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**A NEW APPROACH FOR CONSTRUCTING SENSITIVE SURFACES:
THE GASEOUS PIXEL CHAMBER(*)**

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ABSTRACT

Many attempts have been made to construct a gaseous chamber with the anodes attached to an insulating film. However, this insulator becomes charged so that it is difficult to obtain the high electrical fields needed for gas amplification. We have discovered an anode design that overcomes this problem. Moreover, this surface operates in limited streamer mode and is capable of working at high rates. We present here the current status of this device.

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1. INTRODUCTION

Many people have had the desire to build a chamber by 'printing' the lines on an insulator, using the techniques of printed circuit boards or some similar technology. In fact there have been successes. Neumann [1,2] et al. built a chamber where they glued wires onto a resistive foil and obtained efficiencies of 85%. Recently Oed [3] followed by others [4,5] built a device with 10 μm wide lines, with 200 μm pitch evaporated onto a glass plate. They have obtained gas gains of 10^3 and 10^4 . This was the starting point of our investigation. We scaled up their device and had lines of 100 μm etched onto standard Kapton and epoxy sheets with a pitch of 1 cm. This is shown in fig. 1. After initially applying positive high voltage to the anode lines we observed large signals correlated to a ^{57}Co gamma source irradiating the surface. However, these signals quickly disappeared until only a low rate of signals remained. On investigation we found that the signals were produced just around the tips of the lines [6]. From this observation we have developed a surface of 'tips'. These are small pads connected by small diameter plated through holes to a high voltage bus on the other side of the insulating foil. An example of this foil geometry is shown in fig. 2. We will discuss this type of surface for the remainder of this report.

2. DESCRIPTION OF FOIL

We have tested various foils where changes to the geometry have been made. The design of a typical foil is shown in fig. 2. The sheet of insulator is Kapton of 125 μm thickness. This is available commercially with a layer of copper (18 μm thick) glued onto each surface. The glue is a polyurethane glue and is 25 μm thick. This is treated by standard printed circuit board techniques to produce plated through holes and the desired design of copper conductor. The thickness of the copper is increased to 35 μm after this treatment. The final surface of the conductor is protected by a chemical deposit of gold. The layer of glue is left on the surface of the Kapton.

The basic cell of this surface consists of an anode surrounded at some distance by a cathode area. A typical radius for this clearance is 3.5 mm although we have tested other radii. We have also constructed surfaces where the cathode is a grid structure. These work in a similar manner. The anode is a small pad. We have tested various sizes with diameters between 200 μm and 1 mm. These pads are connected to a high voltage bus line on the other side of the insulating foil with a plated through hole of diameter 200 μm .

3. TESTS

We have fabricated foils of 160 x 160 mm^2 . We have installed these in a gas tight box. The volume of gas above the foil was 5 cm thick. The cathode was connected to ground. The anodes were connected to a positive high voltage unit via a 10 M Ω resistor. The anode signal was decoupled with a 1 nF capacitor, then connected to a x5 LRS 335L amplifier. In case we had electrical breakdown on the foil we provided extra protection to the input of the amplifier with diodes and further decoupling with a transformer. We then studied this signal with a variety of instruments; a Tektronix 2440 digital oscilloscope, a LRS 3001 qVt or standard CAMAC ADC's and TDC's for the beam tests. In fig. 3 we show the oscilloscope traces of three successive pulses when a typical foil is irradiated with a ^{55}Fe source.

We flowed a mixture of isobutane and argon (most tests were done with pure isobutane) through the gas tight box. The box can be irradiated with a ^{55}Fe or ^{57}Co source. We built a simple cosmic ray telescope of three scintillators to study the response of the foils to minimum ionizing particles. For a more complete study we have tested some foils in a 6 GeV/c pion beam in the CERN East hall.

4. ELECTRIC FIELD

We have calculated the electric field produced by this surface in three dimensions. This has been done under the assumption that no field line crosses an insulating surface. We assume that initially crossing field line will transport free electrons and/or ions onto these surfaces and modify thereafter locally the field. With an ideal insulator we reach a situation where all equipotential surfaces end perpendicular on the insulators. In fig. 4 we show the potential on the surface between the anode and cathode. We superimpose two curves that fall as $1/r$ and as $-\ln(r/R)$. We expect the field to vary as $1/r^2$ around the anode point.

In reality there is a bus line on the backside of the foil that supplies the voltage to the anode spot. Immediately after turn on, the surface above this line will not be charged and field lines will pass through the Kapton and end on the high voltage bus. These lines will transport electrons to the surface of the Kapton and charge this surface. Ideally this process continues until the surface is 'fully' charged (that is, no field line enters the Kapton). However, when the surface is fully charged, then just above the surface there is a strong electric field parallel to the surface that transports the electrons to the anode. Thus, the fully charged state is unstable and the surface should not be regarded as a perfect insulator, especially above this high voltage bus line.

We have tested two identical foils except that one has the anodes strung together in a chain while the other has a single line running to each anode. This is shown in fig. 5. We installed the surface in a gas box with 5 cm of gas above the surface. We then irradiated each surface with an ^{55}Fe source. We measured the gain and counting rate as a function of high voltage. The gain of the two surfaces is identical but the counting rate was significantly higher for the surface with the single anode line, presumably this is due to primary ionization being transported to the surface above the high voltage bus rather than to the high field around the anode.

Another observation related to the high voltage bus line is that sparks are generally produced from the cathode directly above the high voltage bus. This region has a very high field produced by having the high voltage bus close to the cathode, this field is reduced by charging the surface of the Kapton insulator with electrons. In order to reduce this field to require less electrons on the surface, we mounted a ground plane below the high voltage bus (insulated by 100 μm thick Kapton tape). With this ground plane we found that the potential where sparks are produced is several hundred volts higher.

5. RESULTS

We have investigated the variation of gain with the size of the anode spot diameter. Again this was a foil in a gas box with 5 cm gas above the surface. Figure 6 shows our measurement of gain for a variety of anode spot diameters and also for various cathode radii. For a cathode radius of 3.5 mm there is an increase

in gain by reducing the anode spot diameter from 1 mm to 600 μm . However, reducing the anode diameter further until we reach the 200 μm (which is the minimum as it is the diameter of the plated through hole) does not affect the gain. With a 500 μm anode diameter we reduced the cathode radius from 3.5 mm to 2.5 mm and finally to 1.25 mm. Reducing the radius from 3.5 to 2.5 mm does not affect the gain, however there is an increase for the 1.25 mm radius. With this small radius of 1.25 mm we reduced the anode spot diameter to 200 μm . This produced a further increase in gain. It is clear that there are a wide range of anode spot diameter sizes and cathode radii that produce pixels with the same gain. It will make it easy to fabricate surfaces with uniform operational characteristics. Another important characteristic of the foil is the voltage at which we produce sparks. The end points of the various curves in fig. 6 show the onset of sparking (this is not a very precise measurement as some surfaces would hold a voltage for 10 minutes before producing a spark). However, it is clear that a geometry with a smaller cathode radius produces sparks at a lower potential.

We have investigated the variation of the average streamer charge versus high voltage for various mixtures of argon and isobutane. This is for a foil with 500 μm diameter anodes with a 3.5 mm cathode radius. The results are shown in fig. 7. We also show the counting rate variation. This is for the experimental setup with a single foil within a gas-tight box. The gain is higher for an increased fraction of argon within the mixture. However, with this rather elementary setup we have a coupling between the drift field and the voltage that we apply to the anode. For example with a high fraction of argon the pixel operates at the highest gain, but the counting rate is low. Thus, the source counting rate is not too meaningful in an absolute sense except that it suggests that we will need other electrodes to shape the field in order to build an optimal detector for minimum ionizing particles.

Our first attempt for these field shaping electrodes is described in fig. 8. These electrodes are printed on a 200 μm thick epoxy-glass board. This board is mounted 8 mm above the Kapton foil. We show the efficiency versus high voltage with pure isobutane for cosmic rays for two cases in fig. 9. In the first case it is the board without the shaping electrodes and the other case is with the shaping electrodes. The effect of the shaping electrodes is clear, it allows the chamber to become efficient at a much lower voltage.

We mounted this chamber with the shaping electrodes in a test beam in the East hall at CERN. We could vary the intensity of the core of the beam spot from 5000 particles/cm²/s to 100 000 particles/cm²/s. The efficiency versus the voltage for various fluxes is shown in fig. 10. It is clear that at the highest flux we are becoming dominated by space charge effects. Also at this high flux we have rate induced sparking above 6.4 kV. However, at 50 000 particles/cm²/s the onset of rate induced sparking is 6.8 kV although we are seeing a drop in efficiency due to space charge effects. We expect that the rate capability to be affected by the geometry of the cell so we will start to build chambers of different geometries to investigate and hopefully further improve the response at high rates. However, it should be noted that this chamber is already operating at a relatively high rate in a very stable manner. We have been working in a pulsed environment (one 0.4 s spill every 30 s) so it appears that worries regarding the stability of having an insulator close to the anode are unfounded.

6. CONCLUSIONS AND FUTURE

We have shown that we have discovered a way to construct surfaces that can detect particles in a very similar fashion to a plane of wires. However, our foils have the following advantages:

- (a) They are flexible and can be bent or cut to fit any geometry.
- (b) The gain is defined by the shape of the electrodes on the foil, not by the distance to some cathode plane. This makes the mechanical stability and mounting easy.
- (c) Our present design is pixel-like in character, it would be easy to place these on some curve to satisfy some geometrical requirement of an experiment.
- (d) The foil is easy to build using standard printed circuit board technology. Mass production can easily be contemplated.

The drift time is associated to the distance the track is from the anode. We will start on measuring the space resolution of this device once we have optimized the field shaping electrodes.

We have not worked on aging studies of the chamber yet, but do not expect it to behave badly in this respect as: (a) we can smear other materials onto the surface of the Kapton/glue insulator (such as silicon rubber) and not change the operation of the surface at all; (b) no special care is taken of the foil (sometime we wipe it with alcohol) but all the foils operate in a similar manner; (c) we can allow the surface to enter a continuous spark mode but once we reduce the voltage to the normal operation point, the foil works as before. However, more quantitative aging tests are essential and we will start on such a program in the near future.

So far we have only observed operation within the limited streamer mode of gas amplification. Obviously it would be very interesting if we can operate in a proportional mode. For this it may be necessary to work with a smaller anode diameter (and corresponding smaller anode-cathode spacing). We have built a similar but scaled down geometry on ceramic using standard thick film printing techniques. We do have ceramic surfaces that operate in a 'limited streamer' gas amplification mode. A lot more work is needed to investigate how to build this device on a small scale.

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FIGURE CAPTIONS

- Fig. 1 An attempt to scale up the Micro-Strip Chamber.
- Fig. 2 Schematic view of 'typical' foil.
- Fig. 3 Typical signals produced by foil being irradiated with ^{55}Fe .
- Fig. 4 Potential on the surface between the anode and cathode.
- Fig. 5 Two varieties of anode high-voltage bus.
- Fig. 6 Variation of gain of pixel for a variety of pad sizes and anode-cathode spacing.
- Fig. 7 Charge versus voltage and counting rate versus voltage for different fractions of argon in isobutane.
- Fig. 8 Diagram of roof electrodes.
- Fig. 9 Efficiency versus voltage for cosmic rays for two chamber configurations.
- Fig. 10 Efficiency versus high voltage for various particle flux.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Pattern of electrodes on roof

Cross section of foil with roof

Fig. 8

Fig. 9

Fig. 10