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THE COATED CATHODE CONDUCTIVE LAYER CHAMBER

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ABSTRACT

We describe a gaseous detector consisting of thin anode strips vacuum-evaporated on one side of a 100 μm thick plastic layer, alternating on the back side of the same foil with wider parallel cathode strips. Ionization released in a drift space on the anode side is amplified and detected much in the same way as in the microstrip gas chamber; in our detector however spontaneous breakdown due to surface currents is completely avoided by the presence of the insulating layer between anodes and cathodes. To reduce surface and volume charging up, we have used polymer foils with a moderate volume resistivity. The first results show good efficiency, good plateaux and time resolution in detecting low-rate minimum ionizing electrons. Although not suited for high rate or good energy resolution applications, this kind of detector seems rather promising for realizing cheaply large active surfaces.

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Great interest has been raised recently by the development of the microstrip chambers, gaseous devices having as detecting element a set of thin metal strips laid on an insulating glass support [1-5]. Proportional amplification with gains above 10^4 , very good localization accuracy and high rate capability have been demonstrated (see other contributions to this conference).

The crucial importance for correct operation of the nature of the insulating substrate appears clearly in the quoted works. When using a very high resistivity support, charging up of the surface due to deposition of ions modifies dynamically the electric field and hence the operating characteristics. Use of a low resistivity support, on the other hand, may lead to leakage currents and breakdown. Due to the small cross section of the anodes (typically $5 \times 1 \mu\text{m}^2$) a discharge results inevitably in a permanent damage of the strip.

In the Coated Cathode Conductive Layer (COCA COLA) chamber we have attempted to solve the breakdown problem by placing the anode and the cathode strips on opposite sides of a thin plastic foil (see Fig. 1). Apart from a small modification due to the dielectric constant of the support, and before charge-up process sets in, the electric field in the COCA COLA chamber is sensibly the same as in the original microstrip detector, and one would expect gaseous amplification to occur. However, quite soon after applying the voltage, positive ions produced at the anodes would drift towards the cathode and attach to the foil in front of the cathode strips, thus creating a local dipole field that cancels the original one.

It is conceivable that if a support is chosen with sufficiently low bulk resistivity, charges would neutralize with a time constant smaller than the ions production rate and a stable operating condition could be reached. A detector based on similar principles was described some time ago [6], but then apparently abandoned (probably because of the competing simultaneous development of multiwire proportional chambers).

For the measurements described we have used the configuration shown in the figure, with the anode strip facing the drift space; it is however not inconceivable that a reverse geometry, with the cathodes facing the drift space, would work as well if using a support with the proper conductivity. Indeed it might be easier to neutralize by conduction the electrons produced in the avalanche, as compared to ions.

A rough estimate of the resistivity required to handle moderate intensities provides values in the range 10^{10} - 10^{11} ohms.cm. In our first attempt to realize the COCA COLA chamber we have used as support a $100 \mu\text{m}$ thick foil of White Tedlar*, having a bulk resistivity around 10^{12} ohms.cm. We actually measured a value higher by an order of magnitude, which may explain some observed charging up phenomena to be described later. The nominal dielectric rigidity of the $100 \mu\text{m}$ Tedlar foil is 10 kV. Anode strips were vacuum evaporated on one side with a 3 mm pitch; because of the process used, their width varied between 200 and $300 \mu\text{m}$. A printed circuit with wider ($500 \mu\text{m}$) strips and the same pitch was mounted on the back side of the foil, to realize the geometry sketched in the figure. The active area of the detector was $10 \times 10 \text{ cm}^2$, although for practical reasons only half a dozen strips were actually readout. An 8 mm thick gap, overlaying the plastic foil on the anode side and delimited by an upper electrode served to collect and drift the ionization. For most measurements, we have used an argon-methane (90-10) gas filling.

On power on, the detector exhibits some erratic bursts of pulses for a few seconds, probably due to polarization of the dielectric, followed by a more stable condition of moderate noise signal rate (few hundred hertz over the entire sensitive surface). The dynamic charging-up behavior is apparent when, with high voltage applied, the detector is exposed to an intense radiation source. At the moment of exposure an intense burst of pulses appears on the anodes, quickly decreasing with a time constant of a fraction of a second; the detector recovers in about the same time after removal of the source.

At moderate detection rates (around hundred hertz per cm^2), the operation seems instead rather stable. Due to the variable anode strip width, we did not expect (and in fact

* Trade name of Du Pont de Nemours & Co

did not find) a uniform gain distribution across the active area. Using a collimated Ru^{106} electron source in coincidence with a small scintillator behind the chamber, we have recorded the pulse height distribution on individual anode strips; an example is shown in Fig. 2. The peak corresponds to a detected charge of about 0.1 pC which, taking into account the ionization loss in the gap (~ 70 electron-ion pairs) implies a proportional gain of around 10^4 . The distribution is more or less the one expected for minimum ionizing electrons; the cut at low pulse heights is given by the discrimination threshold on the anode strip signal, about 0.02 pC. In these conditions, for a single strip readout, we have measured the efficiency plateau as a function of cathode voltage (the anode being grounded). An example is shown in Fig. 3. We believe that the fact that we could not reach 100% is due to the poor geometry and to the use of a single scintillation counter as trigger; the fact that the plateau remains constant up to the highest voltages supports this statement. Fig. 4 shows the singles rate with the source in the same range of voltages.

The time resolution spectrum for the signals in coincidence, Fig. 5, has a FWHM of around 250 ns; this corresponds roughly to the total drift time in the gap, as one would expect for the described geometry.

Various phenomena that can be associated to charging up of the insulator have been observed in the detector. The most obvious one is a large drop in efficiency observed whenever the voltage to the cathodes is decreased, even by a few hundred volts. With a time constant of minutes, leaving the chamber exposed to the source, the efficiency recovers its normal value; there seems to be a slight dependence of the recovery time from the source intensity. As shown in Fig. 6, we have measured the efficiency as a function of time (after a decrease of the voltage from -3.5 to -3 kV), with the chamber exposed to the low activity electron source only (at a singles counting rate of around 700 counts s^{-1}), and with a local loading with an x-ray source added ($\sim 5 \times 10^3$ counts s^{-1}). In the second case the recovery seems slightly faster, but perhaps not significantly. When however the voltage is increased by the same amount, no similar effects are observed; full efficiency indeed is measured immediately even when powering the cathodes all the way up from zero potential. We explain the observation as follows: due to the very high resistivity of the foil (as mentioned before, above 10^{13} ohms.cm), ions actually accumulate on the surface until, with their distribution, they oblige the electric field to be parallel to the foil surface for most of the anode-to cathode distance. This is a condition of equilibrium, since it prevents more ions to reach the insulator. When increasing the voltage, ions produced in the avalanches easily attach to the surface to recreate an equilibrium condition. However, when the voltage is decreased, to obtain the same equilibrium one has to actually remove ions from the surface, a much longer process. Note that similar arguments have been used to explain the behavior of the so-called electrodeless drift chambers [7, 8]. Obviously, so far this is a rather superficial analysis and more measurements and model calculations are certainly required for a better understanding of the detector. It is interesting to note that the gain does not increase much when raising the voltage, from 3 up to 5 kV; this is probably again a manifestation of the dynamic search of an equilibrium in the charge distribution.

Several problems have appeared during these early tests. As already mentioned the anode strips, obtained by evaporation in vacuum through a mask, were not constant enough in width to provide decent gain uniformity. Their thickness, around 300 Å, made manipulation of the foils rather delicate and we had often contact interruption along the strips; the fact that anodes and cathodes were realized on separate supports created some electrical contact problems. We are currently investigating alternative technologies to obtain a better quality and uniformity of the strips; a promising approach appears to be a complete metallization by vacuum evaporation of aluminum around 3000 Å thick, followed by a high-quality photographic engraving.

While obviously not suited for high or even moderate rate applications, the COCA COLA chamber may be a valid alternative to existing low-cost devices designed to cover very large surfaces (as for example for muon detection). The very large efficiency plateaux, together with complete immunity to spark breakdown, make the detector rather suitable for use in this case.

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FIGURE CAPTIONS

Fig. 1: Schematics of the COCA COLA Chamber. Thin anode and cathode strips are placed on the two sides of a plastic foil. Ionization electrons released in the gas are drifted towards the anode strips, where avalanche multiplication occurs.

Fig. 2: Pulse height spectrum for minimum ionizing electrons recorded on one anode strip. The peak corresponds to about 0.1 pC of charge on the anode.

Fig. 3: Efficiency plateau on a single strip as a function of cathode voltage, measure for minimum ionizing electrons.

Fig. 4: Singles counting rate on a strip as a function of voltage.

Fig. 5: Time spectrum measured at $HVC = -3.5$ kV.

Fig. 6: Efficiency recovery time, observed when reducing the voltage on cathodes from -3.5 to -3.0 kV. The measurement has been done with the electron source alone (full circles) and in presence of a local loading with an x-ray source (open circles).

Fig. 1

Fig. 2

Fig. 3

Fig.4

Fig. 5

Fig. 6