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Application of a wedge strip anode in micro-pattern gaseous detectors*

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Abstract: The wedge strip anode (WSA) has been widely used in 2-D position-sensitive detectors. A circular WSA with an effective diameter of 52 mm is successfully coupled to a tripe gas electron multiplier (GEM) detector through a simple resistive layer. A spatial resolution of 440 μm (FWHM) is achieved for a 10 kVp X-ray using 1 atm Ar:CO$_2$=70:30 gas. The simple electronics of only three channels makes it very useful in applications strongly requiring simple interface design, e.g. sealed tubes and high pressure detectors.

Key words: wedge strip anode, micro pattern gaseous detector, resistive layer

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1 Introduction

Wedge strip anodes, first invented by Anger [1], have been widely used in 2-D position-sensitive detectors. The fundamental structure of a WSA is shown in Fig. 1. The entire metallic anode is divided into three electrodes, which are separated by a thin insulating gap. The typical value of the gap width is within several tens of microns. This is usually realized by laser machining or chemical etching.

This structure makes it capable of determining the gravity of an incident Gaussian distributed charge cluster using Eq. (1). Here, X and Y are the coordinates of the gravity in the coordinate system shown in Fig. 1. $Q_{\rm W}$, $Q_{\rm S}$ and $Q_{\rm Z}$ are the charge collected by the three electrodes (wedge, strip and z), respectively. $S_{\min}$ is the minimum width of the strips in Fig. 1. The other symbols have similar meanings. In order to apply Eq. (1), the rms deviation of the cluster should be at least 0.6 times the pitch in order to eliminate the modulation effect [2].

$$X=\frac{Q_{\rm S}/(Q_{\rm W}+Q_{\rm S}+Q_{\rm Z})-S_{\min}}{S_{\max}-S_{\min}},\qquad Y=\frac{Q_{\rm W}/(Q_{\rm W}+Q_{\rm S}+Q_{\rm Z})-W_{\min}}{W_{\max}-W_{\min}}. \tag{1}$$

A wedge strip anode can either directly collect the incident charge or be capacitively coupled to a thin resistive layer, i.e. using the image charge technique [3]. In the latter case, the incident charge cluster is first collected by the resistive layer and then dispersed on its surface. The gravity can be calculated by Eq. (1) similarly. But $Q_{\rm W}$, $Q_{\rm S}$ and $Q_{\rm Z}$ are the amplitudes of the induced charge signals on the electrodes.

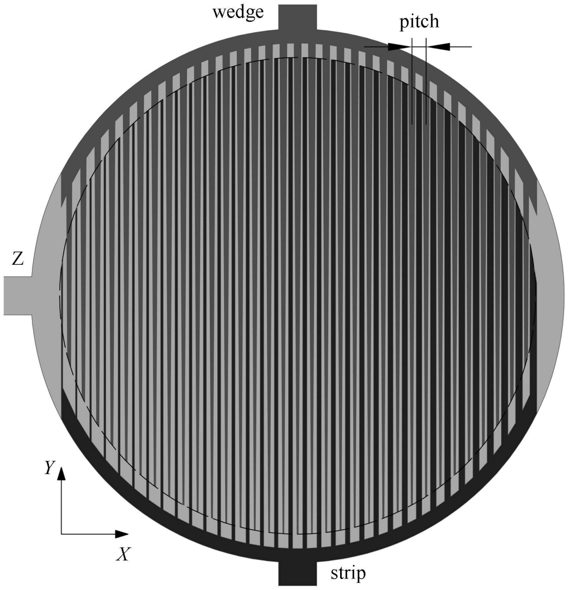

Fig. 1. The structure of the wedge strip anode. The effective area is within the dashed-line circle with a diameter of 52 mm. The pitch is 1.6 mm in our design.

According to the results given by Dixit et al. [4], the surface charge density still follows Gaussian distribution after charge collecting by the resistive layer. The charge gravity remains in the same position. The rms deviation is a function of t (the time from the collecting of

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the charge) determined by Eq. (2). Here, R and C are the surface resistance and capacitance per unit area, respectively. σ_c is the original rms deviation of the charge cluster. For a given electronic system, there is an average value σ_T over the rising time. This value can be used to evaluate the modulation index.

$$\sigma=\sqrt{\frac{2t}{RC}+\sigma_c^2}. \tag{2}$$

In typical micro pattern gaseous detectors (MPGDs), the anode is usually placed within 1 cm from the sensitive volume. For most operation gas mixtures, the rms deviation of the electron cluster is smaller than 200 μm when it reaches the anode [5]. If a WSA is directly coupled to such a detector, the cluster size is not enough to eliminate the modulation effect as described above. A WSA with a resistive layer is suitable for MPGDs, as σ_T can easily be changed by adjusting the surface resistance.

In this study, a 52 mm diameter WSA with a germanium resistive layer was assembled to a tripe GEM detector. The spatial resolution and distortions were studied to optimize the design.

2 The experimental setup

The detector structure is illustrated in Fig. 2. A germanium layer of 70 nm is coated on a 2.5 mm thick ceramic substrate by vacuum evaporation. A wedge strip anode is placed in direct contact with the other side of the ceramic plate. The WSA was produced by lithography technology with a pitch of 1.6 mm and insulating gap of 75 μm.

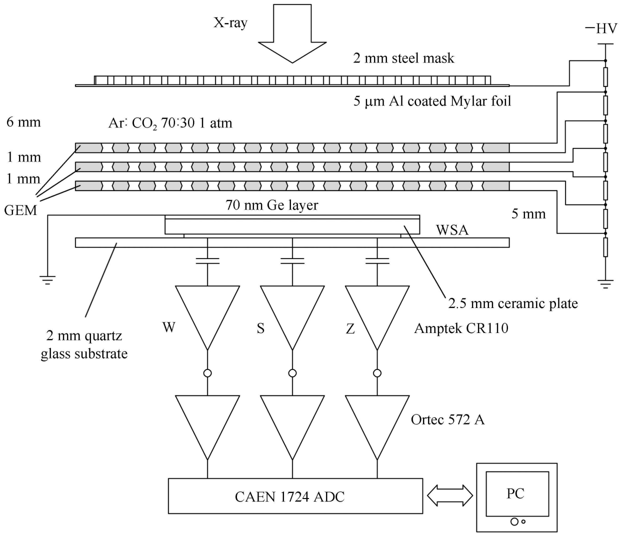

Fig. 2. The GEM detector and the electronic system.

A 2 mm thick stainless steel imaging mask with a 2-D array of holes of 0.3 mm diameter in a pitch of 4 mm in both directions is fixed above the cathode of the detector. An Amptek mini X-ray tube with a silver target is placed 45 cm away from the cathode. The tube voltage is set to be 10 kV.

The electronic system is also shown in Fig. 2. The Amptek CR110 is a charge sensitive preamplifier with an ENC slope of only three elect. RMS/pF which is suitable for the WSA with an input capacitance as large as 300 pF. A shaping time of 10 μs was used in the following measurements.

3 X-ray imaging results and discussion

3.1 Spatial resolution

The X-ray imaging of the steel mask is shown in Fig. 3(a). The projections to both directions in Fig. 3(b)

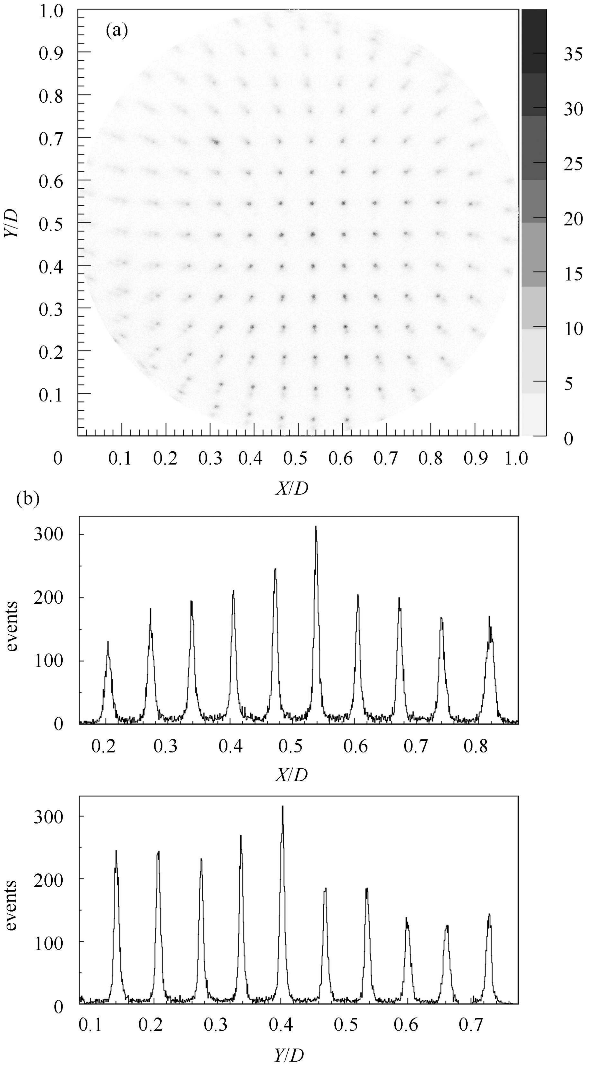

Fig. 3. X-ray imaging results. D is the diameter of the dashed-line circle in Fig. 1. (a) Transmission imaging of the mask, and (b) projections of the row between Y/D=0.46 and Y/D=0.50, and the column between X/D=0.50 and X/D=0.56.

were fitted. Both the hole size and positioning uncertainty contribute to the peak distribution, i.e. each peak is the convolution of the X-ray spatial distribution in the hole's cross section and the positioning uncertainty of the detector. Supposing the X-ray is uniform in one certain hole, one can get the positioning uncertainty, i.e. the spatial resolution by deconvolution. The result is presented in Fig. 4 for a 0.3 mm diameter hole. For each peak in Fig. 3(b), the FWHM is better than 470 μm. The derived spatial resolution is better than 440 μm. The results close to the edge are worse because of the parallex effect, as can be seen in Fig. 3(a).

Figure 5 illustrates the contribution of photoelectron energy to the total positioning uncertainty. The right part is the imaging of the standard lead line pair card. The left part selects only the events with a total energy deposit lower than 8 keV. Thus the resolution is better. The 2.5 lp/mm group is well separated (better than 400 μm FWHM).

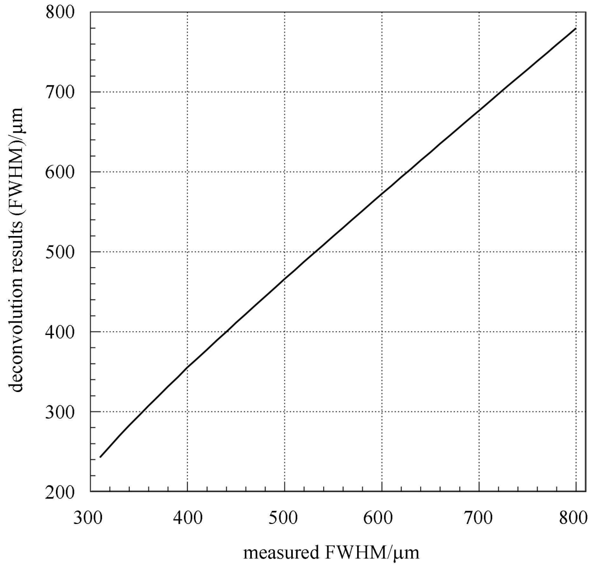

Fig. 4. The deconvolution results of spatial resolution for the 0.3 mm diameter hole.

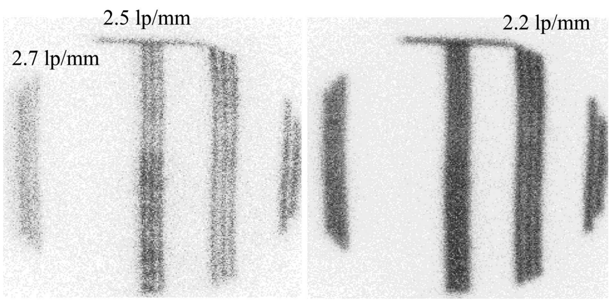

Fig. 5. The imaging of one part of a lead-made line pair card.

3.2 Surface resistivity and modulation effect

As mentioned above, the surface resistivity should be carefully adjusted to fit the pitch of the WSA in use. This can be done by changing the thickness of the coated Ge layer. The surface resistivity of our Ge layer is shown in Fig. 6 as a function of the thickness.

As shown in Fig. 1, the WSA has a periodical pattern disregarding the increase in the strip width. For cluster smaller than the pitch, i.e. the period, the charge Q_S or Q_W might be collected by only one strip or wedge. In this case, no average over one period is made. The

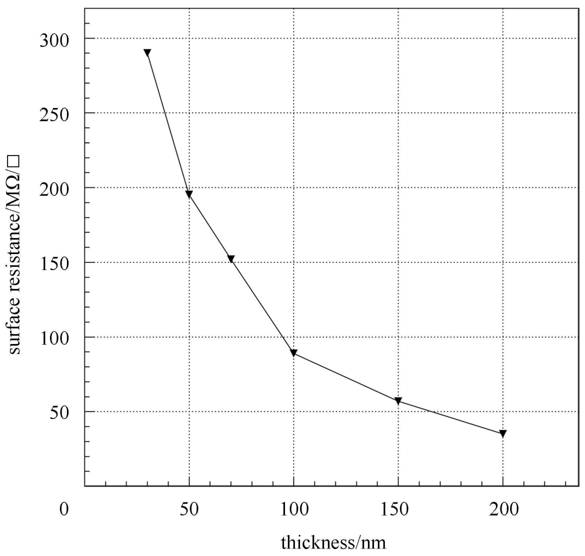

Fig. 6. Measured surface resistance as a function of coating thickness.

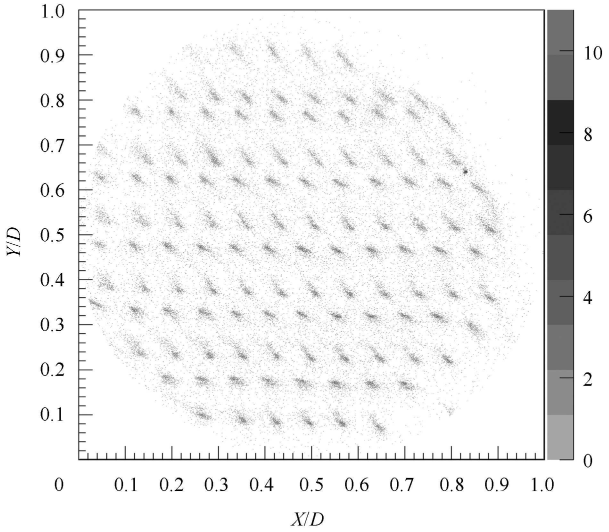

Fig. 7. The modulation effect. This imaging was taken using a 30 nm Ge-coated ceramic plate.

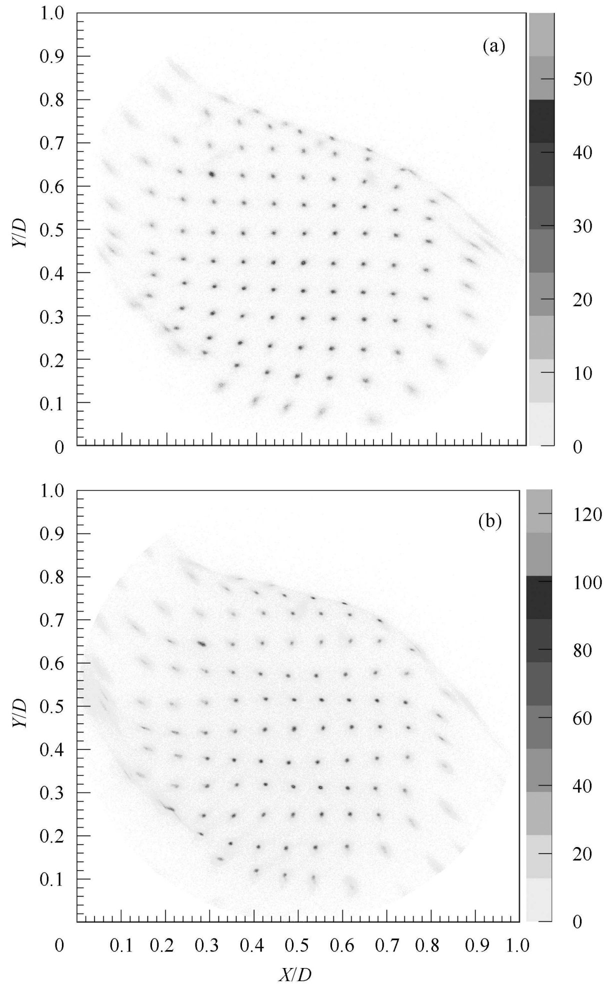

Fig. 8. The edge distortions. (a) Is taken using a 100 nm Ge-coated ceramic plate with 75 mm diameter; (b) is taken using a 70 nm Ge-coated ceramic plate with 60 mm diameter.

decoding by Eq. (1) no longer applies. The resulting modulation effect [2] can be illustrated by the imaging of the previous steel mask (Fig. 7) using a much thinner Ge layer (30 nm).

3.3 The edge distortion

The Ge layer should be thick enough to eliminate the modulation effect. Nevertheless, a layer that is too thick will cause severe edge distortion (Fig. 8(a)). There are two causes of edge distortion. One is the same as the “S” distortion [6] of direct-coupled WSA: the charge cluster steps into the edge connection part of the WSA. The other is the size of the resistive layer. Dixit’s theorem only applies to the infinite-sized resistive layer. In practice, that size is limited. For an incident cluster close to the edge of the resistive layer, the Gaussian distribution is no longer applicable. The gravity changes with time. To relieve the latter effect, one should make the resistive layer larger than the coupled WSA. In our detector, the diameter of the Ge layer is 75 mm. As a comparison, the imaging with a smaller Ge layer (60 mm diameter) is shown in Fig. 8(b). The thickness of the Ge layer is 70 nm, which is the same as the one used to take Fig. 3(a).

4 Conclusion

A wedge strip anode of 52 mm in diameter was coupled to a 2.5 mm thick ceramic plate coated with a 70 nm thick Ge layer. This structure can be used as a 2-D position sensitive anode for MPGDs. The imaging results using a three-stage GEM detector show that this anode can achieve a spatial resolution of 440 μm (FWHM) for a 10 kVp X-ray. The simple electronics of only three channels greatly facilitates the experimental setup and interface design.

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