Computer Physics Communications

Aging tests of MSGC detectors

Isabelle Boulogne, Evelyne Daubie[a*], Francis Defontaines, Fernand Grard

Université de Mons-Hainaut, Mons, Belgium

[a] *Scientific Collaborator FNRS, Belgium*

Elsevier use only: Received date here; revised date here; accepted date here

Abstract

MSGC aging effects have been systematically studied to determine optimal performance in the design framework of the CMS forward tracker. Tests were conducted on prototypes under various operating conditions (glass substrates, Cr or Au strips, Ar-DME or Ne-DME gas mixtures, gas set-up purity, and others), using an X-ray generator for irradiation. The different steps of our investigations are summarized. They demonstrate the complexity of the aging phenomenon as well as the difficulty of getting stable behavior of MSGC detectors under high rates of irradiation.

Keywords: gaseous particle detectors; MSGC; aging; X-ray generator

1. Introduction

An early approach to the construction of the forward tracker of the CMS detector included ≈20000 MSGC (Micro Strip Gas Chamber) detectors of an average size of 10×10 cm^2 [1].

Simulations of the expected levels of radiation at the localization of the MSGCs give a maximum charged particle rate of about 4×10^4 tracks / sec mm^2, corresponding to a maximum current density of ≈ 0.5 nA/mm^2. Over time, this value has decreased to ≈0.1 nA/mm^2 due to tracker design changes that increased the distance between the first MSGC layer and the beam interaction point [2]. This means that during 10 years of LHC operation (i.e., an integrated

* Corresponding author. Tel.: +32-65-37.33.90; fax: +32-65-37.33.86; e-mail: evelyne.daubie@umh.ac.be.

effective running time of ≈10^8 seconds), a total charge of at least 20 mC would be accumulated per centimeter of anode strip. It should be pointed out that the radiation doses could still be larger due to neutron and gamma backgrounds [2].

MSGCs made of different glass substrates and metal strips were extensively tested in the framework of the RD28 program at CERN [3]; two workshops were devoted to their development and application [4,5]. The most often used glass substrate in a tracker context was the formerly commercially available boro-silicate glass DESAG D263, which was characterized by a rather high electric resistivity (≈10^{15} Ωcm).

Very soon, it turned out that the MSGCs were particularly subject to fast aging and that the aging phenomenon was affected by many parameters in the fabrication and operation of the MSGCs, such as metallization processing, flushing gas purity and composition, and outgassing of assembling materials [3,6]. Proposals to overcome this serious problem focused mainly on the gas mixture (such as use of non-polymerizable mixtures like argon-dimethylether (DME) and minimization of the level of impurities, especially freons) and on the materials used for the construction of the detector and the gas circuit (no organic outgassing components like PVC, teflon, rubber) [7]. Concerning the kind of strip metal to be used, gold is recommended because it is relatively inert [8] (compared to aluminum) as already reported for wire chamber aging [9]. As for the substrate material, several approaches have also been proposed in order to avoid the suspected damaging accumulation of positive ions on the insulating surface between the strips (charging-up). The aim was to reduce the surface resistivity to ≈ 10^{15} Ω/□ which could be achieved in two ways: either by using glass with reduced bulk resistivity of about 10^{11} -10^{12} Ω cm called “semi-conducting” glass (such as the commercial S-8900 glass from Schott or the so-called “Pestov glass” developed by the B.I.N.P. Novosibirsk [10]) or by evaporating a weakly conducting material (such as diamond-like carbon, DLC) on the glass before or after printing the microstrip pattern. MSGCs made with substrates of low surface resistivity were observed to sustain relatively high rates of irradiation [11,12,13].

Our group, in association with several European research groups, has been intensively testing MSGCs in order to find their best operational conditions and to demonstrate their reliability in an LHC environment [14,15]. This report will present the results of our tests.

2. Experimental set-up

We performed the MSGC tests in the following conditions.

- Different kinds of glass substrates were used: Pestov glass[1], bare DESAG D263[2], and DLC-coated DESAG[3], on which were printed chromium or gold strips. We measured their surface resistivity to be ≈10^{13}, 10^{17} and 10^{14} Ω/□ respectively. The active area was 3×3 cm^2. The strip pattern was as follows: ≈10 µm anode width; ≈80 µm cathode width; 200 µm anode pitch.

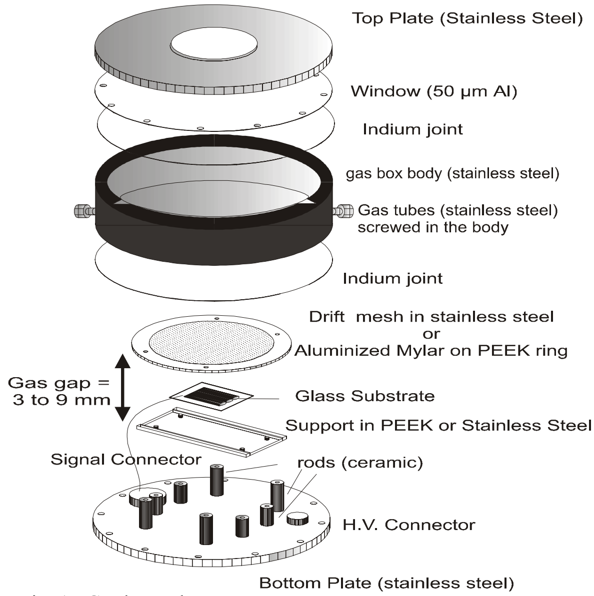


Fig. 1. Gas box scheme

[1] Received from Lev Shekhtman (Budker Institute for Nuclear Physics / Novosibirsk).

[2] Bought at IMT (Greifensee / Switzerland).

[3] Bought at IMT (Greifensee / Switzerland), SURMET coating.

- The substrates were fixed by means of porcelain clips into a stainless steel gas box whose design was similar to the one used in Prof. Fabio Sauli's group [7]. The entrance window of the MSGC detector was a 50 µm aluminum foil to allow irradiation by keV X-rays. The drift electrode inside the gas volume was made from a stainless steel mesh or from an aluminized Mylar sheet stretched on a PEEK ring. The electrical connections used mainly metal-glass feed-through connectors soldered in the bottom cover. Gas tightness of the two covers of the box was ensured by indium joints (Fig.1).
- The MSGC detector was connected to a clean custom-made gas system, with all stainless steel tubing, metallic filters, and electronic mass flow meters. No organic materials, such as TFE sealant, were allowed so that gas pollution would be avoided (Fig.2). The gas mixtures used in our tests consisted of either Ar-DME (50-50) or Ne-DME (50-50) as recommended [7].

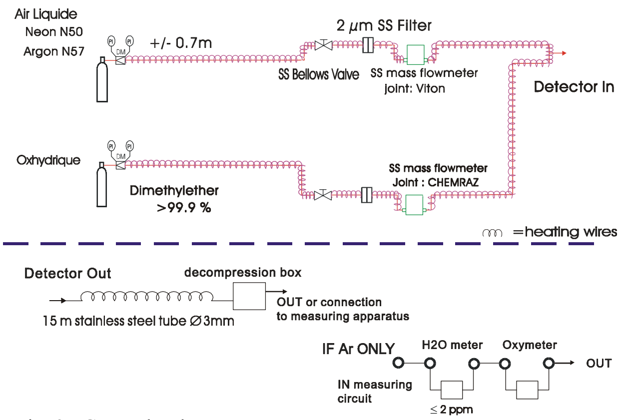


Fig. 2 . Gas rack scheme

- Tests under intense irradiation were done using an X-ray generator[4] equipped with an Fe or Cu anode, delivering 6.4 or 8.0 keV X-rays respectively. A collimator placed between the generator and the aluminum window of the MSGC box defined an almost parallel beam with an irradiation surface of the order of $1mm^2$.
- Because the first aging results we obtained were unsatisfactory, we thought they could be due to some "pollution" coming either from the set-up, or from the DME bottle. We then reduced the length of the gas pipes as much as possible to take away the gas mixer and to heat the gas pipes to help outgassing. In the testing of different substrates, DME gas from three different suppliers claiming DME purity of 99.9% (compared to 99.9997% for the rare gas) were used. The typical flow rate corresponded to about 4-6 renewals of the gas volume per hour.

- Signals from one group of about 50 interconnected cathodes[5] (grounded) were read. To determine the gain of the MSGC, we used one of two methods: we either recorded the pulse height by means of a peak sensing ADC[6] at a reduced rate (inserting a thin absorber between the collimator and the detector), or we measured the current by means of a voltmeter[7] in parallel on a precise resistor, leading to an accuracy of about 0,01 pA.

3. Test results : aging study

The results will be presented in chronological order. At the start of an aging test session, the following parameters were fixed:
- the MSGC drift field and the anode potential, such that the MSGC gain reached a value of around 1000;
- the X-ray intensity varying from 2 to 20 nA/mm^2, which defined an aging accelerator factor of about 10 to 100 times the maximum expected value in the real experiment.

3.1. Bare DESAG substrates equipped with Cr strips

The results we obtained from several tests were compatible, and some of them are presented in Fig. 3. They showed a rather fast aging rate (≈20% gain loss after an accumulated charge of 2 mC/cm of strip), with a faster gain decrease at the start of the test.

Although these results are not compatible with the one observed by [7], they are quite compatible with the one obtained by [16], though with different strip materials.

[4] XR tube Philips PW 2217/20FF or PW2773/00LFF.

[5] electrical contacts made using a conductive glue (EPOCTENY E204) and passivation of strip ends by means of the epoxy (EPOCTENY E505SIT).

[6] LeCroy 2259B.

[7] Keithley 182 sensitive digital voltmeter.

We have not observed any drastic effect when changing the rare gas nature (from Ar to Ne / Fig. 3 a and b) and when changing the drift field configuration (from a low drift field of −1000V/9mm to an increased field (×3) of −1500V/4.5 mm).

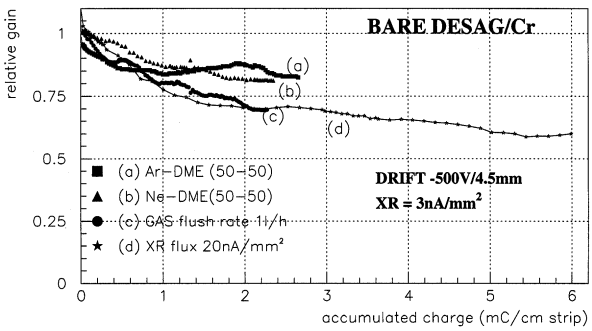


Fig. 3. Aging tests of MSGC's equipped with DESAG substrates.

A decrease of the gas flush rate (from 4 gas renewals per hour to 1 renewal per hour) shows a slightly faster gain decrease, indicating the presence of pollutants in the set-up (comparison of the curves 3 a and c); on the other hand, tests conducted with an increased X-ray intensity (from a current density of 3 nA/mm^2 to 20 nA/mm^2) also showed a faster decrease (Fig.3 a and d). One should notice that similar curves of the relative gain versus time were obtained from either pulse height or current measurements.

Visual inspection performed after the tests showed that, in each case, a faint brown coloration of the anode strips had appeared in the irradiated area.

3.2 Pestov glass equipped with Au strips

Before performing these tests, we replaced a metal glass feedthrough multipin connector in the bottom plate of the gas box with 2 separate SHV connectors in order to be able to increase the drift potential.

The aging behavior achieved under these conditions, with this kind of substrate using the Ne-DME gas mixture, was significantly better when compared to the bare DESAG substrates: gain loss of 14% for an accumulated charge of 23 mC/cm strip (Fig. 4).

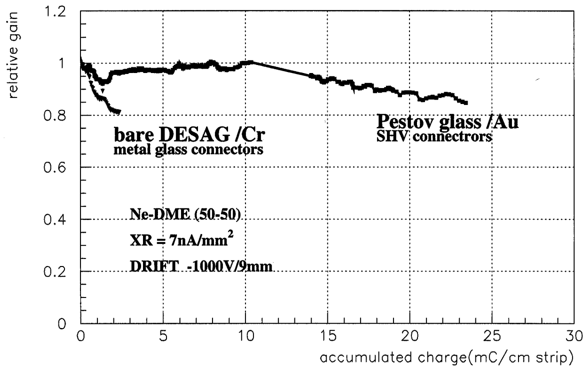
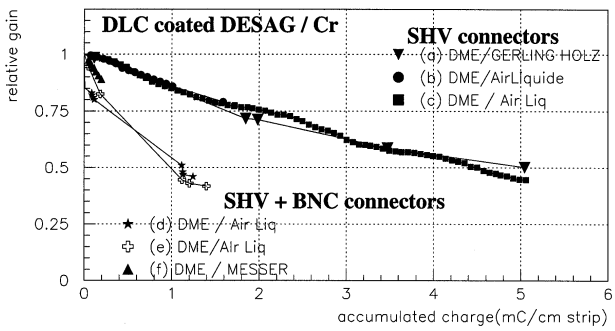


Fig. 4. Aging tests of MSGCs equipped with Pestov glass substrates.

Visual inspection performed after the tests showed that in the irradiated area, only the anode strips were covered by a thin black deposit.

3.3 DLC coated DESAG equipped with Cr strips

Keeping the SHV connectors in the gas box, we got worse results from several reproducible tests using the DLC-coated substrates as compared to the bare DESAG substrate: a very fast aging rate of ≈50% for an accumulated charge of 5 mC/cm strip. In view of this, the purity of the DME bottle and the presence of dangerous contaminants were intensely questioned. We changed to a new DME supplier in order to obtain the "purest" DME available. We repeated the measurements and got similar poor results (Fig. 5.a



5.b 5.c).

Fig. 5. First aging tests of MSGC's equipped with DLC coated DESAG substrates.

In the next step, we replaced for handling convenience the multipin metal-glass feedthrough signal connector with three separate BNC connectors. Still worse results were obtained, even after we changed the DME supplier again (Air Liquide → Messer-Griesheim/Oxydrique). Three different substrates were tested (Fig. 5.d 5.e 5.f). We thus opened the gas box and observed that the insulating parts (containing some PTFE) of the connectors had taken on a brown coloration. We then suspected that there could have been an interaction between this material and the DME, which could liberate halogens in the gas flush and accelerate the gaseous detector's aging as already observed in the case of wire chambers [9,17]. If this hypothesis is correct, we have to conclude that small amounts of pollutant in the flushing gas are extremely detrimental to the MSGC behavior. Visual inspection performed after these tests revealed, in the irradiated areas, the presence of a faint brown coloration of the anode strips.

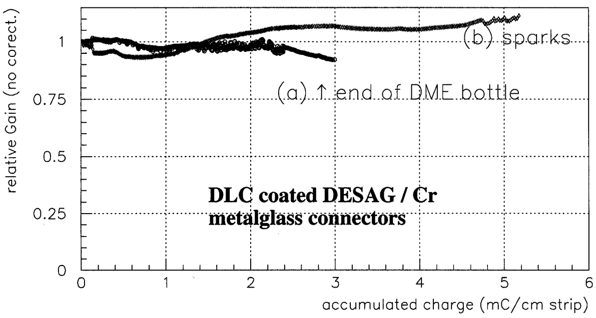


Fig. 6. Aging tests of MSGC's equipped with DLC coated DESAG and Cr strips

Coming back to the gas box equipped with metal glass feeedthrough connectors (instead of 2 SHV and 3 BNC connectors), we successfully operated the MSGC under better conditions. Fig. 6.a shows the resulting aging curve: a constant gain until 2 mC/cm followed by a small gain decrease at the end of the test, which corresponds to the end of the DME bottle. This kind of decrease was already reported by [18] in the case of a wire chamber and can be interpreted as a result of DME pollutants accumulating when the bottle empties. After replacement of the DME bottle, test (b) was conducted, leading to an almost constant gain up to an accumulated charge of 6 mC/cm strip. However, sparks occurred at an increasing rate during the irradiation, which forced us to stop the test. Signs of sparks were indeed observed during visual inspection after these tests: both the anodes and the adjacent cathodes were found to be corroded.

3.5 DESAG substrates equipped with Au strips

Several months after the last tests, we tested bare DESAG glass equipped with gold strips using an Ar-DME mixture. This was done after a careful control of the gas set-up tightness, one week of gas pipe heating with rare gas flushing, and a replacement of all the components inside the gas box by new ones made mostly from PEEK (substrate support, rods, drift electrode made from aluminized Mylar on a PEEK ring). Moreover, we chose a rather low irradiation rate at the beginning of the test and progressively increased it from 0.2 nA/mm^2 to 2 nA/mm^2.

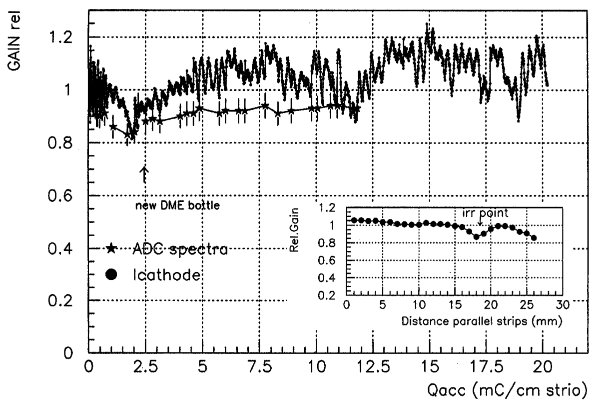


Fig. 7. Aging tests of MSGC equipped with bare DESAG and Au strips

The aging results were satisfactory. Current and pulse height measurements were compatible and showed a small initial decrease of the gain (less than 10 % from 0 to 2 mC) and then a gain stability until at least 20 mC/cm strip (Fig. 7), the value at which we decided to stop the irradiation. The observed variations of the relative gain during the relatively longer irradiation time can be attributed to the ambient temperature variations as they were simultaneous to the dark current variations. One should notice that no corrections for temperature or atmospheric pressure variations were applied for the graph presented in Fig.7.

A scan performed at a low rate across the irradiation point confirmed that the observed gain decrease was due to a local permanent deterioration of the MSGC performance (see Fig.7).

4. Conclusion

The results we obtained from the MSGC's aging, under various conditions of testing operation, revealed that the aging phenomenon is complex, subject to the obscure influence of several parameters. Avoiding any trace of pollutants appears to be particularly crucial in order to ensure stable behavior of these detectors under a high rate of irradiation.

In our set-up, the first aging tests conducted using bare DESAG glass equipped with Cr strips showed an initial fast decrease of MSGC gain, followed by a quasi-constant gain from 0.5 to 2.5 mC/cm strip.

DLC-coated DESAG with Cr strips led to an almost constant gain up to 6 mC/cm as far as the gas mixture could be considered pure enough to prevent aging. However, sparks occurred rather easily during the tests.

No significant difference between Ar-DME and Ne-DME (50-50) mixtures could be noticed.

The best results were obtained using substrates from semiconductive or bare boro-silicate glass equipped with gold strips: less than 10% gain decrease for an accumulated charge of ≈20 mC/cm strip.

Acknowledgments

We are very indebted to Lev Shektman for providing us with the substrates. We would like to express our sincere gratitude to Prof. F. Sauli and members of his group at CERN for their invaluable advice and help.

We would like to thank M. Chevry and J. Minez for their contribution to the construction of the various parts of the testing equipment.

References

[1] CMS collaboartion, The Compact Muon Solenoid Technical Proposal, CERN/LHCC 94-38, 1994.
[2] CMS collaboration , The tracker project Technical Design Report, CERN/LHCC 98-6, 1998.
[3] F. Sauli, CERN/DRDC/93-34 (1993).
F. Sauli, CERN/DRDC/94-45 (1995).
F. Sauli, CERN/LHCC 96-18 (1996).
F. Sauli, Development of high rate MSGCs : overview of results from RD-28, CERN-PPE/97-19 (1997).
[4] Proc. Int. Workshop on Micro-Strip Gas Chambers (Legnaro, Italy, 1995).
[5] Proc. Int. Workshop on Micro-Strip Gas Chambers (Lyon, France 1996).
[6] R. Bouclier, et al., Ageing studies with microstrip gas chambers, Nucl. Instr. and Meth. A 348 (1994) 109.
[7] R. Bouclier, et al., Ageing of Micro-Strip Gas Chambers : problems and solutions, Nucl. Instr. and Meth. A 381 (1996) 289.
[8] F. Angelini, et al., in ref.[5] pp. 297-306.
[9] J.A. Kadyk, Wire chamber aging, Nucl. Instr. and Meth. A 300 (1991) 436.
[10] G.D. Minakov, et al., Performance of gas microstrip chambers on glass with ionic and electronic conductivity, Nucl. Instr. and Meth. A 326 (1993) 566.
[11] L. Alunni, et al., Performance of MSGC on electronically and ionically conductive substrata in various operational conditions, Nucl. Instr. and Meth. A 348 (1994) 344.
[12] A. Barr, et al., Operation of high rate microstrip gas chambers, Nucl. Phys. 61B (1998) 264.
[13] B. Boimska, et al., Study of ageing and gain limits of Microstrip Gas Chambers at high rates, Nucl. Phys. 61B (1998) 498.
[14] D. Abbaneo, et al., Test of a CMS MSGC tracker prototype in a high-intensity hadron beam, Nucl. Instr. and Meth. A 409 (1998) 37.
[15] R. Malina, et al., High rate tests of Microstrip Gas Chambers for CMS, Nuclear Physics B 78 (1999) 80.
[16] F.D. van den Berg, Ph.D. thesis, Delft University press(2000).
[17] M. Jibaly, et al., The aging of wire chambers filled with dimethyl ether: wire and construction materials and freon impurities, Nucl. Instr. and Meth. A 283 (1989) 692.
[18] R. Bouclier, et al., Results of wire chamber ageing tests with CH_4 – DME – based gas mixtures, Nucl. Instr. and Meth. A 346 (1994) 114.