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Section A

Further experimental results of gas microdot detectors

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Abstract

The present status of microdot (MDOT) gas avalanche detectors is described. Two separate batches have been produced from which results are presented, showing the detectors gain dependence on cathode and drift voltage and the performance of such detectors to high intensity X-ray fluxes. The energy resolution at high rate and high gain are also shown along with preliminary ageing results.

1. Introduction

Previous results have been published [1] for half of the first batch of MDOT detectors produced by Hughes Microelectronics [2]. Results from the second half of this batch and from a newly designed batch are presented in this paper. The main differences between the two batches are in the processing stage and the geometry of the electrodes.

The processing steps for the first batch are outlined in Ref. [1] and the major change for the second batch has been to increase the oxide thickness between the two layers of metal to 2.7 μm. This was increased as a result of optical inspection of the first-half of the batch-1 MDOTs where they showed that "punch-through" breakdown has occurred between the two metal layers. It was found that the short circuits were developing between the anode bus and the cathode at sites on the metal-1 layer where "hillocks" had formed. These are regions formed on the metal-1 layer where a defect has occurred causing a raise in profile at the point. This is a common occurrence in the semi-conductor industry and is due to the high temperatures used during the deposition of the oxide layer onto the underlying substrate. The mask defining the geometry of the electrodes was also changed in an attempt to both reduce capacity between the two metal layers and to reduce the amount of crossover between the anode readout bus and cathode, see Fig. 1(b).

2. Geometry of the MDOT

Results from simulation of the MDOT structure using a finite element electric field simulator [3] have shown that the anode bus significantly distorts the electric field in the gas directly above the surface of the bus. The effect is to create a potential well for electrons created in the avalanche into which they can fall and be focused onto the bus lines rather than the anode dot. The addition of a "floating" potential ring between anode dot and cathode serves to restore symmetry to the electric field allowing higher drift fields to be applied without electrons focusing onto the bus lines. The rings also serve to reduce the electric field at the intersection point of anode bus and surface cathode where a large field could arise.

Half of the first batch of detectors had this floating ring incorporated into their design, see Fig. 1(a). In the second batch, after further simulation, structures were produced with 2 and even 3 floating rings between anode and cathode.For the second batch of MDOTs the anodes are connected in strings along a bus line in the metal-1 layer, as for the first batch, but the cathodes are also connected in strings in an orthogonal direction to the anodes on the metal-2 layer, see Fig. 1(c).

3. Results

The absolute gain of the detector was determined by two methods: (1) the calibration of the electronics chain by the injection of a pulse of known amplitude to the input capacitor of an Ortec 142AH preamplifier and (2) by monitoring the chamber current, performed using a Keithley 237 source measure unit (SMU) and the X-ray rate. The two methods agree to 10–15% which is consistent with the systematic errors. The presented results are obtained from the signal of 14 strings of anodes, each of length 6 cm, for the 200 μm pitch structures and 28 strings of anodes for the 100 μm pitch structures, which

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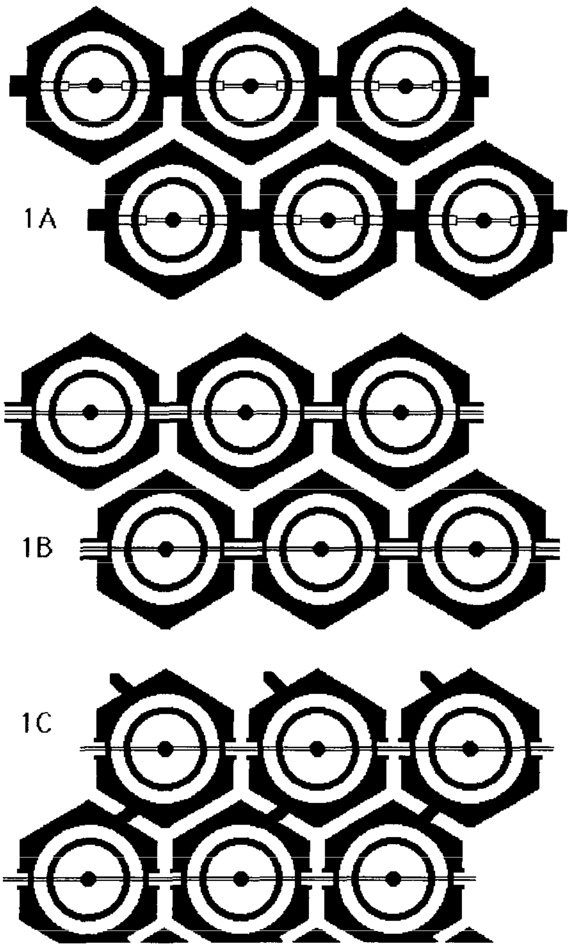

Fig. 1. Schematic of the described Microdot structures.

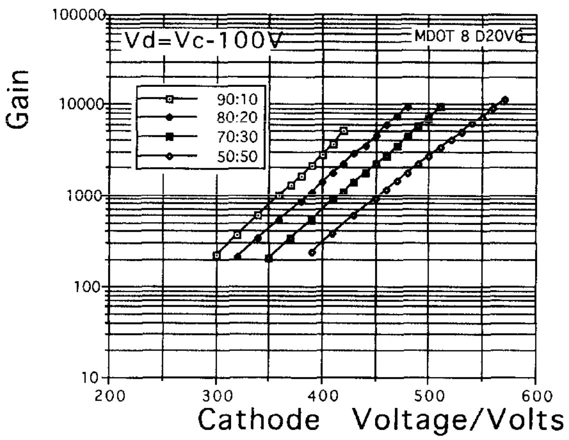

Fig. 2. Gain curves for 200 μm batch-1 structure with floating rings.

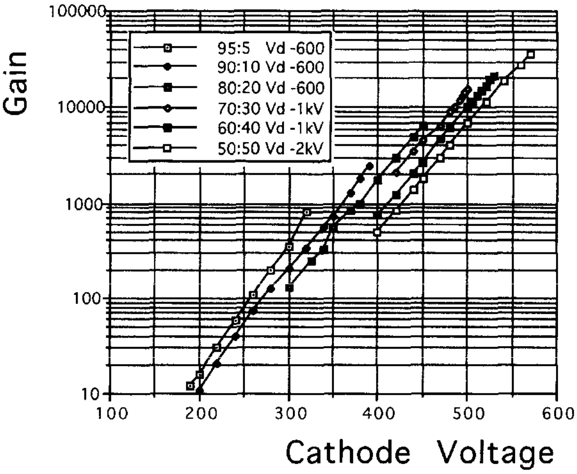

Fig. 3. Gain curves for 100 micron batch-2 structure.

are connected together and input to the preamplifier. No passivation was applied to the electrode ends.

4. Gain measurements

Fig. 2 shows the gas gain dependence on cathode voltage for a 200 μm pitch structure detector from the first batch, in various Ar:DME gas mixtures. The results were obtained using an ^{55}Fe 6 KeV X-ray source at low rate (~ 10 cts/(mm^2/s)). The maximum voltage in each mixture was defined by a current trip on the SMU of 20 nA. This limit was determined from experience with MSGCs and marks the onset of microdischarges or punch-through breakdown. The upper gain limit of 12 000 is typically a factor of 1.4 higher than that obtained with an MSGC on an electronic conducting substrate [4] and is obtained at a lower value of drift field and for a much reduced cathode voltage. Fig. 3 shows gain curves obtained with a 100 μm pitch structure from the second batch of wafers. Gains of up to 40 000 have been measured and this coupled with the detectors low noise levels allows these detectors to be used to detect single photo-electrons. Results are not presented for 200 μm pitch structures from the second batch, but gains of up to 50,000 have been measured. Their behaviour is not stable due to surface charging and due to lack of surface current in the implant layer. This could be compensated for by reducing the anode-cathode gap or by modifying the implanted layer.

The ratio of gain measured on the anodes to the cathodes has been investigated, and Fig. 4 shows this ratio for various applied drift voltages and for differing shaping times on an Ortec571 post amplifier. The applied voltage to the cathodes was -400 V for the three values of drift voltage used. The graph shows that for an applied drift voltage of -1 kV corresponding to a

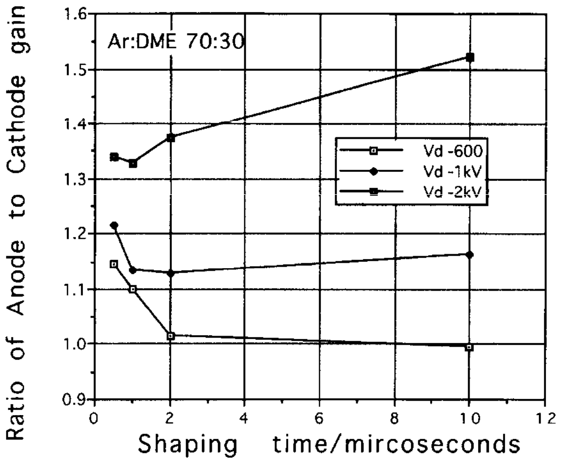

Fig. 4. Ratio of anode to cathode gain for 100 micron pitch batch-2 structure.

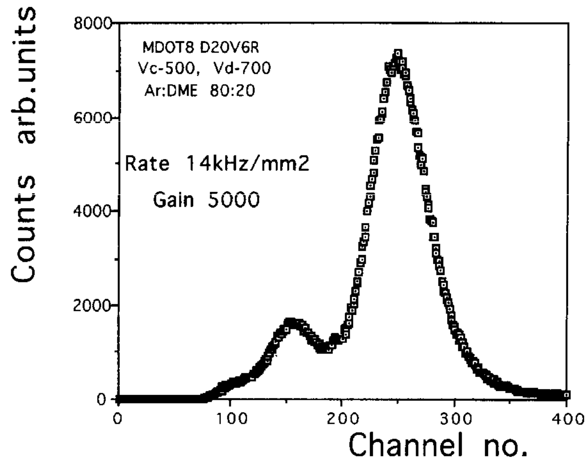

Fig. 5. 8 keV spectrum taken at high rate and high gain.

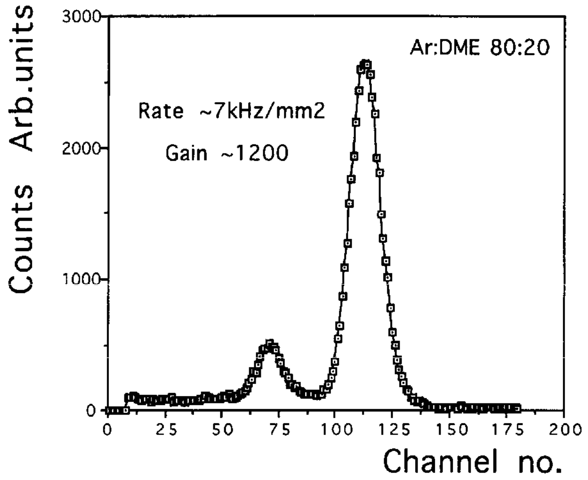

Fig. 6. 8 keV spectrum obtained with batch-2 200 micron microdot.

drift field of $2\,\mathrm{kV\,cm^{-1}}$ and at all values of shaping time that 85% of the anode signal is collected on the cathodes. The dependence of charge ratio on drift field and the dependence on integration time have been simulated and are found to agree well with the experimental results. The change in ratio at integration times below 1.5 μs is caused by the slow rise time of the preamplifier due to capacitive loading caused by bussing a large number of channels into the preamplifier. When this effect is removed the ratio is predicted to stay constant from 2 μs to below 500 ns.

5. Spatial and energy resolution

The spatial resolution of the MDOT structures for minimum ionising particles has been simulated using the MDOTSIM code [5], which gives $\sigma_x = \sigma_y = 16$–$18\,\mu\mathrm{m}$ in the case of 100 μm pitch MDOT and $\sigma_x = \sigma_y = 32$ to 35 μm for 200 μm pitch. In both cases the simulation gives $\sigma_E = 6\%$ for the energy resolution for 6 KeV X-rays.

The energy resolution, for 8 KeV X-rays, at high rate and high gain is shown in Fig. 5 for a 200 μm pitch batch-1 structure. A FWHM of 19% compares well to the 18% achieved at lower rates. Fig. 6 shows an 8 KeV spectrum obtained with a batch-2 200 μm pitch microdot at a gain of ~1000 and gives a FWHM of 14% which is limited by avalanche fluctuations.

6. High rate studies

The response of the detector to high fluxes of X-rays is crucial if the use of such a device for high rate applications is considered and Fig. 7 shows the behaviour of a 200 μm pitch MDOT from the first batch to high fluxes of 8 keV X-rays. The gain is monitored at high rates using the current drawn from the anode dots. The figure shows an initial charge up to 15% in gain which is stable to further increases in rate. Fig. 8 shows a similar behaviour for the case of a 100 μm pitch structure. The MDOTs produced without rings gave a larger increase of 30% but were similarly stable to further increases in rate. Ion implanted MSGCs using the same technology showed a decrease in gain of 33% but again were stable to increases in rate [6].

The initial rise in gain of the MDOTs and the fall in gain of the MSGCs can be understood by considering the interaction of the anode fields and the substrate fields. The MSGC field has a natural logarithmic fall off which

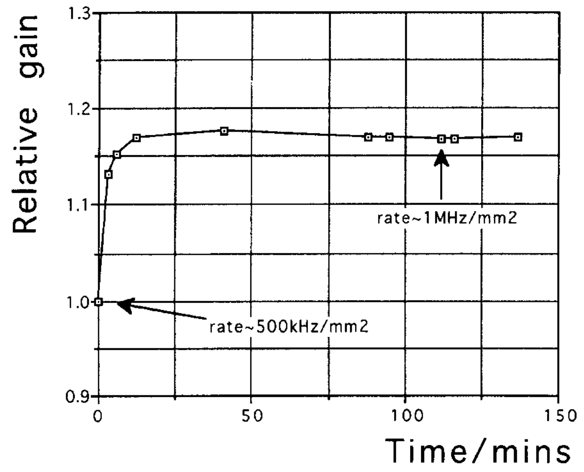

Fig. 7. Response of batch-1 200 micron MDOT structure to high X-ray flux.

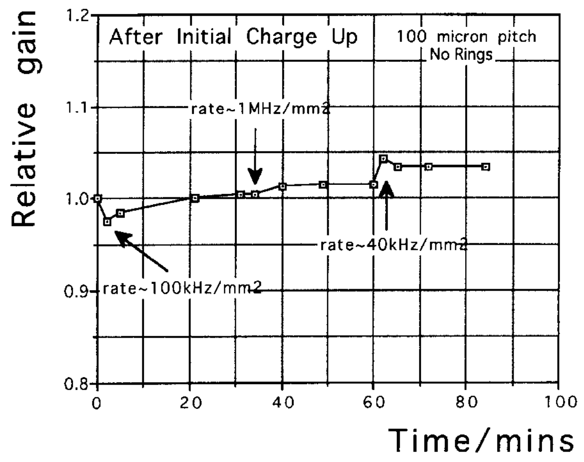

Fig. 8. Response to high X-ray flux for batch-1 MDOT with no rings.

is modified by the linear potential divider on the surface, in the case of the thin oxide ion implanted substrate detectors. For the case of the MDOT there is a better matching of the quadratic anode field to the quadratic surface field potential divider. This matching should be exact but is broken by the substrate bus effects.

Preliminary ageing measurements on 100 μm pitch batch-1 structure are given in Fig. 9 at a similar gain to the tests performed with MSGCs using a clean gas supply but with plastic pipes and plastic chamber materials.

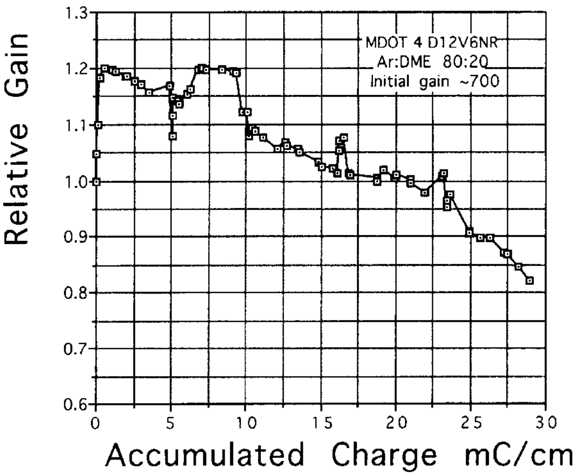

Fig. 9. Ageing curve for 100 micron MDOT structure.

No decrease in energy resolution was observed up to 25 mC/cm. After irradiation the detector was scanned under a microscope and not spark damage could be seen, but deposits however had formed on the electrodes where the X-ray beam was incident on the substrate.

7. Conclusions

Microdot gas avalanche detectors have been shown to operate at over 4 times higher gain than MSGCs of equivalent detector pitch. The detectors also show large induced pulses of over 80% on the cathodes allowing good 2D detector operation for X-rays or minimum ionising particles.

References

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