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Wire ageing with the TEA photocathode.

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ABSTRACT

Recently several RICH prototypes successfully tested a gaseous TEA photocathode. However, its wire ageing behavior is unknown. In principle, TEA is a more strongly bonded molecule than TMAE, and, as a result, one would expect better wire ageing behavior. This paper explores this question.

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INTRODUCTION

This paper contributes to the basic understanding of how photocathode materials behave at high rates in typical applications of photon detectors based on a gas amplification method. Tests with TMAE (Tetrakis-dimethylamino-ethylene; $[(CH_3)_2N]_2C=C[N(CH_3)_2]_2$) and CsI photosensitive materials were described previously [1,2]. Tests with the TEA molecule (Tri-ethyl-amine; $(C_2H_5)_3N$) are presented now.

The present measurement was motivated by the very good results obtained from the TEA-based prototypes of the College de France [3] and Cornell [4] groups. We were was also encouraged by the Cornell group to compare TEA and TMAE in the same apparatus, since this yields similar systematic errors.

One may expect that TMAE wire ageing is faster because the TMAE molecule is more fragile than the TEA molecule. The TMAE molecule has an ionization potential of only ~5.4 eV, and its lowest dissociation energy may be as low as 2.7 eV; TEA's ionization potential is ~7.8 eV.

Photosensitive molecules such as TMAE or TEA, or their ageing products, may have a large volume resistivity when deposited on the cathode surfaces. Therefore the possibility exists of exciting self-sustaining cathode currents by a high radiation dose [1].

Finally, TEA has been used successfully to quiet down noisy wire chambers in the past. This is presumably because TEA has a very short absorption length (ℓ~0.6 mm) for hard UV photons originating from atomic excitations in the avalanche. Consequently, it was also interesting to investigate whether TEA might serve as a "magic" additive to normal gases in order to reduce drift chamber ageing rate.

RESULTS

Following the experience of the Cornell group, we did not clean the TEA in any special way. It was simply transferred from a manufacturer's bottle [5] to a bubbler in an oxygen free glove box filled with N_2 gas. Prior to a test, ethane gas was passed through the bubbler for ~24 hours. This approach is very different from that used in TMAE applications, where the TMAE liquid must first be cleaned by a combination of water washing, filtering and pumping before being used in applications involving long electron drift distances [6].

A carrier gas, C_2H_6, at 1 atm was used in obtaining all results presented in this paper. For the TEA tests, the bubbler was kept at 15°C using a thermostatic bath, and the detector vessel and associated plumbing were kept at ambient temperature. For the TMAE tests in this paper, the bubbler was kept at 40°C, and the detector vessel and associated plumbing were kept at ~50°C (in the past, we have not seen any ageing dependence on the TMAE concentration [1]). The ageing tests were performed in the setup used previously [1], and the MWPC was instrumented with 7,

20 and 33 μm diameter carbon wires [7]. The chamber used a nickel-plated cathode, which was washed in ethanol prior to use. The chamber operated at a total wire gain of about 3-4x10^5, and dark current was kept below 0.5 nA, as in all previous TMAE ageing tests. Radiation was provided by a ~5 mC Fe^{55} source, which simulates well the ageing caused by X-ray backgrounds present at colliding beam machines. We did not perform ageing tests with a UV source. A typical starting ageing current density was ~200 nA per 5 mm of wire length for all measurements mentioned in this paper. The role of the rate at which a TMAE ageing test should be performed was investigated in CRID Note#36 in ref.1. At that time, we did not see any difference in ageing performance when the starting current density was varied from ~5 to ~200 nA per 5 mm of wire length.

The experiment was carried out under the same strict conditions required for TMAE operation, i.e. electropolished stainless steel tubing and VCR fittings were used, the ageing vessel was made of stainless steel, and the oxygen content was maintained at a level of less than one ppm. Other construction materials present in the MWPC were G-10 (unpainted with epoxy), 5 min. epoxy, and conducting epoxy, solder, etc.

Fig.1 shows the wire ageing results with C_2H_6+TEA for various anode wire diameters. One can see that the gain change correlates with the anode wire diameter. This is similar to the result obtained during the TMAE tests [1].

Fig.2 shows a comparison between TMAE and TEA wire ageing for the 33 μm diameter wire. A relative gain decrease of ~20% is observed after ~4 mC/cm. The corresponding result with C_2H_6+TMAE indicated the same drop after only ~1 mC/cm.

Fig.3 shows a comparison between TMAE and TEA wire ageing for a wire diameter 20 μm. One can see that the TMAE ageing rate is considerably faster. A relative gain decrease of ~20% is observed after ~1.5 mC/cm with C_2H_6+TEA, and after only ~0.2 mC/cm with C_2H_6+TMAE. We conclude that the TEA wire ageing rate (20% gain drop) appears to be slower than that of TMAE by a factor of 4-7.

As in the TMAE case [1], we have also found that the anode wires can be "regenerated" by passing a small current through them. This heats the wire to a high temperature (> 300°C), and causes the deposits to evaporate. We heated the wires for few minutes using a current of ~25 mA. The "regenerated" wires showed ageing behavior similar to that of the "brand new" wires.

Another critical question is whether TEA is less susceptible to self-sustaining cathode currents. Such a problem is recognized by removing the source, and observing whether the cathode current disappears instantly or lingers for a long time (various time constants were observed, ranging from tens of seconds to minutes, including just bursts of charge [1]). An example of the onset of such currents in TMAE-based gas is shown in Fig. 3, where a sudden flattening of the ageing curve can be seen in one test, and the residual current persisted even after the source was removed. TMAE-

based gases show such a sensitivity quite readily. As was suggested in Ref.1, such sensitivity may be related to high TMAE resistance which results probably from the very rigorous purification procedure adopted (water is removed). TEA, based on the experience of only 12 ageing trials, appears to be less sensitive to self-sustaining cathode currents. In this sample of 12, we have observed only one case in which a self-sustaining current was triggered. However, care has to be exercised in this regard if one wants to operate a system with a large number of wires. One can attempt to cope with such a problem by running at as low a wire gain as possible, or by including an additive (perhaps a small amount of water), or by having a very clever high voltage system which is capable of recognizing the onset of such currents, and automatically lowering the voltage. Clearly, a low wire gain operation of about $3\text{-}4\text{x}10^4$, as envisaged in the Cornell detector, is a step in the right direction.

CONCLUSIONS

1. The TEA wire ageing rate (20% gain drop) appears to be slower than that of TMAE by a factor of 4-7.
2. The TEA wire ageing rate is inversely proportional to the anode wire diameter. This is similar to TMAE.
3. We found that a TEA-aged anode wire surface may be regenerated as a result of the heating which accompanies the passage of a small current through the wire. This is similar to TMAE.
4. We have observed one case in ~12 tries in which a normal wire ageing process turned into a self-sustaining cathode current condition, i.e. a current persisted even after the source was removed. The best way to protect against this problem in a system consisting of a large number of wires is to try to run at as low a wire gain as possible.

ACKNOWLEDGEMENTS

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FIGURE CAPTIONS

1. Wire ageing results with C_2H_6+TEA for anode wire diameters 7, 20 and 33 μm.
2. Wire ageing results with C_2H_6+TMAE and C_2H_6+TEA for wire diameter 33 μm.
3. Wire ageing results with C_2H_6+TMAE and C_2H_6+TEA for wire diameter 20 μm.

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[7] The 7 μm wire was made by Toho Rayon Co., Japan (it is also used in the SLD CRID detectors); the 20 μm wire was made by Energy Science Lab., CA 92121-2232, U.S.A.; the 33 μm wire was made by Textron Co., U.S.A.

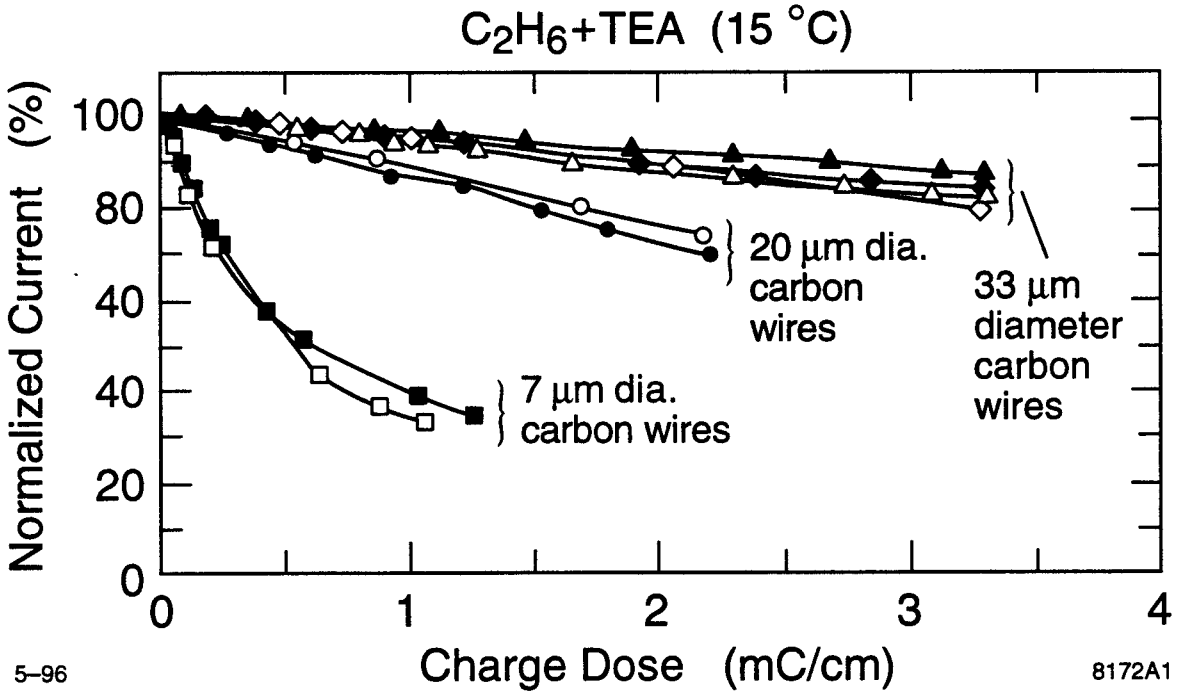
C_2H_6+TEA (15 °C)
Normalized Current (%)
100
80
40
40
20
0
0
1
2
3
4
Charge Dose (mC/cm)
20 µm dia. carbon wires
33 µm diameter carbon wires
7 µm dia. carbon wires
5–96
8172A1

Fig. 1

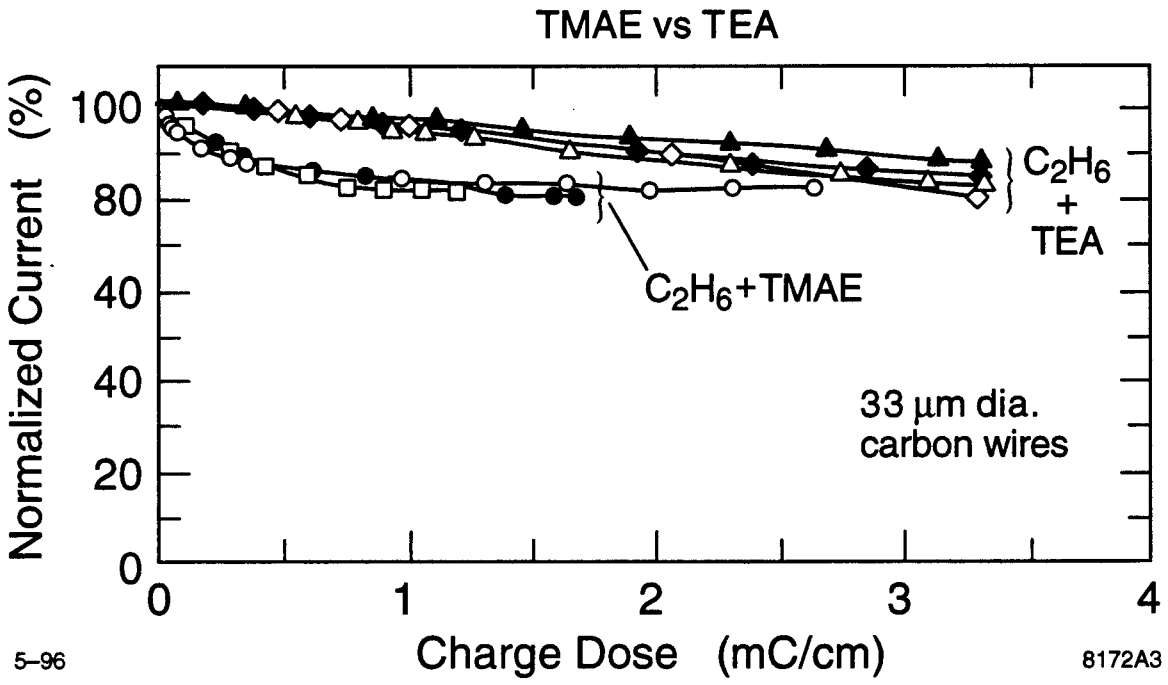
TMAE vs TEA
Normalized Current (%)
100
80
40
40
20
0
0
1
2
3
4
Charge Dose (mC/cm)
C_2H_6 + TEA
C_2H_6+TMAE
33 μm dia. carbon wires
5–96
8172A3

Fig. 2

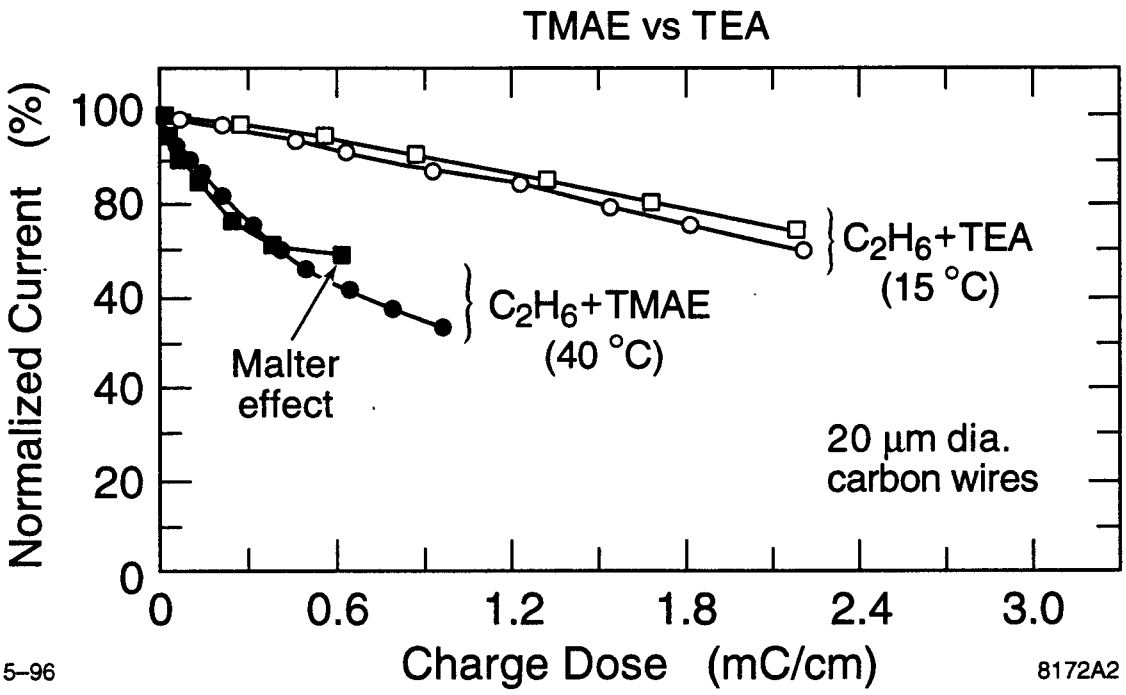
TMAE vs TEA
Normalized Current (%)
100
80
40
40
20
0
0
0.6
1.2
1.8
2.4
3.0
Charge Dose (mC/cm)
C2H6+TEA
(15 °C)
C2H6+TMAE
(40 °C)
Malter
effect
20 μm dia.
carbon wires
5–96
8172A2

Fig. 3