was presented.

It can be summarised that our activities until now were:

⇒ **At UB EPPG and IMT Bucharest:**
  - activities - design, simulation, wafer processing, electrical characterization;
  - results - gained experience, published papers, 900 4” wafer processed for INFN Bari, Florence, Perugia, Pisa.

⇒ **At INFN, Italy:**
  - activities - electrical measurements and assembling;
  - results - 12 ladders assembled for L3-SMD (1995);
    - full assembling work activity at Perugia for AMS (1996-1997);
    - work in progress at Pisa, Bari and Perugia for CMS;

For the future, we intend to:

⇒ **Continue the present activity of:**
  - wafer processing for mechanical detectors at Bucharest;
  - electrical measurements and assembling work at INFN.

⇒ **Add new activities to be performed at UB EPPG and IMT Bucharest:**
  - CAD and simulation, electrical measurements, assembling, radiation tests.

⇒ **Strength our collaboration in terms of international projects:**
  - Governmental agreements program (in progress);
  - European community projects.

5. Bibliography

1. The Collaboration is supported by the following peoples from Romania.
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