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Investigation of Discharge Limits in Diamond Coated Microstrip Gas Chambers

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Abstract

Microstrip gas chambers are highly performing in terms of stable operation at high rates and fluxes of minimum ionizing particles. They are manufactured on thin glass (D-263) coated with a thin diamond-like layer by Chemical Vapor Deposition (CVD) before photolithogrpahy (undercoated) or after (overcoated), thus rendering the substrate within the desired range of surface resistivities 10^{14}-10^{16} $\Omega/\square$. Several overcoated and undercoated chambers have been operational for detecting minimum ionizing particles. The highly ionizing fragments due to copious rate of thermal neutrons and low energy hadrons however, are a serious concern for the discharge limits of these devices in a severe environment like that of the CMS tracker at LHC. In this work, we have performed a systematic investigation of such limits exposing overcoated and undercoated chambers to 5 MeV alphas, operating with gas mixtures of argon or neon with DME. The results indicate a definite decrease of maximum voltage and a weak dependence on the gas choice. The dependence on the artwork and the metalization used for the strips remains to be investigated.

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1. INTRODUCTION

MicroStrip Gas Chambers (MSGCs) are a new generation of gas detectors based on the microlithographic techniques from the established semiconductor manufacturing technologies [1]. Intrinsic to the design, the very high granularity of detection elements offers a high rate capability due to the fast clearance of positive ions offered by the very close proximity of cathodes. The rate capability and stability of operation is enhanced by using substrates with surface resistivities in the range from 10^{14} to 10^{16} $\Omega/\square$ [2-4]. We have obtained these peformances by coating the glass with a diamond-like carbon (DLC) layer by Plasma assisted Chemical Vapor Deposition (CVD)[+] before photolithography and subsequent wet etching for chromium or gold by lift off[*] for undercoated chambers. The diamond-like layer can be deposited after the preparation of the chamber, for the so called overcoated chambers [5].

In the CMS experiment at LHC the MSGCs are arranged with the closest chambers at ~ 50 cm from the interaction point. The closer chambers face a severe environment of radiation namely neutrons, low energy hadrons and gammas. At 50 cm for neutrons, typical energies range uniformly from thermal to 100 MeV at a rate of typically few 10^5 n/cm^{2}s upto 10^6 n/cm^{2}s. Especially in the forward MSGCs (η~1.6-2.4, closer to the calorimeter) the average total neutron rate is higher. The rate of hadrons at hadron energies in the range of 1-100 MeV are a few 10^6 h/cm^{2}s at a 50 cm radius from the interaction point. While minimum ionizing particles give 1-2 keV of energy loss in the detector, the neutrons may knock-off protons, alphas or nuclear fragments releasing several hundred keV in the gas. Hence, the microstrip detector should be operated within a safe margin of operating voltage at which, if a highly ionizing particle appears, the chamber sustains the voltage with the large amount of ionization and does not trip off. In earlier works [6] the geometry and operating conditions of the MSGC structure have been optimized with theoretical and experimental investigations of discharges. As a consequence of these optimization studies the following typical geometry has been opted for most subsequent investigations: anode widths 7 μm, cathode widths 100 μm with a 200 μm pitch. The thickness of the substrate has been specified to 300 μm governed by mechanical stability and low multiple scattering arguments. The drift electrode is usually made of a 100 μm gold plated glass typically at 3 mm from the substrate. Enclosed in a gas volume of argon or neon with DME, this detector has been demonstrated to operate up to very high fluxes of 10^6/mm^{2}s and accumulated charge of the order of 100 mC/cm per

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strip for the undercoated chambers [3,4] and 50 mC/cm for the overcoated chambers [6].

In this work, we have investigated systematically the limits of operation of the undercoated and overcoated chambers exposed to highly ionizing tracks.

2. EXPERIMENTAL PROCEDURES

The two chamber structures employed for this test are: one Diamond Undercoated Chromium (DUC) [2], and the other Diamond Overcoated Chromium (DOC). The other details are summarized in table (1). Both chambers were prepared at IMT and the diamond-like coating was done by Surmet having a high quality mechanically, optically as well as in performance. With gains up to 10^4, DUC has been the plate reported to have accumulated a charge of 100 mC/cm of strip with no deterioration. A new section of the plate was used for discharge limits investigations. DOC, on the other hand, was a new plate used only for these measurements. The surface resistivity of the diamond coating is ensured to be uniform and with an average value of 2.10^{14} for DUC and 2.10^{13} for DOC. Plates were fixed in a standard stainless steel box with a drift electrode made of a stainless steel mesh at 7 mm. A high voltage of 1.5 kV was applied on the drift for all measurements with argon or neon with DME as gas mixture, while it was raised to 2.5 kV for pure DME to the collection efficiency. This drift field is somehow low (due to mechanical limitations of our assembly box) as compared to the design drift fields of 10 kV/cm, but still is representative. Gas mixtures of equal proportions of argon and neon with DME, a (30-70) mixture of argon-DME and neon-DME and pure DME have been investigated.

Chamber	DOC	DUC
Active area	10x10 cm^2	80x80 cm^2
Grouping	10 anodes/cathodes	20 anodes/cathodes
Anode width	7 μm	7 μm
Cathode width, pitch	100 μm, 200 μm	100 μm, 200 μm
Anode/Cathode Metal	Chromium	Chromium
Substrate	Desag D-263 300 μm	Desag D-263 300 μm
Drift distance	7 mm	7 mm
Readout	anode strips	cathode strips

Table (1)

To simulate a large ionization loss, the MSGCs were illuminated with an Am^{241} alpha source, which deposits ~ 500 keV in the chamber per track. This was made possible by glueing on the aluminium window, which is at a distance of 1.5 cm from the drift electrode, a 1 mm wide slit a few cms in length made of a 3 μm Hostaphan foil, which permitted the α's in the sensitive volume of the MSGC hence, to establish the trip voltage and thus the limiting gain. The trip level for all measurements was set at 8 μA for DUC since only one group was connected and 20 μA for DOC for which two neighboring groups were grounded.

A schematic of the setup is shown in fig. (1). For the undercoated chamber, a cathode readout scheme was used, while for the overcoated chamber it was anode readout. The HV strips are biased through a protection resistor, while the grounded strips are grouped together and read out with a charge sensitive (ORTEC 142) preamplifier and (ORTEC 450) amplifier. Gain was calibrated for the whole chain, and all the settings were maintained for all measurements. Measurements were performed with Fe^{55} and Am^{241} sources, and maximum possible gains were attained. The maximum operational voltage with α's emulates the limiting voltage at which the MSGCs could operate safely in an environment with heavily ionizing particles. The gain at this voltage ($V_{max}\alpha$) offers a comparison between argon and neon mixtures with DME and other chamber characteristics.

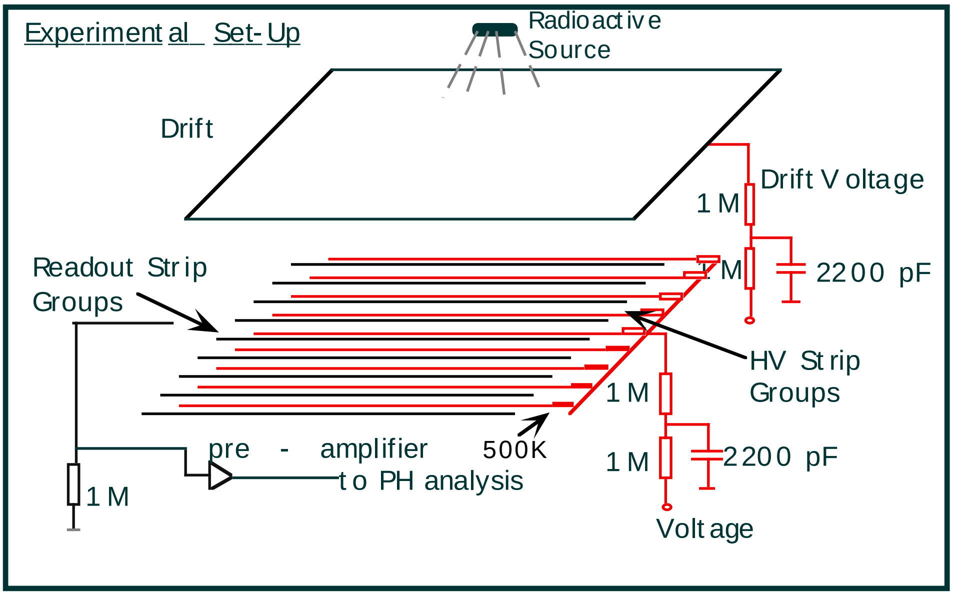

Fig. (1)

For DOC, and subsequently in all other chambers also, we observed that when the neighboring anode group was not grounded (left floating), a number of large signals is found increasing at lower voltages, accompanying the Fe^{55} signal which has a good energy resolution. This implies some sharp ends with higher gain/high electric field. These large signals were seen to disappear when these neighboring groups were grounded. The reason for this observation is as follows: When the neighboring anode groups are floating, the cathodes being on voltage induce similar potential on the anodes, thus enhancing the electric field in the region at the very edge of the sector that has been connected to the preamplifier for measurements. This gives rise to higher gains at the edges. When the neighboring sectors are grounded, the electric field is uniform at and beyond the edges of the measured sector.

3. RESULTS

Fig. (2) shows typical pulse height spectra with Fe^{55} in the DOC chamber at different cathode voltages and fig. (3) shows the same for signals from Am^{241}.

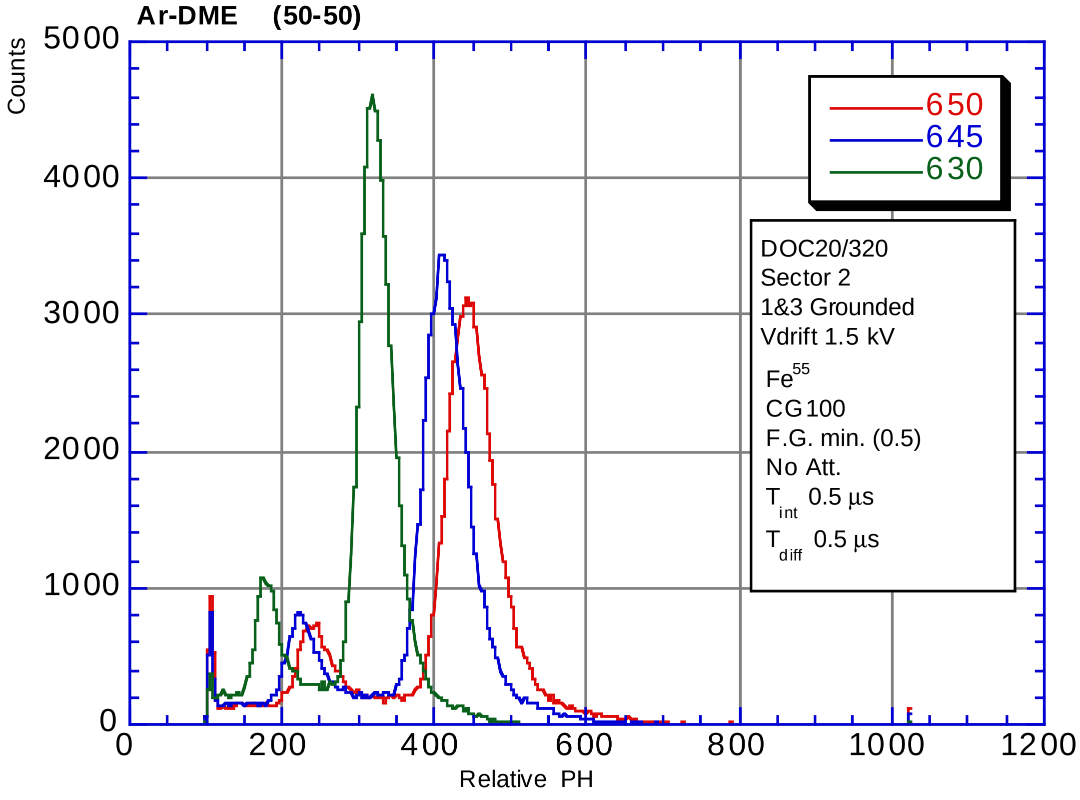

Fig. (2)

Gaussian fits were made to the Fe^{55} spectra at various operating voltages and the peak positions were recorded with the corresponding gains using the calibration factors. For the alpha spectra shown in fig. (3) for example for Ar-DME (50-50) with DOC; the middle points between 10 % and 90 % at the high pulse height edge of the spectra were determined using an exponential fit to represent the maximal primary charge with gain at the given voltage.

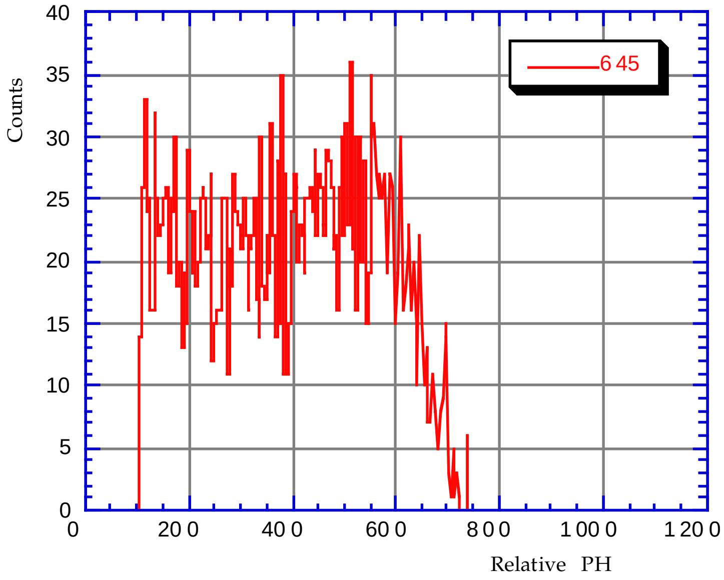

Fig. (3)

The typical rate of α-particles counted with the Am^{541} source was ~ 3 $mm^{-2}s^{-1}$.

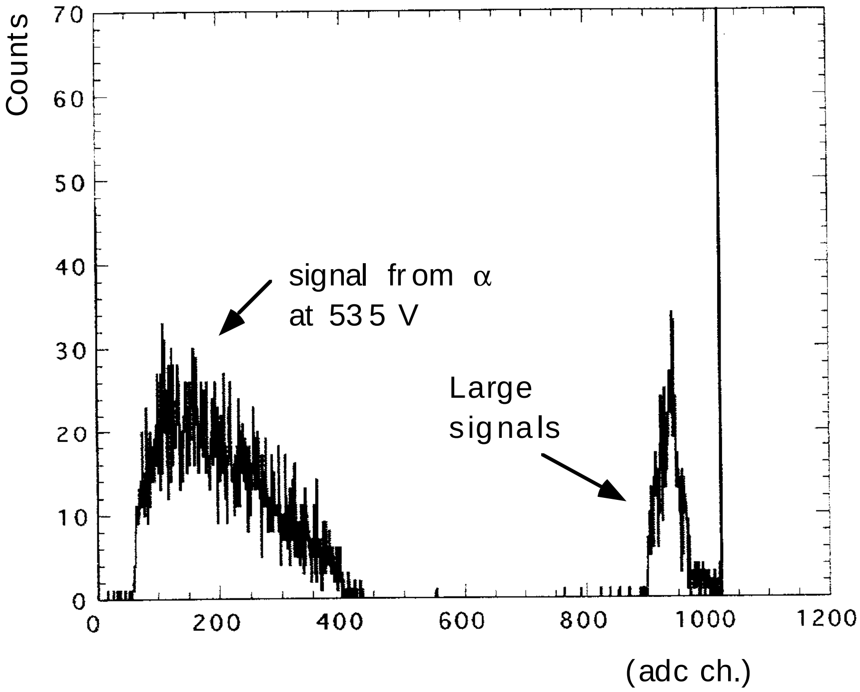

Fig. (4)

In the case of the undercoated chamber, large signals before the discharge limit were seen on the oscilloscope and also in the pulse height spectra with alphas, as shown in fig. (4). They could be interpreted as precurosors to the discharge, maybe a transition from the proportional mode of operation of the MSGC into the streamer mode. The rate of such large pulses was monitored and a discharge criterion could be made; close to discharge however the background counts (without source) increase. This happened approximately 10-15 V beyond the voltage attainable with Fe^{55}. The reason for this final discharge is probably due to cathode emission at very high electric fields. Precursors were not observed with the overcoated chamber, nevertheless the discharge without source happened at similar higher voltages than the operational ones.

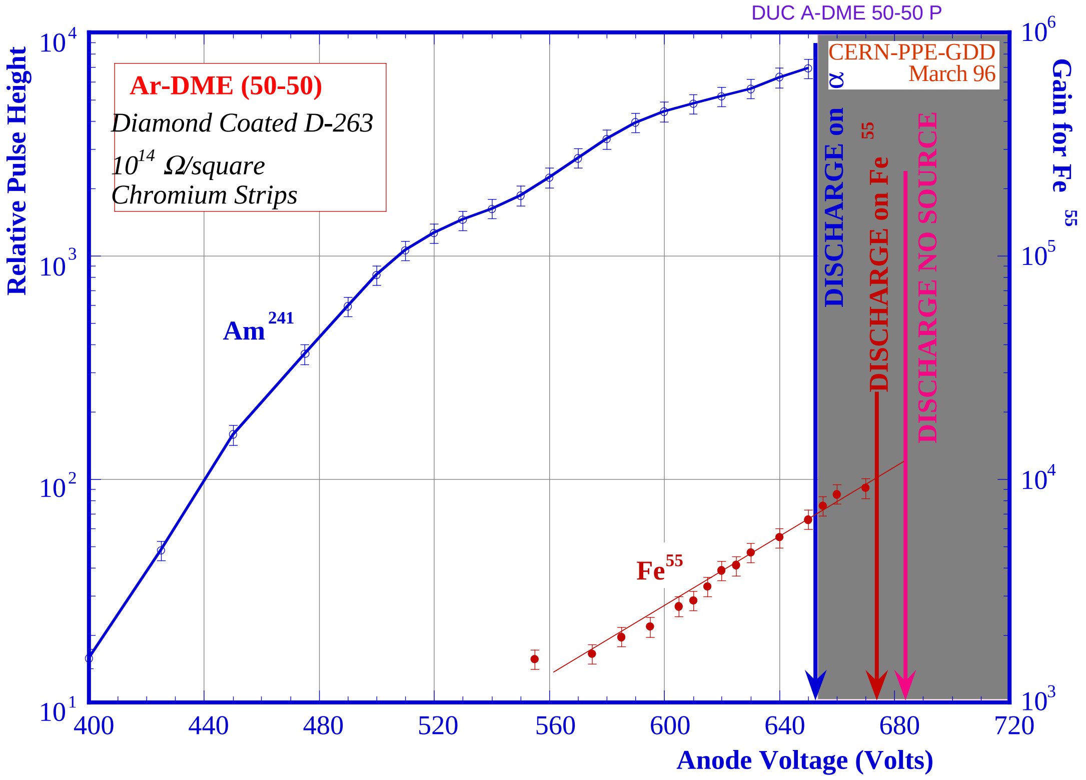

Fig. (5)

Fig. (5) shows a typical gain versus voltage curve for DUC having Ar-DME (50-50) as operational gas mixture. As can be seen the maximum gain that is achievable in the presence of an alpha source is lower than that obtained with the iron source thus causing a loss of few tens of volts of operational voltage. Fig. (6) shows a comparison of the gain attained with argon/neon-DME mixtures with the undercoated chamber with x-rays, and the corresponding discharge points in the presence of alphas. Clearly pure DME is the best choice gains being in excess of 2.10^{4}. The chamber was stable during its operation for all the measurements; discharge occurring only at the specified voltages (± 5V). An average of ~ 50 discharges in total have occurred on the exposed region of the chamber. Insepection of the plate after the tests did not reveal any damage to strips or to the diamond layer.

Note that the desired operational gain for efficient detection of minimum ionizing particles' detection is around 2-3.10^3.

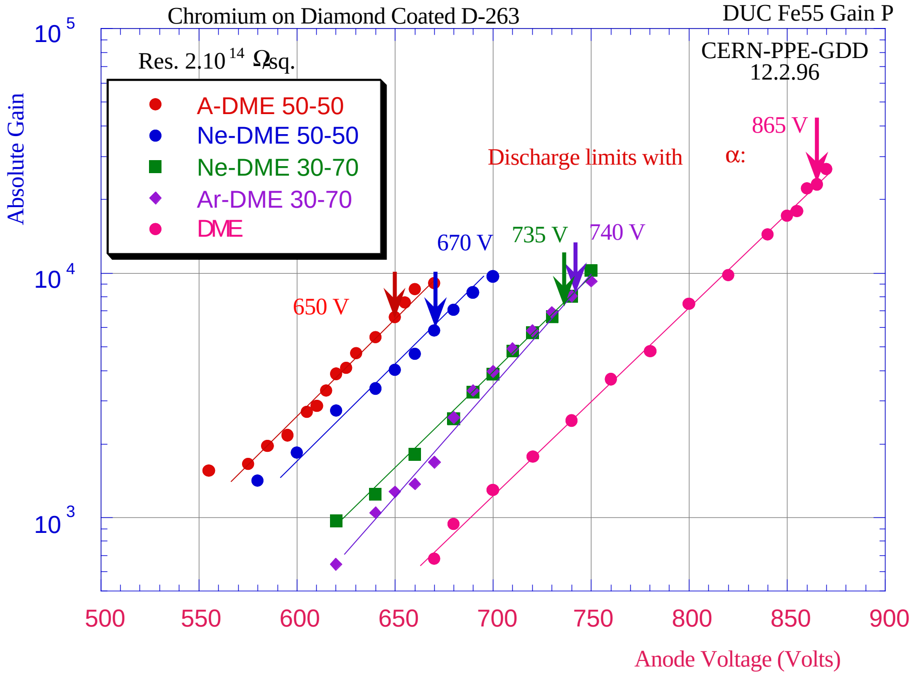

Fig. (6)

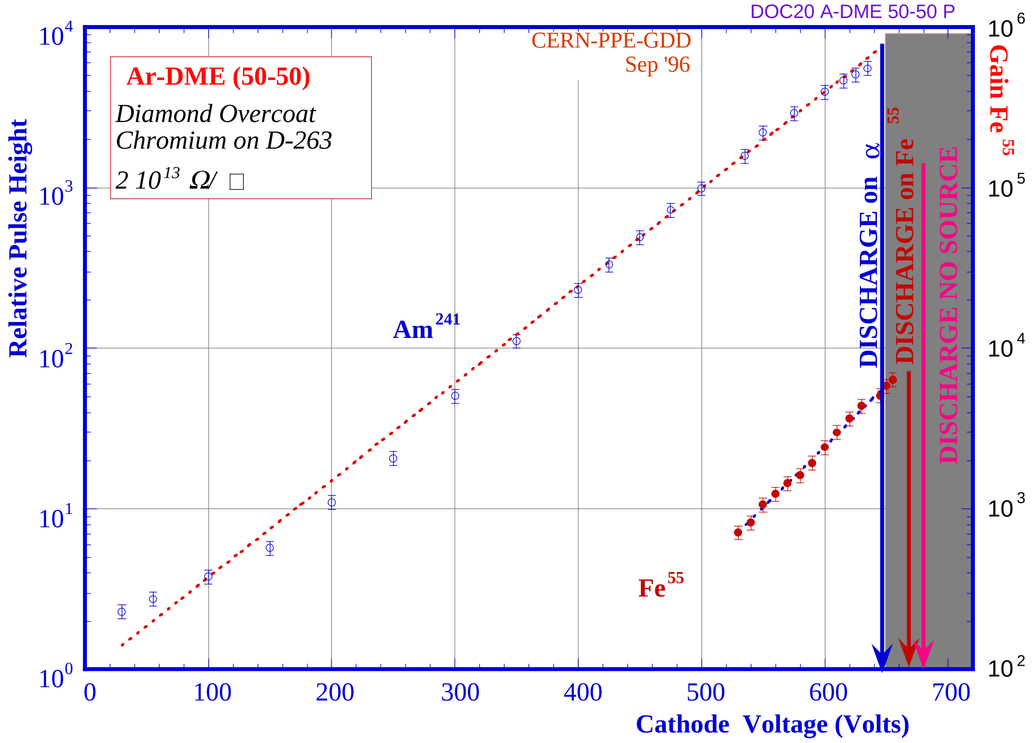

Fig. (7)

Fig. (7) shows the gain with Fe^{55} and Am^{241} for the overcoated chamber with Ar-DME (50-50) and fig. (8) shows a comparison of the performance of the various mixtures studied for the overcoated chamber. Again DME is seen to be the best candidate for stable operation. Also in this plate, no damages were observed on inspection after the tests were completed.

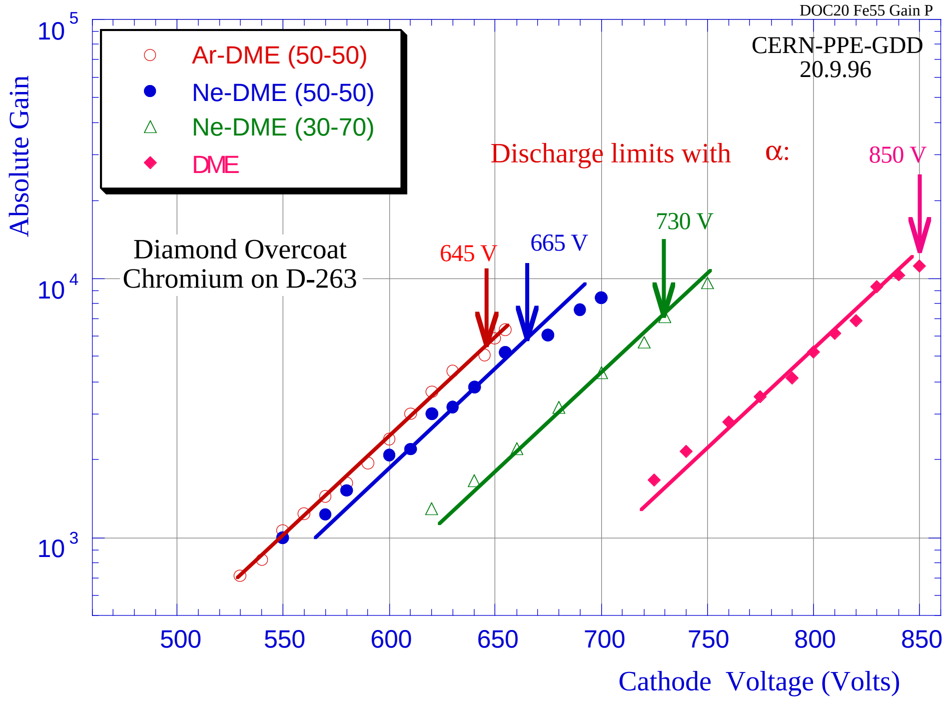

Fig. (8)

Table (2) summarizes the results for the DUC and table (3) that for the DOC. The slightly larger gain reachable with neon mixtures is in practice nullified by the reduced ionization for minimum ionizing particles (mip); this is estimated to be 1.14 times lower than that of a similar argon based mixture.

From these results it is clear that in our MSGC structures there is only a small advantage using neon, made ineffective by the reduced ionization. The highest gains were achieved with DME, being higher for the undercoated chamber. The required higher voltage, however, can have adverse consequences in case of a discharge since the energy is about twice than the corresponding energy for the overcoated chambers.

Gas Mixture	Maximum Voltage (Gain) without any source of radiation (Volts)	Maximum Voltage(Gain) for stable operation with Fe^{55} (Volts)	Maximum Voltage(Gain) for stable operation with Am^{241} ($Vmax_{\alpha}$) (Volts)
Ar-DME (50-50)	680 (10000)	670 (9130)	650 (6660)
Ne-DME (50-50)	710 (15000)	700 (9660)	670 (5900)
Ar-DME (30-70)	755 (15000)	750 (9260)	735 (7100)
Ne-DME (30-70)	760 (15000)	750 (10260)	745 (9150)
DME-Ar (98-02)	860 (25000)	850 (21000)	850 (21000)
Pure DME	870 (26600)	870 (26600)	865 (23000)

Table (2) Gain Limits in Undercoated Chamber

Gas Mixture	Maximum Voltage (Gain) without any source of radiation (Volts)	Maximum Voltage (Gain) for stable operation with Fe^{55} (Volts)	Maximum Voltage (Gain) for stable operation with Am^{241} ($Vmax_{\alpha}$) (Volts)
Ar-DME 50-50	670) (9000)	665 (6340)	645 (5090)
Ne-DME 50-50	710 (10000)	700 (8460)	665 (6040)
Ne-DME 30-70	755 (11000)	750 (9610)	730 (7020)
Pure DME	850 (11200)	850 (11200)	850 (112000)

Table (3) Gain Limits in Overcoated Chamber

REFERENCES:

[1] A. Oed, Position-sensitive Detector with Microstrip Anode for Electron Multiplication with Gases. Nucl. Instr. and Methods **A263** (1988)351

[2] R. Bouclier et al, Nucl. Instr. and Methods A367(1995) 163

[3] F. Angellini et al., NIM **A362** (1995) 273.

[4] F. Angellini et al., Proc. Int. Workshop on MSGCs, Lyon, (1995) 307.

[5] R. Bouclier et al Paper presented in the International Conference on Advanced Technology and Particle Physics, Centro di Cultura Scientifica A. Volta, Villa Olmo, Como, Italy Oct 7-11, 1996

[6] R. Bouclier et al CERN PPE/95-95 (1995)

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