Designing and Performance Testings of Microdot Detectors

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Abstract

We describe recent observations and measurements realized with microdot (MDOT) detectors having 50 mm, 100 mm, and 200 mm pitches for 3.7 keV X−rays. A gas gain of 3.1×10^3 has been measured with 50 mm pitch MDOT at potential difference much lower than those usually obtained with MSGCs. The defocusing effect caused by the existence of the readout lines passing below the insulator layer has been investigated from the drift voltage dependence of the count rate variation and the electric field simulation for all the detectors. Results concerning the spatial resolutions are presented with collimated X−ray beams.

Ⅰ. Introduction

The microdot (MDOT) detector was first proposed by S.F. Biagi et al.[1], and shown to have a superior avalanche gain performance, high rate capability and good spatial resolution, compared with other existing gas avalanche microdetectors [2,3]. The buried nature of the anode bus limits the damage from sparking to a single cell, leaving the remaining cells on the same bus intact. In the case of the MSGC or MGAP, a single spark can result in breaking the anode thus reducing the active area. Moreover, this structure is inherently pixel-like and is probably most suited to two-dimensional experiments operating in a very high rate environment. However, the MDOT encounter a new problem with regard to defocusing of the primary electrons from the anode dots due to the influence of the readout line potential in the drift region [4], because a column of anode dots is connected to a strip buried below the insulator surface for ease of readout. Results are presented for the defocusing effect in terms of count rate variation with applied drift voltage, as well as by means of electric field simulation. The spatial resolutions of the MDOTs having 50 mm and 100 mm pitch were also estimated by using an X-ray collimator and precision stage system.

Ⅱ. Experimental Procedures

MDOT detectors having anode-to-anode pitches of 50 mm, 100 mm, and 200 mm, respectively, have been built on quartz wafers using standard photolithography processes. Fig.1 shows a schematic structure of the 50 mm pitch MDOT. A 0.2 mm thick chromium layer was deposited onto the quartz substrate, and was patterned as a readout strip line, using RF sputtering and lift-off techniques. And then, a 7.5 mm thick a-Si:C:H(r_V = ~ 10^{13} W.cm) was deposited on the readout pattern as an insulating spacer using the plasma enhanced chemical vapor deposition (PECVD) technique. Square holes (5×5mm for the 50mm and 100 mm pitch, and 10×10mm for the 200mm pitch) were made through the a-Si:C:H insulating layer by the reactive-ion etching (RIE) technique. Then anode dots and cathode were defined with 0.2 mm thick chromium by RF sputtering and lift-off techniques. The MDOT plate was mounted on a printed circuit board inside a clean stainless steel test vessel with a metal gasket.

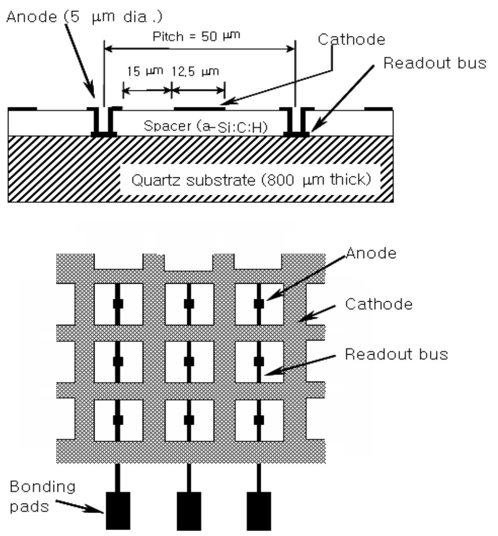


Fig. 1. Schematic diagram of a 50 mm pitch MDOT. For ease of readout, columns of anode dots are connected together.

A gas mixture of Ar-Isobutane (50:50) was used as the filling gas with a flow rate of about 100 sccm. For the spatial resolution measurement, the test vessel containing the microdot detector in its gas environment is mounted and moved on a set of X and Y precision stages, capable of computer-controlled motion with step sizes as small as 2.5 mm (or any larger increments), while the X-ray source and collimator remained fixed. It is also necessary that the diffusion and photoelectron range be small enough, so that the X-ray beam can be used effectively as a high resolution probe. The drift plane made of a thin stainless steel wire mesh was located just 2.0 mm above the detector in order to reduce diffusion of the primary electrons in the gas gap.

Ⅲ. Results and Discussion

1. Pulse Height Spectrum

Fig. 2 shows a typical pulse height spectrum of a 50 mm pitch detector exposed to X-rays from an X-ray generator with vanadium filter at a gas gain of around 2000 in Ar-Isobutane (50:50).

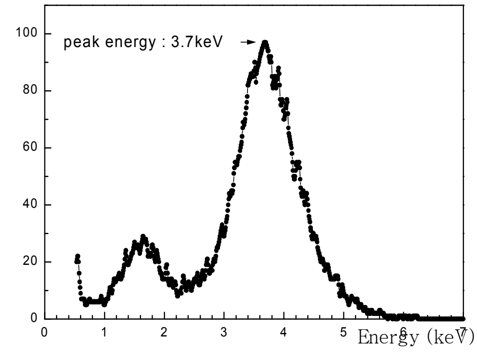
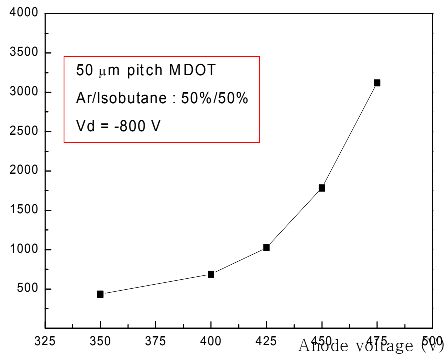


Fig. 2. The measured pulse-height spectra with a 50mm pitch MDOT for x-rays from an x-ray generator using a vanadium filter.

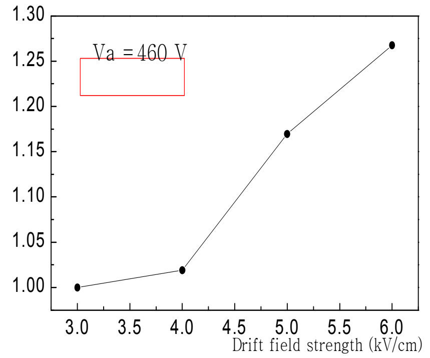
The detector was irradiated with 3.7 keV X-rays and the spectrum was obtained from 12 anode strips ganged together to collect all of the charges produced in the avalanche. The anodes and drift were put at 450 V and 800 V each, while the backplane and cathode electrodes are kept at 0 V. The energy resolution at the main peak was calculated to be 25% FWHM. The effective range of the photoelectron produced by X-ray conversion at the energy of the main peak is less than 50 mm [5], and the mean distance of ionization from the conversion point is only about 20 mm. Therefore, a highly collimated X-ray beam with low energy should provide an effective measurement of the spatial resolution of gas avalanche microdetectors.

2. Gas Gain

Operation of the detector at low voltages is important in order to avoid sparking and the subsequent risk of destructing the fragile electrodes. The gas gains of a 50 mm pitch MDOT with respect to anode voltage and drift field strength are shown in Fig. 3. The maximum gain of the MDOT is ~ 3.1×10^{3} and is obtained at a much more reduced anode voltage than that of MSGC. For gain measurement, the voltage was increased up to the point where a sudden increase in noise as a discharge precursor was detected. The gas gain is limited by a small high field region between the buried anode readout bus and the cathode at the point of intersection. This could be compensated for by modifying the cell geometry [6]. Fig. 3(b) shows the relative gas gain measured as a function of drift voltage. The gas gain increased as the drift voltage become more negative, since a more intense drift field enhances the field in the avalanche region.



(a)



(b)

Fig. 3. Gas gains measured as a function of (a) anode voltage and (b) drift voltage for a 50 mm pitch MDOT in Ar−Isobutane (50:50).

3. Insensitive Zones

The microdot detector is intrinsically a 2D device with buried anode readouts. One problem associated with readout line, however, is the tendency of drift field lines to defocus from the anode to the readout line, terminating on the insulator instead. An "insensitive zone" will be created in the gas drift region, where some of the drifting electrons will be directed toward the readout strip line below the insulating surface instead of toward the anode dots, leading to loss of detection efficiency [7]. The addition of a "floating" potential ring between anode dot and cathode is helpful in reducing this effect by shielding the readout region from the gas drift region [4]. As an alternative solution, we reduced the pitch from 200 mm to 50 mm. One way to characterize the defocusing effect of the readout is to measure the count rate variation with respect to drift field strength. Fig. 4 shows the count rate variation with respect to drift field strength for 50 mm, 100 mm, and 200 mm pitch detectors.

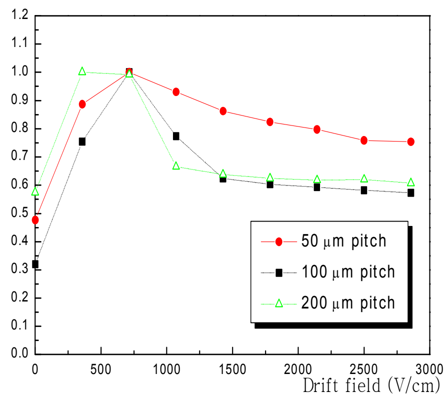
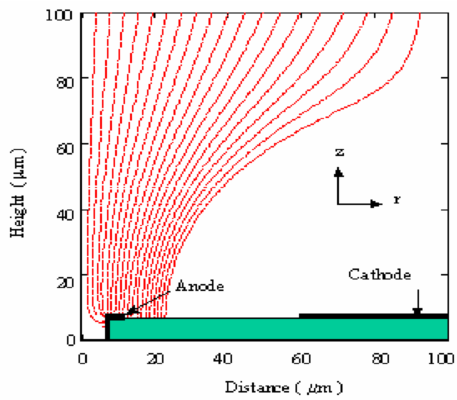
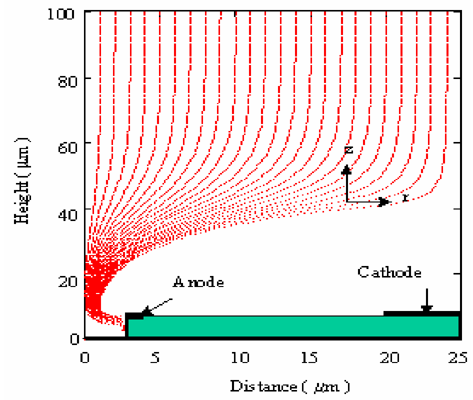


Fig. 4. The variation of the count rate with drift field strength for 50, 100, and 200 mm pitch MDOTs.

The count rate increased sharply at first and then decreased severely with the drift field strength, except for the 50 mm pitch MDOT. Lowering the drift field results in an increase of diffusion and a loss of electrons by the lack of field in the drift region to collect ionization, while in strong drift fields, some drift field lines reach the insulator surface above the readout line, thus reducing the count rate. The defocusing effect of the readout line was, as expected, more severe for the MDOT having a wider pitch. A wider gap between anode and cathode allows the drift field line to pass through the insulator surface and arrive at the adjacent readout line buried. To investigate this further, a two-dimensional electric field profile simulation was carried out to help verify the insensitive zones, using the Maxwell [8] and GARFIELD program. Fig. 5 shows that a significant portion of the drift field lines falls on the insulator surface between the anode and cathode in the 200 mm pitch MDOT, whereas all the field lines arrive at the anode in the 50 mm pitch MDOT. Therefore, this simulation result agrees well with above count rate variation measurement with drift field.





4. Spatial Resolution

To measure the spatial resolution of the MDOTs for X-rays, the detectors have been uniformly irradiated from above the drift plane with 3.7 keV X-rays through a 20mm wide collimator.

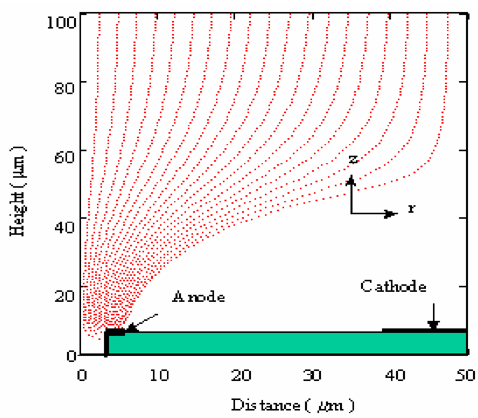
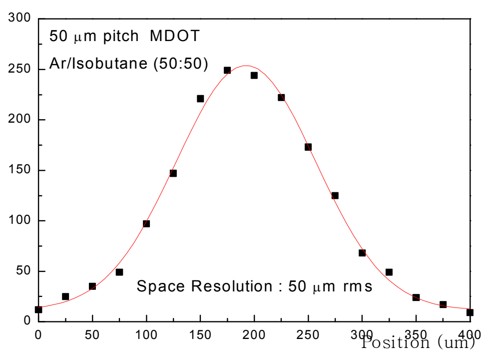


Fig. 5. Drift field maps in two-dimensional view for three different pitches of 50 , 100 , and 200 mm, at a fixed drift field strength of 2.5 kV/cm and an anode voltage of 500 V.

The absorption of an X-ray by photoelectric absorption causes a cloud of electron-ion pairs of a certain size. The smaller this cloud, the better the spatial resolution. The liberated electrons by X-ray absorption drift to the microdot detector and in the mean time can diffuse in transversal direction, which results in a larger electron cloud and a worse spatial resolution. The spatial resolutions of the MDOTs are shown in Fig. 6. The doctors were scanned along the direction perpendicular to the anode strips by steps of 25 mm. The data presented here were taken with a gas gap of 2 mm above the detector to keep diffusion small. The resolutions obtained under the same conditions are 50 mm and 69 mm (rms) for the 50 mm and 100 mm pitch detectors, respectively.



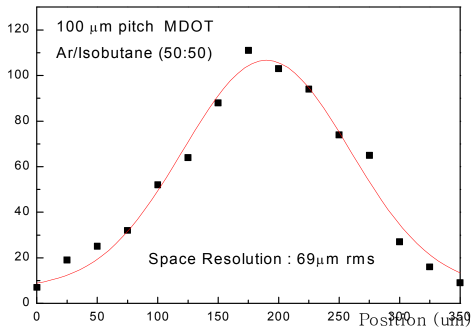


Fig. 6. Spatial resolutions for X-rays in MDOT detectors with 50mm pitch and 100mm pitch.

IV. Conclusion

The main characteristics of several microdot detectors having a square geometry have been investigated in a gas mixture of Ar-Isobutane (50:50) with collimated 3.7 keV X-rays. The microdot detectors have the intrinsic advantage of two-dimensional readout and high gas gain. However, owing to the existence of the readout strip line passing below the insulating surface, the drift field lines defocus from the anode dots, resulting in an insensitive region (dead zone). The defocusing effect was characterized by measuring the count rate variation with the drift voltage and using the MAXWELL program. According to our experimental and simulation results, the 50 mm pitch MDOT appears to be effective in reducing the dead zone, but for the 100 mm and 200 mm pitch MDOTs there are indications that a significant insensitive zone due to the wider anode-cathode gap and anode-anode pitch. The measured spatial resolutions are 50 mm and 69 mm (rms) for the 50 mm and 100 mm pitch detectors, respectively. In these measurements, Microdot gas avalanche detectors have shown a possibility of good 2D detector for X-rays or minimum ionizing particles.

Acknowledgment

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