ELSEVIER

Nuclear Instruments and Methods in Physics Research A 384 (1996) 192–195

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

# The Micro-Gap Chamber: new developments

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**Abstract**

To fully exploit the capabilities of the Micro-Gap Chamber, new geometries are examined in the light of the recent work performed in our labs. Results on the usage of neon in the gas mixtures necessary to operate the chamber at high gas gain and of ageing tests with these new mixtures are also discussed.

## 1. MGC geometries

Since the first proposal of the MGC [1] it was clear that the new detector could provide signals of essentially the same amplitude and rise time both from the anode and the cathode strips. Furthermore, the high electric field that extends from one anode strip is not very much influenced by the distance to other strips (pitch) [1], providing great flexibility in the design of the electrode structure. The point here is to find the best practical way to segment the cathode plane in order to extract, and fully exploit, the information on the second coordinate of the avalanche position in the detector.

A bi-dimensional readout detector had been already proposed and built, but only with very small dimensions [2]. It is of paramount importance that the edges of the cathode, whether at the segmentation where the anode strips run over the cathodes edges or at the external border, be covered with a thin layer of high dielectric strength in such a way as to avoid an early onset of instabilities at these locations (see for example Ref. [3]). Different geometries for the segmentation of the cathode plane have been studied [3], built in large dimensions ($\approx 10 \times 10$ cm$^2$) and tested. The scheme is based on the segmentation of the cathode plane into many rectangles with one of the two dimensions equal to twice the pitch between the anodes. These small pads are then connected together to form a cathode strip running at an angle with respect to the direction of the anodes. The advantage of this configuration is that the signals can be extracted from the anode-strip side of the detector substrate.

Another prototype, with the cathode plane segmented in a direction orthogonal to the anode strips at a pitch of 200 $\mu$m (the same pitch of the anodes), has also been built and tested. The passivation of the edges is done by depositing a 20 $\mu$m-thick , 25 $\mu$m-wide strip of polyimide that also overlaps a very small section of the anode strip, as shown in Fig. 1. A detector with this geometry on a DE263 glass [2] substrate of $2.6 \times 2.6$ cm$^2$ has been built and operated successfully. In an effort to couple the Micro-Gap field configuration to a pixel-like readout, we have built and tested the geometry proposed and simulated in the work of Bellazzini and Spezziga [4]. Fig. 2 shows the simulated electric field in the amplifying region.

With such a structure, by applying the high drift field necessary to obtain fast response and high rate capability, we

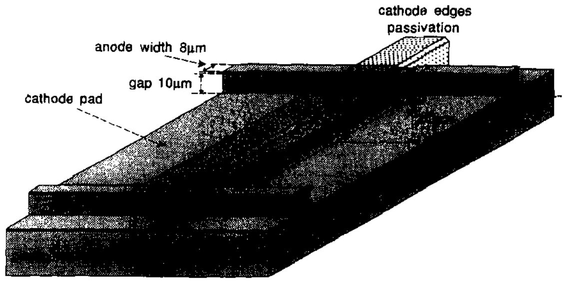


Fig. 1. Details of the geometry of a 2D-MGC with 200 $\mu$m cathode pitch. The passivation of the cathode edges is meant to avoid points where the electric field intensity could impair the detector operation.

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[1] At least up to the smallest pitches that are feasible with today's technologies.

[2] DESAG, Deutsche Spezialglas AG, Grünenplan, Germany.


*PII* S0168-9002(96)00982-5

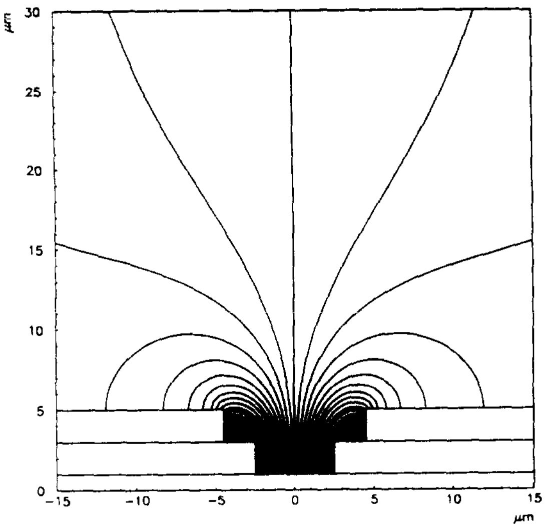


Fig. 2. The electric field lines for the sunken anode.

achieved amplification but not full efficiency. A high value for the drift field is in fact the cause for a region of surface inefficiencies if the electrode is sunken in a hole. We have thought up and simulated a new structure (currently being fabricated) that has the anode standing on a small "button-like" insulating support.

The simulation (see Fig. 3) indicates clearly that for this particular geometry the amplification and the efficiency should also be good in the presence of high fields.

## 2. UV-free gas mixtures

Recently our collaboration has suggested that using neon instead of argon [5] can improve the performance of the detector, albeit with a small decrease in the gas density. Studies to optimize the gas mixture for particular operating condition of proportional counters had already been performed in the past [6] but the problem we wanted to address using neon or helium is peculiar to MSGC and MGC where the very high field present can generate dangerous breakdown from an excess of photoelectrons extracted by the UV photons present in the multiplication avalanche. Studies have shown [5–7] that indeed both detectors with these new mixtures can be operated safely at high anode-cathode voltages (and hence gain larger than $2 \times 10^4$).

Normally the instability limit for mixtures containing argon or xenon, which also depends on the way the detector has been built, is already reached for a gain of a few thousand [3]. One of the reasons for an early onset of the instability is most probably due to the generation of far electrons [4] by the UV photons produced in the region of the avalanche. By reducing the amount of UV radiation, the use of neon or (helium) [5], rather than argon, decreases the production of photoelectrons which could trigger and sustain an electric discharge. In Fig. 4, the gain/voltage curves for different Ne-DME mixtures are reproduced, together with other measurements performed with He-DME mixtures.

The region of safe stable operation of the detector is extended substantially, thereby permitting improved exploitation of the detector's gain capabilities. The measurements were stopped when the anode-cathode voltage reached 490 V for our standard MGC, a safe limit sufficient to prove the interest in the new mixture: no evidence of instability in the operation of the detector was noticed, implying that if needed

[3] MSGC of very accurate construction and particular geometries have also been operated at a gain of a few $\times 10^4$ [8].

[4] For example by the extraction of electrons from the metallic surface of the cathodes.

[5] Ne and He have higher ionization and excitation potentials than Ar.

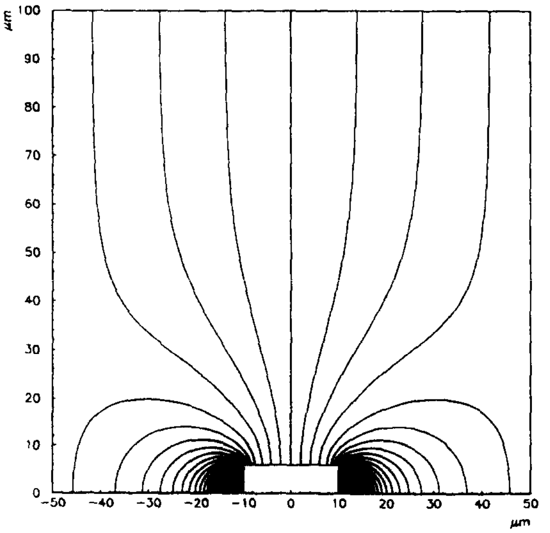


Fig. 3. The simulation of the collecting and amplifying field for a pixel "button" MGC for high drift field values.

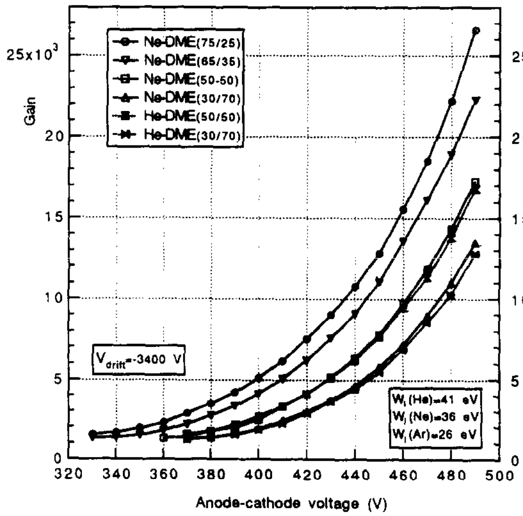


Fig. 4. Pulse height as a function of the anode-cathode potential for different Ne-DME and He-DME gas mixtures in a Micro-Gap Chamber.

the gain could possibly be increased further. Two-step amplification (parallel-plate plus proportional gain) can be obtained (and used profitably) for high drift field gradients: we have demonstrated its usefulness in a detector coated with CsI to detect single electrons emitted by UV photons [9]. Gas mixtures of Ne–DME (or other quenchers) are now used also by other research groups (see Ref. [10]) who confirm the results of our measurements. It is worth adding at this point that the attenuation of the UV components present in the avalanche may have other advantages than the simple possibility of reaching stable and higher gain values, which amply offset the loss in primary radiation [6].

## 3. New ageing results

MSGC and Micro-Gap Chambers are already in use in high energy physics experiments, and they are approved for installation in CMS at LHC. The detectors to be installed in CMS will have to sustain a large integrated radiation dose. Today we are capable of building detectors that should withstand a mean evaluated integral charge deposit of approximately 100 mC/cm per detector strip (equivalent to 10 years of operation in the LHC environment).

The tests performed are intended to clarify the *why's* of the ageing process and to define the appropriate building technology. It has been proven [11] that ageing can be strongly reduced if extreme care is given to the selection of the materials that will be in contact with the gas mixture. One of the major effects of the ageing processes (even if not perfectly understood) is without doubt the deposition on the anodes of a thin layer of polymerized materials coming probably from the organic gases used, and whose growth rate is highly correlated to the impurities present in the gas flowing in the detectors. Polymerization is normally achieved in the presence of organic compounds with high RF electric fields and it is strongly enhanced by UV radiation [12]. This is a situation normally encountered in our detectors.

UV light is emitted in the avalanche process mainly by the de-excitation of a noble gas present in the mixture: heavy noble gases, like argon or xenon are strong UV scintillators. On the contrary, helium and neon are quite poor UV emitters. Table 1 [13] shows the strong enhancement in the polymerization rate in two different hydrocarbons by adding heavy noble gases to the mixture. A large fraction (at least 50%) of a very good and not easily polymerizable UV absorber like DME should be also very useful in the suppression of the UV-polymerization enhancement. Small additions ($\leq 1\%$) of water vapour to the gas mixture could further improve the ageing of the detector as it is well known for many years from results on wire chamber lifetimes [14]. As a matter of fact, water vapour is one of the most effective UV absorbers [15].

More recent results also indicate that the metal employed to build the strip structure and the quality of its surface have a big influence on the rate of ageing. We have indications that ageing is largely reduced if the detector is operated with gold strips and Ne–DME (UV-free) gas mixtures. Gold, being quite inert, is not chemically attacked by reactions with species produced during the avalanche process. It is also a material for which it is easy to obtain smooth and hard surfaces with present technologies. The ageing test presented has been performed on a detector with its casing built with vetronite, mylar and nylon tubing, materials that are currently forbidden if one desires a detector with good ageing characteristics. The gas mixture was Ne–DME (65–35) and the irradiation rate was "fast" [7].

The detector was a standard Micro-Gap Chamber with gold-plated electrodes. After receiving a total of 100 mC/cm on the surface of the chamber, the gain was still very close to the initial value. The very small variation, even if visible (see Fig. 5), is difficult to evaluate since it is of the order of the measurement fluctuations. The data have not been corrected for temperature and pressure variations.

In order to rapidly obtain answers to these crucial questions, ageing tests performed so far by many groups and labs have been done under conditions which are still too far from those that will actually be encountered in the LHC experiments. The dose is normally deposited with an X-ray gun and the conversions in the chamber simulate particle fluxes

[6] Due to the lower density of neon compared to argon.

[7] I.e. 34 $nA/mm^2$, gain $3 \times 10^5$.

Table 1
Accelerating effect of noble gases on polymerization of hydrocarbons (from Ref. [13]).

| Noble gas | Rate of polymerization compared to pure | |
|---|---|---|
| | $C_2H_2$ | 1.3.butadiene |
| He | 0 | - |
| Ne | 5× | - |
| Ar | 30× | 14× |
| Kr | 60× | 28× |
| Xe | 1480× | 75× |

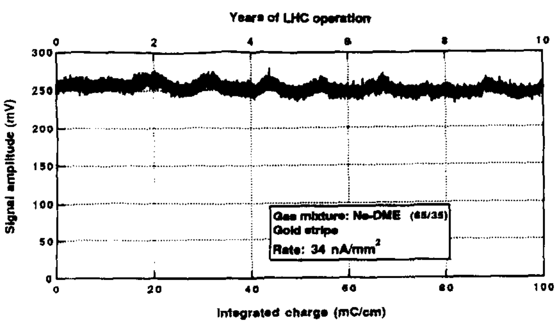


Fig. 5. The gain as a function of integrated charge for a Micro-Gap Chamber with gold plated electrodes and a casing of "dirty" construction (see text). The detector was flushed with a mixture of Ne–DME (65–35).

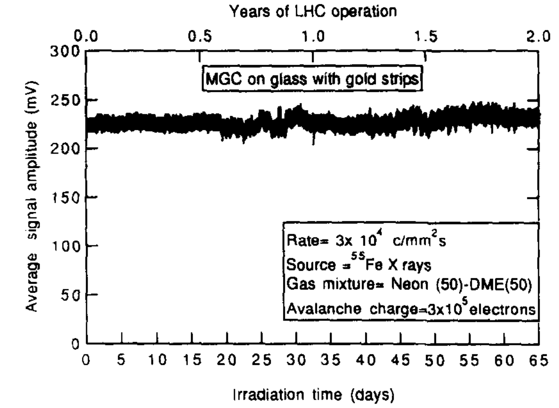


Fig. 6. The gain as a function of integrated charge for a Micro-Gap Chamber with gold plated electrodes. The detector was flushed with a mixture of Ne-DME (50-50).

much higher than at LHC. The gas necessary for the correct functioning of the detector is refreshed very often: in this case the question is "do we need to replace the gas so often because of radiation damage to the gas?"

The goal is then to try to perform ageing tests (i.e. charge collection on the electrodes equivalent to 10 years of operation) under conditions that will more closely resemble the working conditions. A test of ageing with reduced gas flow and also reduced particle equivalent rate has been started in our laboratory: the gas flow was down to the replacement of 5 volumes per hour and the particle rate was reduced by a factor of 20 using X-rays from an $^{55}$Fe radioactive source. The test has to run over longer times to integrate the full LHC dose: in 65 days we collected a dose equivalent to two years of operation with no sign of a decrease in gain (see Fig. 6). The detector employed is built with gold strips but standard assembly components. The gas used was Ne–DME in the ratio 50–50.

## 4. Conclusions

In the past years with the construction of large size detectors, the Micro-Gap concept has proven to be a realistic and performing 2-dimensional complement or alternative to the MSGC. All the problems coming from the dielectric are absent and the new geometries presented here are a proof of the great capabilities of this class of detectors. The new neon-based gas mixtures introduced not long ago are already being employed by many experiments and groups, and have proven to be very reliable in providing good stability at safe voltages. The study of the causes of the fast ageing of these detectors under extreme conditions is giving first encouraging signs of a correct understanding.

## Acknowledgements

We want to thank M. Favati, C. Magazzú and S. Tolaini of INFN-Pisa and A. Morelli of INFN-Genova for their enthusiastic and invaluable technical help.

## References

[1] F. Angelini et al., Nucl. Instr. and Meth. A 335 (1993) 69; See also: R. Bellazzini and G. Spandre, Nucl. Instr. and Meth. A 368 (1995) 259.
[2] J. van der Marel et al., Nucl. Instr. and Meth. A 367 (1995) 181.
[3] F. Angelini et al., Nucl. Instr. and Meth. A 349 (1994) 412.
[4] R. Bellazzini and M. Spezziga, Riv. Nuovo Cimento 17 (12) (1994).
[5] F. Angelini et al., Nucl. Instr. and Meth. A 362 (1995) 273.
[6] A. Sharma et al., Nucl. Instr. and Meth. A 346 (1994) 114.
[7] L. Shekhtman, CMS TN 95-045 (1995).
[8] R. Bouclier et al., CERN PPE 94-27 (1994).
[9] F. Angelini et al., Nucl. Instr. and Meth. A 371 (1996) 358.
[10] O. Bouhali et al., Proc. Int. Workshop on Micro-Strip Gas Chambers, Lyon, December 1995.
[11] R. Bouclier et al., Nucl. Instr. and Meth. A 367 (1995) 168.
[12] M. Millard, Techniques and Applications of Plasma Chemistry, eds. J.R. Hollahan and A.T. Bell (Wiley, New York, 1974).
[13] R.C. Palmer et al., J. Chem. Phys. 28 (1958) 167.
[14] J.A. Kadyk, Nucl. Instr. and Meth. A 300 (1991) 436.
[15] B. Gobbi, private communication.