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MSGCs with Pestov-glass coatings

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Abstract

We report a systematic study of MSGCs built on thin-film Pestov-glass. The glass film prepared by sputtering was found to be electronically conductive. The MSGCs with conductive coatings show high stability in leakage current (less than 1% over 3 hr) and fast response (in seconds) to local charging induced by a high flux of X-rays. The spatial uniformity along the strip is quite good. A gas gain of 5000 is obtained in the Ne(50%)–DME(50%) mixture. The rate capability is over 10^6 Hz/mm^2.

1. Introduction

After the introduction of microfabrication techniques to gas detector [1], much progress has been made in developing the Micro-strip Gas Chambers (MSGC) [2,3]. On the one hand, one is attracted by its promising performances such as high spatial resolution, high rate capability and good energy resolution [2,3]. On the other hand, one is confronted with challenging problems to obtain better gain stability and less long-term ageing. Furthermore, one needs to fabricate the MSGC at a low cost for any large-scale practical application.

To solve the gain-instability problem, several approaches have been tried. Firstly, it was demonstrated that the Pestov glass (or Schott S8900 glass) are well suitable for building stable MSGCs [3–6]. Such semiconducting glass has the electronic conductivity and proper resistivity of $\rho \sim 10^9$–10^{12} Ω cm. The MSGCs on this glass substrate have both short- and long-term gain stability and high rate capability [4,5]. But they usually have large leakage currents ($\sim \mu$A). It is also difficult to obtain thin glass plate of several 100 μm, which is necessary to reduce multiple-scatterings. Secondly, ion-implantation could effectively increase the surface conductivity of the insulating substrate [7], but it often requires rather high ion-dosage, which is costly and time consuming. Thirdly, various surface coating techniques have recently been explored [8–19]. The coating of a semiconducting film (either over or under the metallic strips) could improve to some extent the performance of a MSGC, be it the thin film of Ge [8], Ni/Cr [9], Ti/Al oxide [10], lead-glass [11,12], amorphous C [13], amorphous Si [14], Pestov-glass [15–17], or doped CVD diamond [18,19]. But it is important to study one coating-method systematically in order to make any practical use out of it.

In this work, we have pursued a systematic study of MSGCs built on thin-film Pestov-glass in order to control the gain instability. The first work on sputter-coating thin-film Pestov-glass [15] suggested that high gain stability was achieved, but the measurements were limited to gas gains and pulse height spectra using an ^{55}Fe X-ray source. Here, we have sputtered several Pestov-glass targets of different bulk resistivity. The thin D263 glass was used only as mechanical support. Systematic measurements were performed using an intense X-ray tube. Results on short-term stability and spatial uniformity, gas gain, and rate capability will be presented in the following. Though we refrain from any discussion on ageing in our present work, another work on ageing characteristics of a MSGC coated with Pestov-glass has recently been performed by Bateman et al. [16].

2. Experimental details

The structure of our MSGCs is schematically shown in Fig. 1 for the cross-sectional view and in Fig. 2 for the planar view. The Desag D263 glass (500 μm thick) was used as mechanical support. A layer of Pestov-glass film (0.5–1.0 μm thick) was sputtered onto the thin glass. Conditions for glass sputtering were similar to Ref. [15]. Aluminum film of 1.0 μm thick was coated on top of the Pestov-glass film. After a dry-etch process, the microstrip patterns were formed (see Fig. 2). We found that the curved features of anode and cathode end were helpful in reducing sparks. The widths of the anode and cathode strips were 6 and 90 μm, respectively. The anode-to-anode pitch was 200 μm. The overall dimension was 25 mm × 25 mm.

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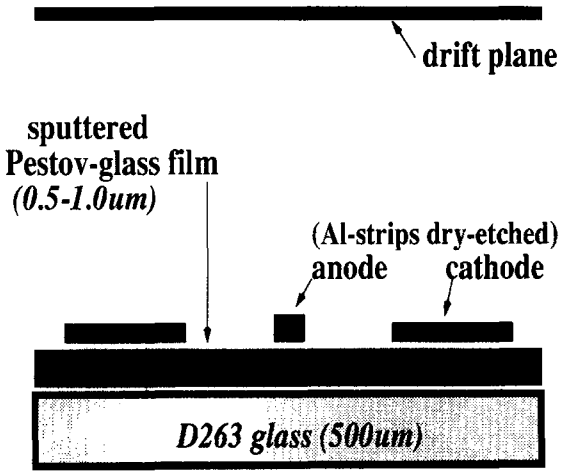

Fig. 1. The cross-sectional structure of the MSGC.

To understand how the sputtering process can affect the resistivity of the glass film, we have prepared four Pestov-glass targets as listed in Table 1. Only three targets labelled as "S8900-I", "Pestov", and "Moscow" were actually used. Each target was sputtered in identical condition to coat a thin layer of Pestov-glass film onto the D263 glass substrate. Four MSGCs were fabricated: of which one MSGC used the blank D263 glass as control, the rest three MSGCs have the Pestov-glass coatings (one from each target).

All MSGCs were tested in the gas mixture of Ne(50%)–DME(50%), using an intense X-ray tube (5.4 keV with Cr target). The output flux of X-ray tube was found to be proportional to the input current. We biased the cathode strips at negative voltages and read out a group of 28 anode strips together. The leakage current between anodes and cathodes was monitored. For unknown reasons, the MSGC with the glass coating from the "Moscow" target had rather large leakage current. This sample was not further tested. In Figs. 3–8 the results are shown for the MSGC with coating from the "S8900" target only, since the results from the "Pestov" target are similar.

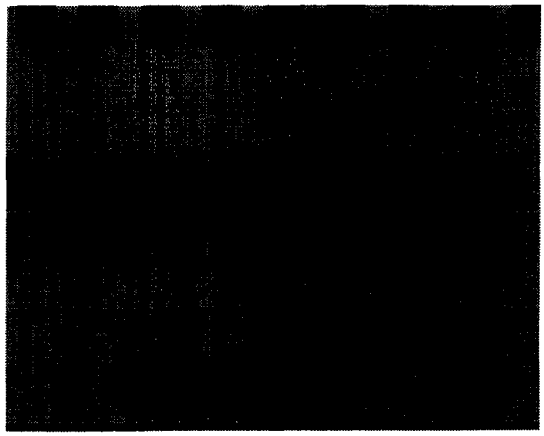

Fig. 2. The planar view of the MSGC structure.

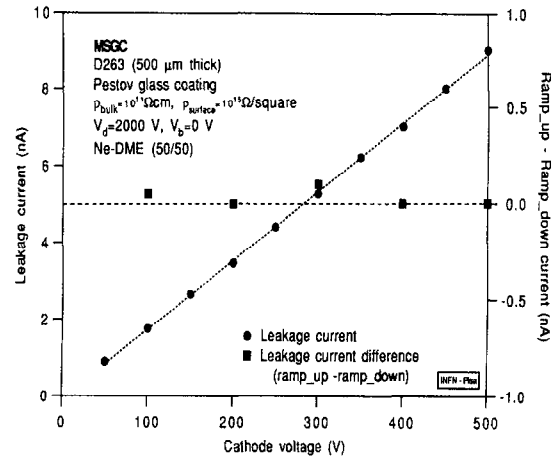

Fig. 3. The I–V curve for the MSGC on Pestov-glass coating.

Table 1
List of various Pestov-glass targets prepared for this work

Target	ρ_{bulk} [Ω cm]	ρ_{surf} [Ω/□]	$Rate_{max}$ [Hz mm^{-2}]	Supplier
S8900-I	1.4×10^{11}	$\sim 10^{15}$	$\sim 1 \times 10^6$	Schott, USA
S8900-II	$\sim 5 \times 10^{10}$		(MSGC to be built)	Schott, USA
Pestov	0.8×10^9	$\sim 10^{15}$	$\sim 2 \times 10^6$	Pestov, Russia
Moscow	$\sim 10^8$		($I_{leakage} \sim \mu$A)	Russia

3. Results and discussions

Fig. 3 shows the ohmic behavior of the Pestov-glass film. The measured leakage currents are strictly linear to the cathode bias-voltages. We also compared two leakage currents at a given voltage by ramping-up and ramping-down the biases. Their differences were plotted as a function of the cathode voltages (square symbols). No hysteresis effect was present. The glass film seems to behave similarly to the bulk Pestov glass. For the MSGC on the uncoated D263 glass,

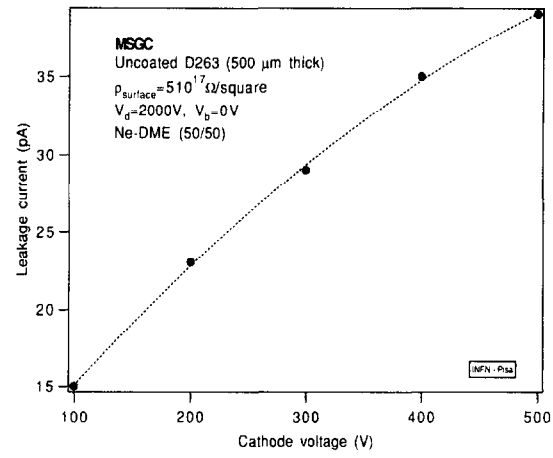

Fig. 4. The I–V curve for the MSGC on blank D263 glass.

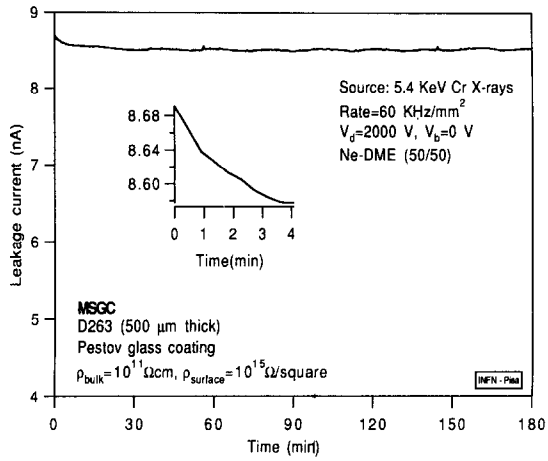

Fig. 5. Time stability of the leakage current.

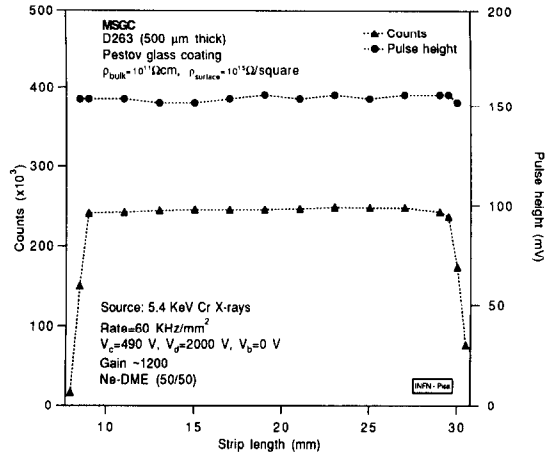

Fig. 7. Spatial uniformity of the response along the strip.

the leakage current vs. the cathode voltage was measured to be not so linear as shown in Fig. 4. The non-linearity can be caused by polarization or ion migration in the glass. Therefore, the semiconducting-glass film coating can provide a layer of shielding against any possible effects of polarization or ion migration in the D263 glass. Such a feature makes the choice of underlying substrate more flexible [15]. One can use any industrially-available thin glass or ceramics as a mechanical support to reduce multiple scattering in a particle experiment.

The time stability of the leakage current is shown in Fig. 5. It took only several minutes before the leakage current stabilized. No variations were visible for hours. Fig. 6 displays the very short-term stability of a MSGC on the conductive layer in response to local charging in the irradiated area. At a higher X-ray flux, there are more charges available to neutralize the static surface charges around anodes. The electric field distribution can stabilize faster to an equilibrium gas-gain. This is a fast relaxation process on a time scale of seconds (determined by the bulk resistivity and the anode-to-cathode capacitance). This effect is indeed visible in Fig. 6.

Our present sputtering chamber has a limited dimension, suitable for a 12.5 cm target. The gap is about 5 cm from the target to the glass substrate. While colored rings were present at the wafer's peripheral, the inner area of 3 in. diameter was uniform. The non-uniformity can definitely be improved when one uses a larger sputtering chamber. However, some non-uniformity in resistivity may not affect directly the quality of a MSGC if one makes the conductive coating thick enough (e.g., 0.5–1 μm). With this in mind, we measured the pulse height and count rate by scanning the collimated X-ray source along the strip. As shown in Fig. 7, there is no obvious non-uniformity that correlates to the visual effect. But one should characterize this spatial uniformity carefully for testing a large MSGC.

The gas gain of our MSGCs were measured in the Ne(50%)–DME(50%) mixture. Because of less UV-photon emission by the Ne atoms and better UV-photon quenching property by the DME molecules in the avalanche process, a rather high gas-gain is achievable in this gas

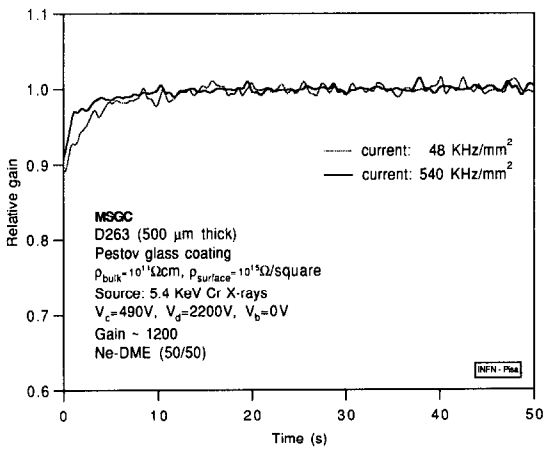

Fig. 6. Short-term stability of response to charging.

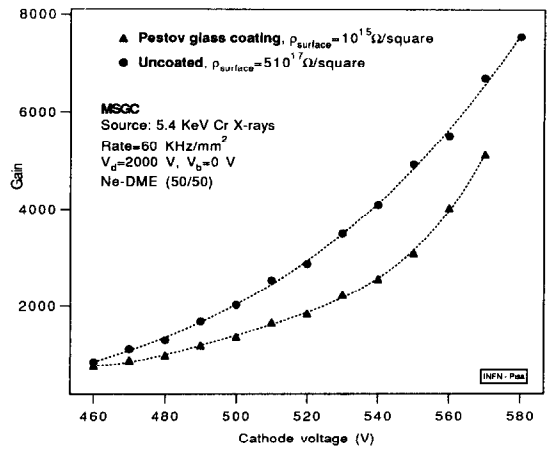

Fig. 8. Gas gains measured in the Ne(50%)–DME(50%) mixture.

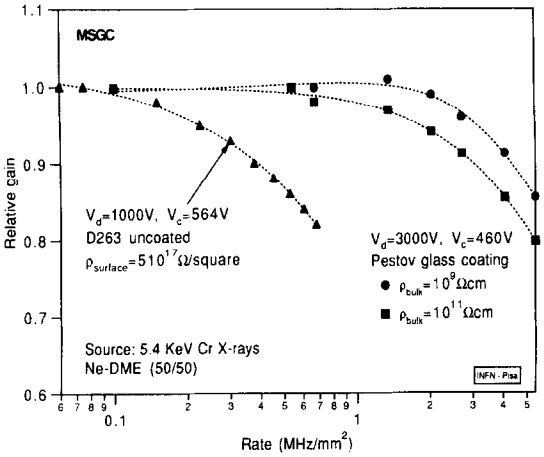

Fig. 9. Rate capabilities of various MSGCs with and without Pestov-glass coatings.

mixture. Fig. 8 compares gas gains for MSGCs without and with Pestov-glass coating. For the MSGC with coating, the gas gains increase exponentially from about 600 to 5000 when the cathode voltages vary from −460 to −570 V. When the conductive coating is absent, the electrical fields are, relatively speaking, stronger and more localized around the anodes [20]. At a given bias, the gas gain is expected to be higher. This effect is observable in Fig. 8.

On the bulk Pestov-glass substrate, the rate capability of a MSGC was found to correlate with the volume resistivity of the Pestov-glass [5]. Within the range of $\rho = 0.9 \times 10^9$ to 2×10^{12} Ω cm, the smaller the bulk resistivity, the larger the rate capability. However, one can not use a glass of too low resistivity to avoid noise and heating caused by the large leakage current. The use of thin-film Pestov-glass would solve this problem by largely reducing the leakage current. It was our motivation to sputter a Pestov-glass of very low resistivity. It turned out that the glass sputtering process was not as simple as expected. We noticed that, for example, the values of "equivalent" volume resistivity of the glass film sputtered from the "Pestov" target was much larger than its bulk resistivity ($\rho = 0.8 \times 10^9$ Ω cm). Here the "equivalent" volume resistivity was inferred from the film thickness, strip geometry, and measured resistance. The relative composition of iron oxides (Fe_2O_3/FeO) is critical for the bulk resistivity of the Pestov glass [21]. The sputtering process must have modified the stoichiometry of bulk glass to some extent. It may be possible to maintain the original stoichiometry by controlling the plasma pressure and by varying the Ar/O_2 mixture. But it is beyond the scope of this work. Nevertheless, the glass film is found to retain the electronic conductivity suitable for a MSGC.

In Fig. 9, we compare the measured rate capabilities for two MSGCs with conductive coatings from the "S8900" target ($\rho = 1.4 \times 10^{11}$ Ω cm) and the "Pestov" target ($\rho = 0.8 \times 10^9$ Ω cm), and for one MSGC on the blank D263 glass. Firstly, the rate capability of a MSGC with the Pestov-glass coatings is over 10^6 Hz/mm^2. It is as high as that of a MSGC on the bulk Pestov-glass [5] and is almost an factor of 10 higher than that of a MSGC on the blank D263-glass. Secondly, higher rate capability is achieved for the MSGC with coating from the target of lower bulk resistivity. This is qualitatively consistent with the finding in Ref. [5], but not in the magnitude.

Finally, we wish to comment on ageing briefly. It was already shown in Ref. [16] that a MSGC with Al metallization aged quickly and the MSGC with S8900-glass coating and Au metallization had a gain decrease of less than 15% after an accumulated-charge dose of 105 mC/cm. Since we used Al microstrips, it was not meaningful to conduct any long-term ageing test. But we are in the process of building a large-area MSGC (10 cm × 25 cm) with the Pestov-glass coating and Au metallization. Systematical tests including a long-term ageing will then be performed.

4. Summary

We have tested, using an intensive X-ray tube, MSGCs with thin-film conductive coatings by sputtering the Pestov-glass. The Pestov-glass thin-film retains the electronic conductivity desirable for a MSGC though its "equivalent" resistivity became relatively higher than the volume resistivity of the bulk glass. The MSGCs with the conductive coatings show high stability in leakage current (less than 1% over 3 hr) and fast response (in seconds) to local charging when a high flux of X-rays is present. Their spatial uniformity along the strip is quite good. A gas gain of 5000 is obtained in the Ne(50%)–DME(50%) mixture. The rate capability is over 10^6 Hz/mm^2. We find that the sputter-coating of thin-film Pestov-glass may be, at least, as effective as the recently-developed CVD diamond coating.

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References

[1] A. Oed, Nucl. Instr. and Meth. A 263 (1988) 351.
[2] F. Angelini et al., Nucl. Phys. B 23A (1991) 254.
[3] A. Oed, Nucl. Instr. and Meth. A 367 (1995) 34.

[4] R. Bouclier et al., Nucl. Instr. and Meth. A 332 (1993) 100.
[5] Yu.N. Pestov and L.I. Shekhtman, Nucl. Instr. and Meth. A 338 (1994) 368.
[6] W.G. Gong et al., IEEE Trans. Nucl. Sci. NS-41 (1994) 890.
[7] F. Angelini et al., Nucl. Instr. and Meth. A 315 (1992) 21.
[8] S. Brons et al., Nucl. Instr. and Meth. A 342 (1994) 411.
[9] M. Salomon et al., Nucl. Instr. and Meth. A 351 (1994) 313.
[10] F. Ortuno-Prados et al., Proc. MSGC Workshop, Legnaro, Oct. 1994, p. 159.
[11] R. Bouclier et al., IEEE Trans. Nucl. Sci. NS-41 (1994) 821.
[12] R. Bouclier et al., Proc. MSGC Workshop, Legnaro, Oct. 1994, p. 39.
[13] U. Werthenbach et al., Proc. MSGC Workshop, Lyon, Nov. 1995.
[14] W.S. Hong et al., Proc. Materials Research Society, San Francisco, Apr. 1995.
[15] W.G. Gong, J.W. Harris, H. Wieman, Nucl. Instr. and Meth. A 360 (1995) 30.
[16] J.E. Bateman et al., Rutherford Appleton Lab. preprint RAL-TR-95-032 (1995).
[17] G. Ekkehard et al., Proc. MSGC Workshop, Lyon, Nov. 1995.
[18] L. Ropelewski et al., Proc. MSGC Workshop, Lyon, Nov. 1995.
[19] R. Bellazzini et al., Proc. MSGC Workshop, Lyon, Nov. 1995.
[20] R. Bellazzini and M.A. Spezziga, Riv. Nuovo Cimento 17(12) (1994) 1.
[21] Yu.N. Pestov, e-mail communication.