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DEVELOPMENT OF MICROSTRIP GAS CHAMBERS ON THIN PLASTIC SUPPORTS

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ABSTRACT

We present the initial measurements realized with microstrip gas detectors on two thin-foil plastic supports, Kapton and Tedlar, having bulk resistivities around 10^{17} and 10^{14} ohms.cm, respectively. Gains up to 10^4 and energy resolutions around 20% fwhm have been obtained in both cases for low rate 5.9 keV x-rays. Long-term and high-flux measurements of gain show time-dependent modifications (charging up), particularly for the higher resistivity support; nevertheless, the results are very encouraging and further developments may lead to the development of a new family of very light, flexible detectors with high resolution.

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1. Introduction.

The experimental requirements at high luminosity machines are seriously challenging the rate capability and granularity of existing position-sensitive gaseous detectors, naturally limited to wire spacings of around a mm due to electrostatic forces and mechanical tolerance requirements. Microstrip gas chambers (MSGC [1]), in which anodes and cathodes are realized as thin metal strips on a solid insulating support, allow to overcome these problems since they can be realized with very small spacings between the electrodes. A small pitch results obviously in a good granularity and resolution, and in a reduction of the counting rate per active electrode, given the flux.

The results obtained by various groups in the development of MSGC are very encouraging: good energy resolutions (12% for 5.9 KeV) at proportional gains above 10^4 , position accuracies around 30 μm rms for minimum ionizing particles, high rate capabilities [2-5]. There are however some problems and limitations. To realize good detectors one has made use of techniques borrowed from the field of micro-electronics; at the present time, this is imposing a limit to the maximum size of the devices to perhaps 10 cm^2 or so. A second, more fundamental problem is connected with the charging up of the insulating support, that can induce a substantial modification of the gain at high fluxes; indeed, ions formed in the avalanches accumulate on the insulating surface between strips, modifying the electric field around the anodes and therefore the multiplication characteristics. This effect can be only partly reduced by a suitable choice of the potentials, particularly the one applied to the back plane, because of diffusion of electrons and ions in the avalanches. A possible solution is to increase the surface conductivity of the insulating support, for example by ion implantation as done by the authors of Ref. 5; again however use of this sophisticated technology imposes a constraint on the maximum size of the detectors.

With one exception [6], all MSGC have been realized so far using various kinds of glass or quartz as support. At CERN, we are investigating the feasibility of implementing the detectors on plastic foils. There are three distinctive advantages of plastic over glass supports: they are flexible and therefore allow to realize detectors of non-planar design, particularly cylindrical geometries with very small radii; they can be much thinner and are constituted of low Z materials, so that multiple scattering and photon conversion rate in the foil is reduced; the availability of materials in a wide range of bulk resistivity may allow to solve the charging up problems in a simple way and over large surfaces. This paper relates the preliminary results obtained with MSGC realized on plastic supports.

2. Prototype chambers and experimental set-up.

While we have and still are investigating many possible choices for the plastic foil support, only two (Kapton and Tedlar⁺) have so far been found suitable for the realization of MSGS, being mechanically stable and with good surface quality, and having a sufficiently strong adherence of the vacuum-evaporated metal layer. Since the two materials differ in bulk resistivity by about 3 orders of magnitude, a comparison of the results obtained is instructive.

All measurements described here were realized on small test chambers, having a sensitive area of approximately $4 \times 1 \text{ cm}^2$; a schematic cross section of a chambers is shown in Fig 1. The pattern is realized by photo-lithographic etching of a layer of aluminum, about $0.3 \text{ }\mu\text{m}$ thick, vacuum-evaporated on the support; anode and cathode strips alternate at a distance between centers of $200 \text{ }\mu\text{m}$ ⁺⁺. The main characteristics of the detectors realized on the two supports are given in the table 1.

A practical consequence of using plastic materials as supports is a somewhat coarser optical quality, probably due to dusts and to a restricted range of allowed surface cleaning procedures (for example one cannot use high temperature conditioning). For this reason we have conservatively used a $400 \text{ }\mu\text{m}$ pitch, as against the $200 \text{ }\mu\text{m}$ pitch used in most other MSGC; the resulting increase of the insulating area between strips has certainly enhanced the charging up processes, to be described later. The quality of the etching tends to be better for the Kapton support (see Fig. 2a) than for Tedlar (Fig. 2b), probably because of the smoother surface. This has resulted in a limitation in the minimum width of the anode strips, coarser for Tedlar as indicated in the table. Both for Kapton and Tedlar the variation of width of the strips around the average is typically $\pm 2 \mu\text{m}$; occasional bumps are visible (probably due to dust particles present during the fabrication process) but they do not seem to affect the performance of the detector.

In all tests, the 25 anodes were connected together to a low-noise charge amplifier; for the study, we used either the 5.9 keV x-rays from ^{55}Fe or a collimated x-ray tube with a copper anti-cathode; the $\text{K}\beta$ line (8.9 keV) could be resolved from the $\text{K}\alpha$ with a nickel filter. The collimator fixed to the tube is 5 cm long with a diameter of $0.9 \text{ }\mu\text{m}$, providing a spot at the detector of about 0.6 mm^2 . The tube could be moved by two-dimensional micrometers in a plane parallel to the plane of the microstrips, with a positioning accuracy in the horizontal and vertical directions of better than $20 \text{ }\mu\text{m}$. Behind the chamber a proportional tube, made of carbon, permits monitoring of the x-ray flux.

⁺ Trade names of DuPont de Nemours Co.

⁺⁺ Artwork realized by the Thin Film & Glass and Printed Circuit groups at CERN.

The electronic chain consists of an Ortec 142A preamplifier, an Ortec 450 research amplifier and a Lecroy multichannel analyzer. Data can be stored and directly analyzed with a PC using a Camac interface.

All measurements were realized using an Argon-Methane 90-10 gas mixture, at atmospheric pressure; whilst this is not the best gas for obtaining large gains [5], it is a mixture for which one can find detailed data to describe the drift and multiplication properties. This is relevant for our work, proceeding in parallel with the measurements and aiming at reproducing with a computer program the operation of the detector.

3. Experimental results.

Using a ^{55}Fe x-ray source at low rate, we have measured the dependence of proportional gain on the anode voltage (with the cathode strips grounded, all other potentials being fixed). In Fig. 3 one can see that for both the Kapton and the Tedlar chambers we could safely reach gains close to 10^4 ; the small difference in the operating voltage is due to the different width of the anode strips. Typical pulse height spectra obtained are shown in Fig. 4a and 4b for Kapton and Tedlar, respectively, in slightly different operating conditions; in both cases, the resolution is around 20% fwhm. These results are comparable with those obtained with standard MSGC, the somewhat worse resolution being probably due to the coarser fabrication. At fixed electronic discrimination threshold (around 0.01pC), we have measured the counting rate with and without the source as a function of the anode voltage, as shown for Tedlar in Fig. 5; the full efficiency plateau extends for about 100V without being affected by noise. This shows that, at least for the geometry chosen, there is no noise problem arising from surface or bulk currents on the resistive support.

As mentioned, the main problem expected with MSGC is the charging up of the support, which can be assumed to be strongly dependent on the resistivity of the foil and the irradiation rate. Kapton and Tedlar have resistivities different by 3 orders of magnitude (see the table); as a consequence, one can expect rather different behaviors. We have studied the charging up effects measuring the long-term variations of gain of chambers exposed to increasing radiation fluxes. The measurements were done with the following procedure. A small area ($\sim 1 \text{ mm}^2$) in the chamber was irradiated continuously at a known rate using the collimated x-ray generator; at time intervals, the flux was reduced to around 100 counts/s to record pulse height spectra for 10 seconds, then the original flux was restored. Figures 6a and 6b show the variation of gain with time for the Kapton and Tedlar chambers respectively; operating conditions are similar in the two cases.

One can see that in absence of irradiation (the zero flux points), the gain of the Tedlar chamber remains constant, whereas the Kapton chamber shows a very strong decrease of gain during the first 5 minutes after turning on the voltages, followed by a slow but steady decrease afterwards. For high irradiation flux, the Tedlar chamber shows an initial

drop in gain of approximately a factor of two, levelling off with a characteristic time of about ten minutes. Under the same conditions the Kapton chamber shows a much stronger decrease in gain with no sign of stability after one hour of irradiation.

The behavior after removal of the radiation source is also quite different. Repeating the measurement at zero flux for Kapton two days after cutting off the high flux provided the points connected by a dashed curve in Fig. 6a; for Tedlar instead one finds again the same points shown in Fig. 6b at zero flux after a short off time. Note that for all measurements the voltage conditions (particularly the back plane voltage) were not the best for decreasing charging up processes; optimization of the potentials for this purpose is presently investigated using a computer program that takes into account the resistive nature of the support [7].

The gain modification due to charging up under irradiation is a local phenomenon, as seen in Fig 7 showing the dependence of gain on position measured at low rate around a previously irradiated spot. For Kapton, Fig. 7a, the three curves 1, 2 and 3 correspond to measurements realized five, twenty and sixty minutes, respectively, after applying the voltage to the chamber irradiated two days earlier in the central spot at high flux (10^4 Hz/mm² for one hour). Obviously, Kapton retains local memory of the irradiation for extended periods of time. After turning on the high voltage, all points that had already been irradiated quickly accumulate at least the same amount of charge that was put on the surface during the irradiation; this is true even after several days. Such is not the case of Tedlar, as shown in Fig. 7b: for this measurement, the central spot in the figure was irradiated at maximum flux for an hour, and the position-dependence measured immediately after stopping the irradiation (points connected by a full curve) and an hour later (dashed curve). One can see that the irradiated point has virtually recovered its gain.

The time evolution of the gain in absence of irradiation appears to depend on the back plane potential⁺. In Fig. 8 we compare, for the Tedlar chamber, the change of gain (measured at low rate) as a function of time from application of the voltage, at equal anodic and drift voltages but for three values of V_b . One can see that, as the back plane voltage becomes more positive, the initial gain of the chamber decreases, but the time drop of gain becomes less important and the gain can even increase with time.

Charging up due to flux always leads to decrease the gain. Fig. 9 shows the gain as a function of time after turning on voltages, with the chamber exposed to a constant counting rate of 10^4 Hz/mm², for different values of anode voltage. At least for the lower initial gains, the curves seem to plateau to a constant value.

⁺ Of course one cannot rule out an effect of natural radiation and of the source used for the measurements, although both have very small rates.

4. Conclusion and Summary

We present the initial measurements realized with microstrip chambers realized on two thin plastic supports, Kapton and Tedlar. In both cases proportional gains up to 10^4 have been obtained, with a rather good energy resolution for low-rate x-rays. Two problems however clearly appear: an overall, rate independent change of gain as a function of time (with a time constant of the order of minutes), and a local temporary decrease of gain if the chamber is irradiated at high flux (10^4 Hz/mm²). The local "memory" of the irradiation is particularly long for Kapton (having a bulk resistivity of around 10^{17} ohms.cm), whilst it reduces to minutes for Tedlar, having a resistivity three orders of magnitude smaller. One should note that the strips spacing chosen for this initial work (400µm between anodes) leaves a wide insulating surface between electrodes, a fact enhancing the adverse effects of charging up processes.

The quoted changes of gain would prevent of course the use of the MSGC as described for high flux application. Nevertheless a more detailed investigation on the charging up processes, accompanied by a parallel search for more suitable (perhaps lower resistivity) supports may lead to the development of a new family of light, flexible gas detectors with good resolutions. Use of a thin support may result also in a simpler and more efficient readout of the second coordinate, with pickup strips on the back plane, particularly if the potentials are chosen in order to keep both the cathode strips and the back plane strips at ground.

We are presently exploring various other options for the plastic support; the possibility exists also to modify the conductivity of an insulating support either by ion implantation (that would act on the surface), or by exposure to radiation; rather promising results have been obtained by neutron irradiation of Kapton that resulted in a decrease of the bulk resistivity by two orders of magnitude⁺.

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7. J.J. Florent et al (in preparation)

⁺ In collaboration with S. Majewski, CEBAF, Newport News.

Figure Captions

- Fig. 1: Schematic cross section of a thin-foil plastic microstrip chamber.
- Fig. 2: Optical microscopy of a section of the microstrip chamber realized on a Kapton support (a) and on Tedlar (b).
- Fig. 3: Proportional gain dependence on anode voltage for the Kapton and Tedlar chambers. The two curves do not coincide because of the different anode strip width (20 μm and 30 μm , respectively).
- Fig. 4: Pulse height spectra measured with a Fe^{55} x-ray source for the Kapton (a) and Tedlar chambers (b).
- Fig. 5: Counting rate plateau (at fixed detection threshold) in the Tedlar chamber as a function of anode voltage, with and without source.
- Fig. 6: Gain variation as a function of time after applying the voltage for the Kapton (a) and Tedlar chamber (b), at various irradiation fluxes. For the high resistivity Kapton, the initial (no flux) curve is not reproduced when repeated after the high flux measurement.
- Fig. 7: Positional dependence of gain after a local strong irradiation. In Fig. 7a, the three curves 1, 2 and 3 were measured for the Kapton chamber five, twenty and sixty minutes from the application of the voltage to the chamber irradiated two days earlier in the central spot (at 10^4 Hz/mm^2 for one hour). In Fig. 7b, the same measurement was performed in the Tedlar chamber immediately after removal of the source (full curve) and an hour later (dashed curve).
- Fig. 8: Normalized gain in the Tedlar chamber as a function of time after application of voltages for different anodic potentials.
- Fig. 9: Dependence of gain from the time after application of voltages in the Tedlar chamber exposed to a constant flux of 10^4 Hz/mm^2 for several values of the anode potential.

TABLE 1: Characteristics of detectors realized on Tedlar and Kapton supports

		Kapton	Tedlar
Geometry	Anode width	20 μm	30 μm
	Cathode width	200 μm	150 μm
	Pitch	200 μm	200 μm
	Strips thickness	0.3 μm	0.3 μm
	Drift gap	4mm	4 mm
	Foil thickness	130 μm	100 μm
Electric properties	Resistivity ($\sim 20^\circ\text{C}$)	$10^{17} \Omega\cdot\text{cm}$	$10^{14} \Omega\cdot\text{cm}$
	Dielectric constant	3	11

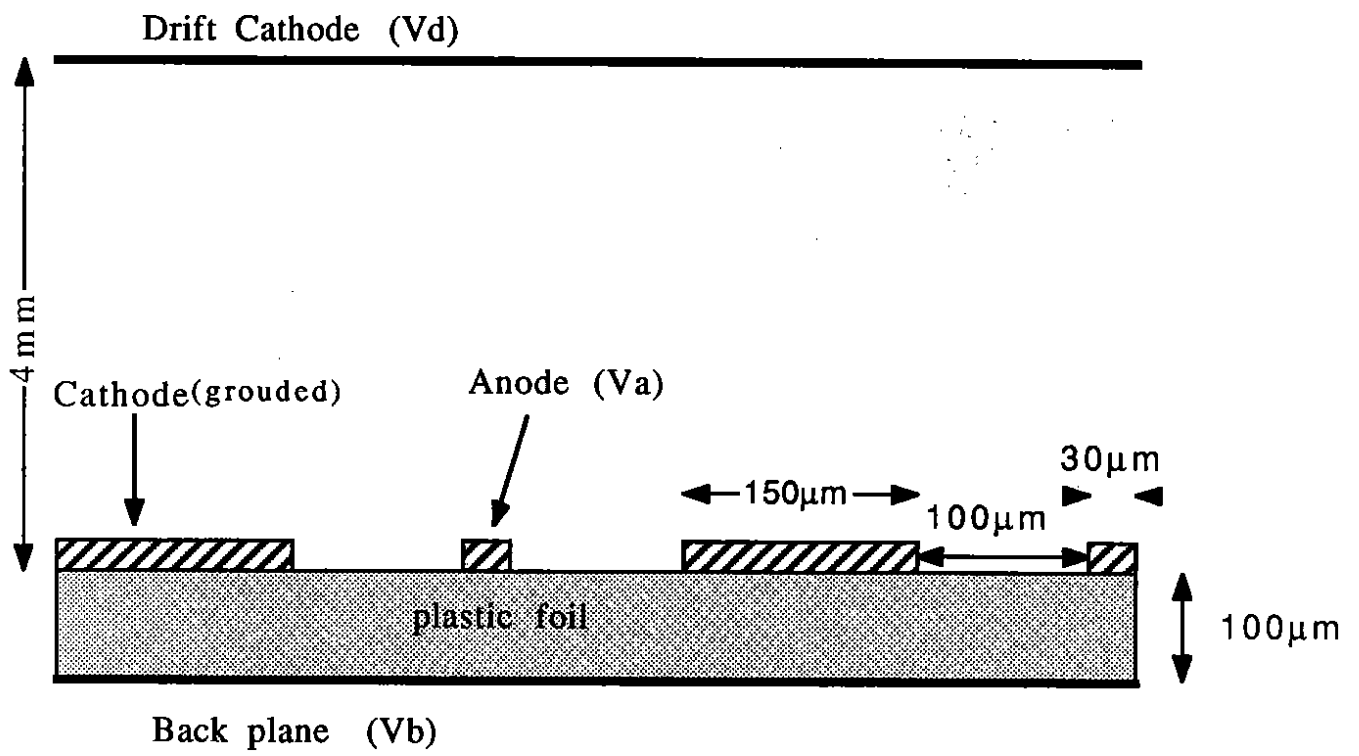
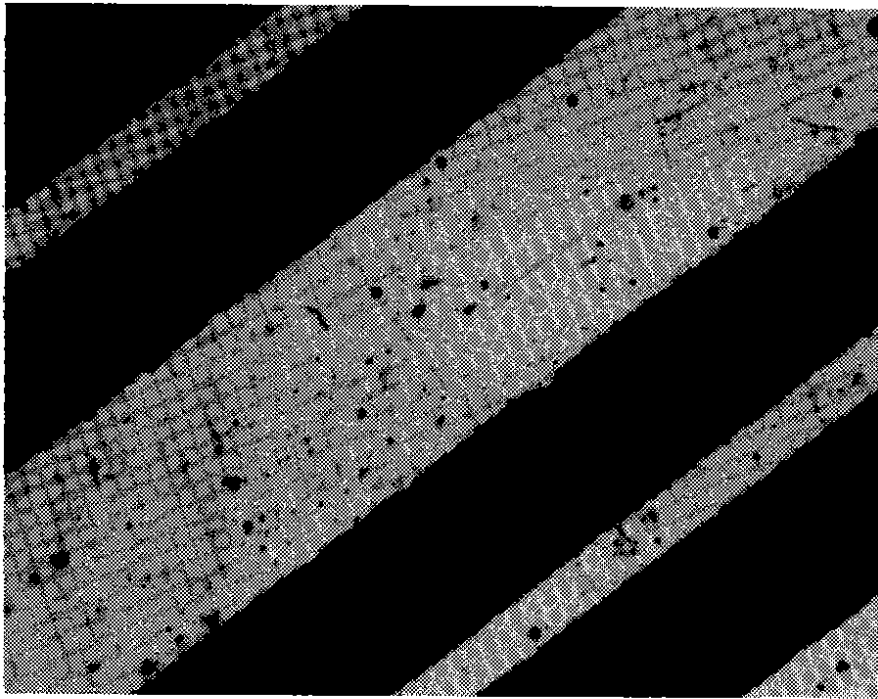
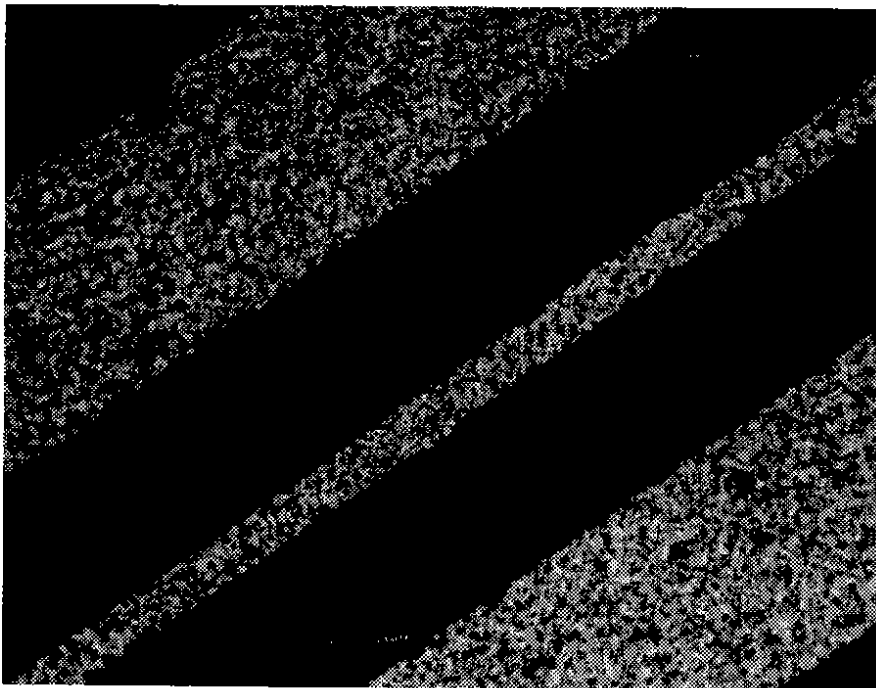


Fig. 1



a



b

Fig. 2

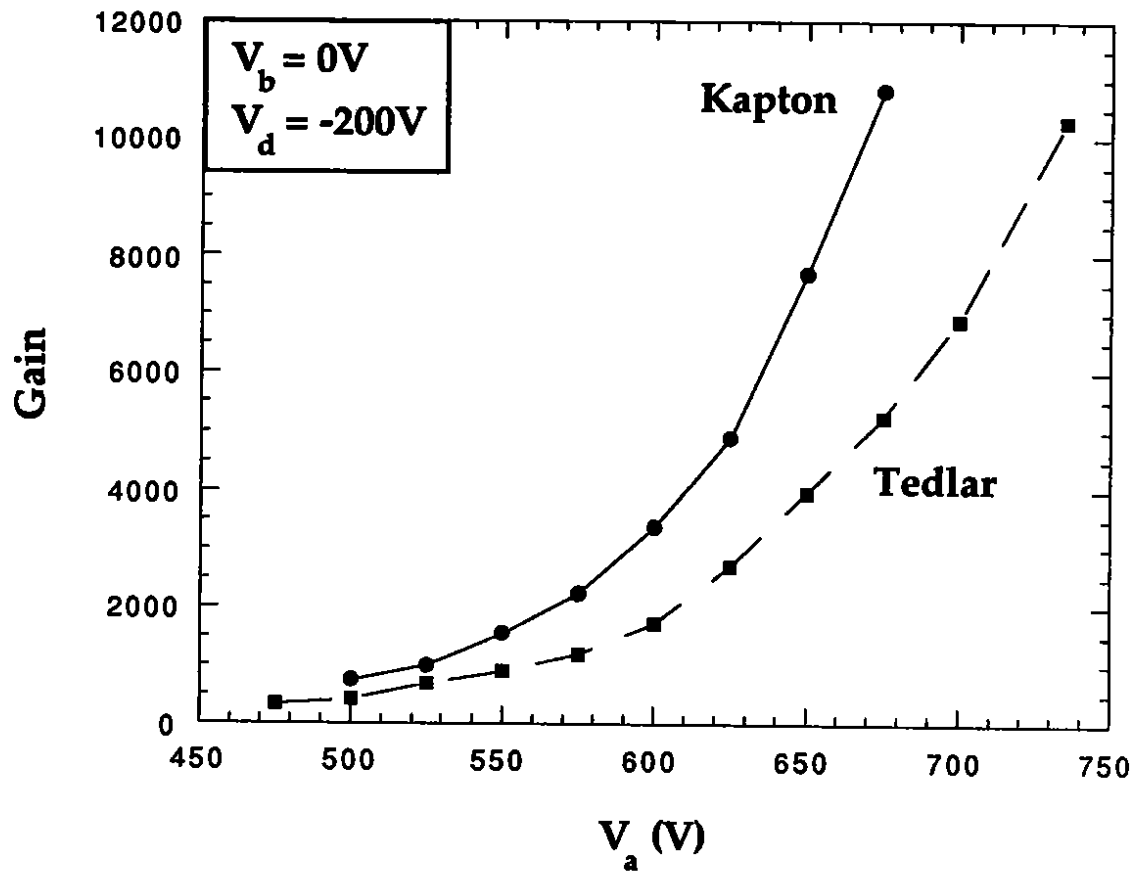


Fig. 3

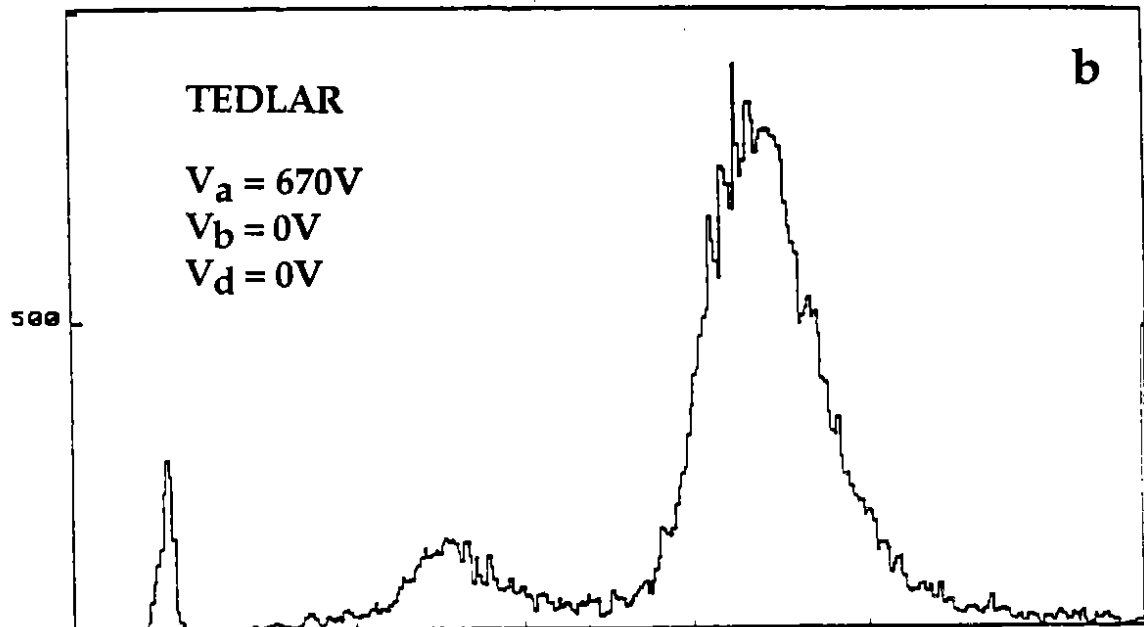
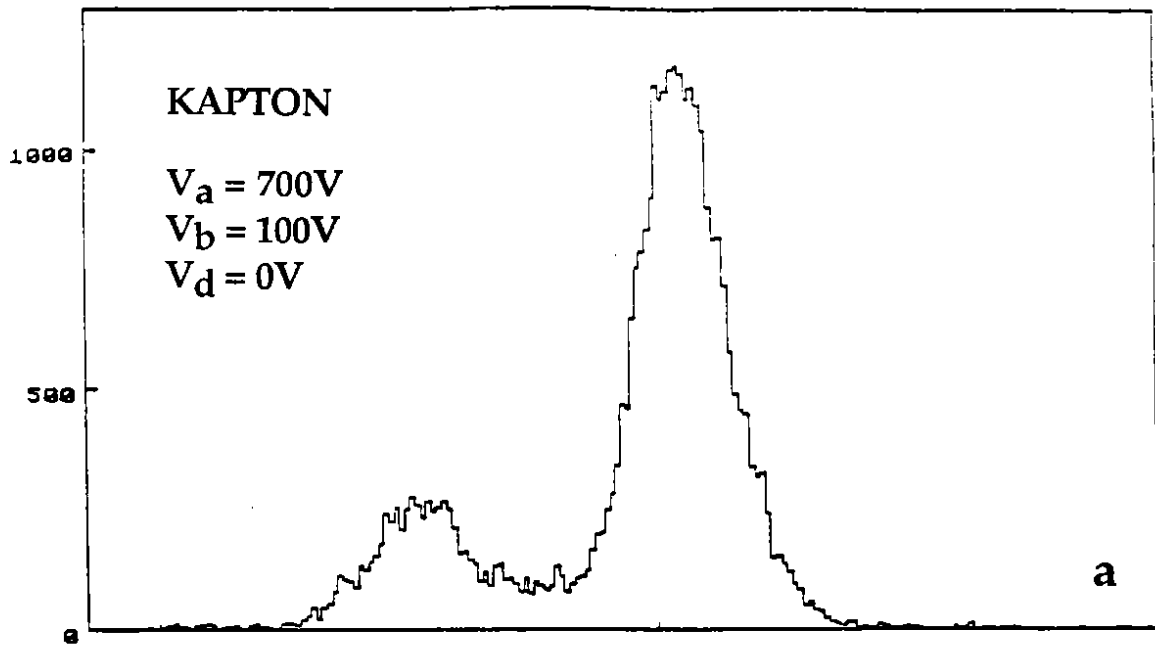


Fig.4

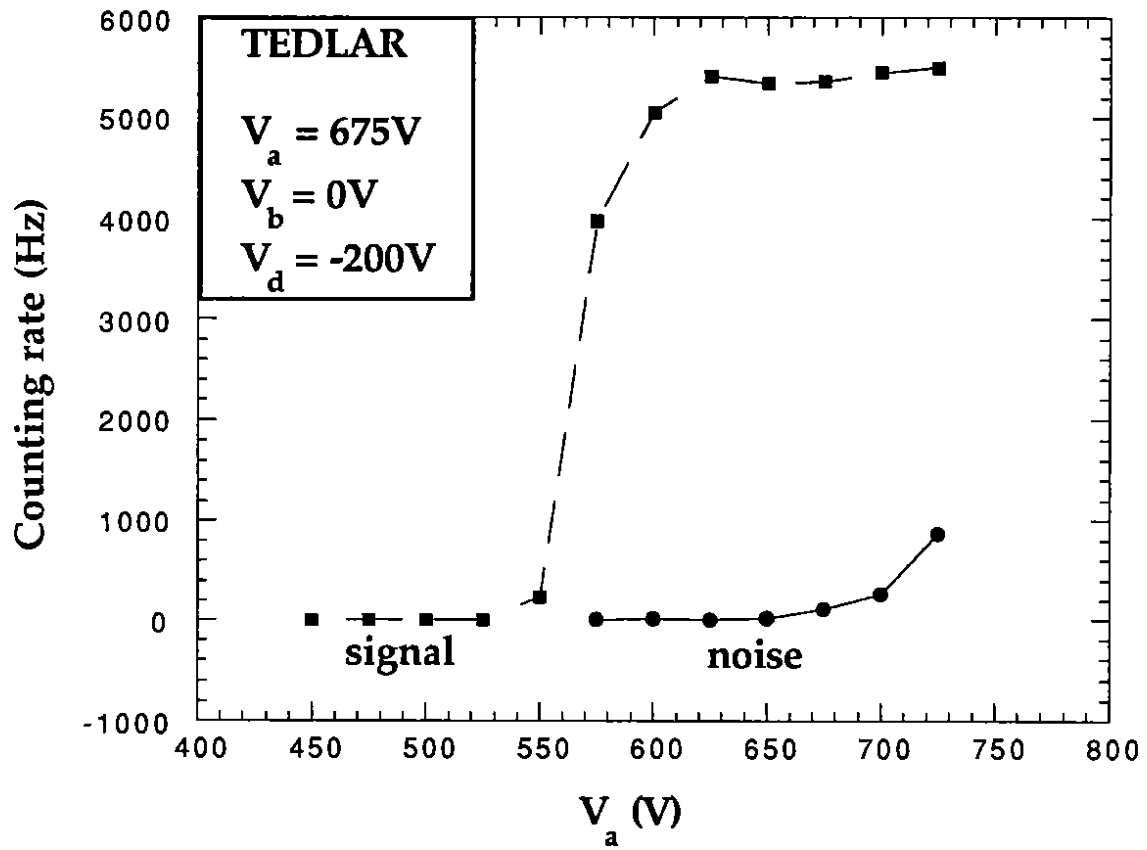


Fig. 5

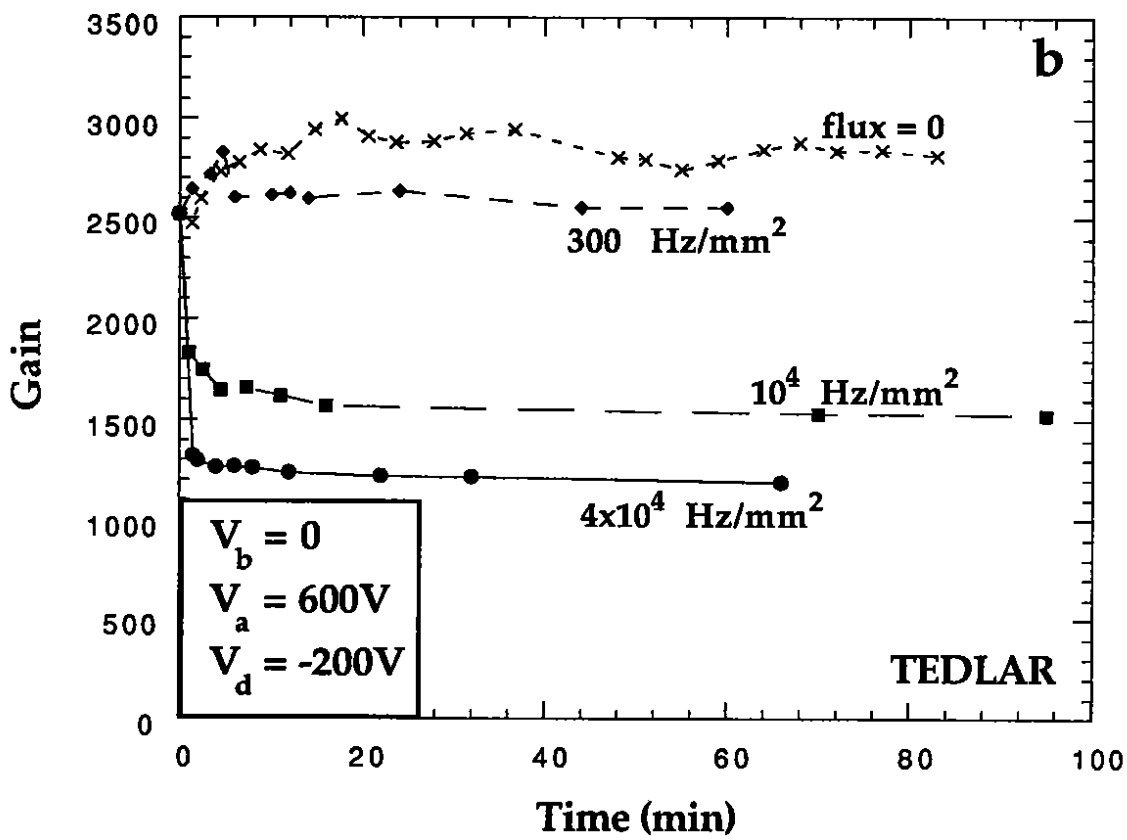
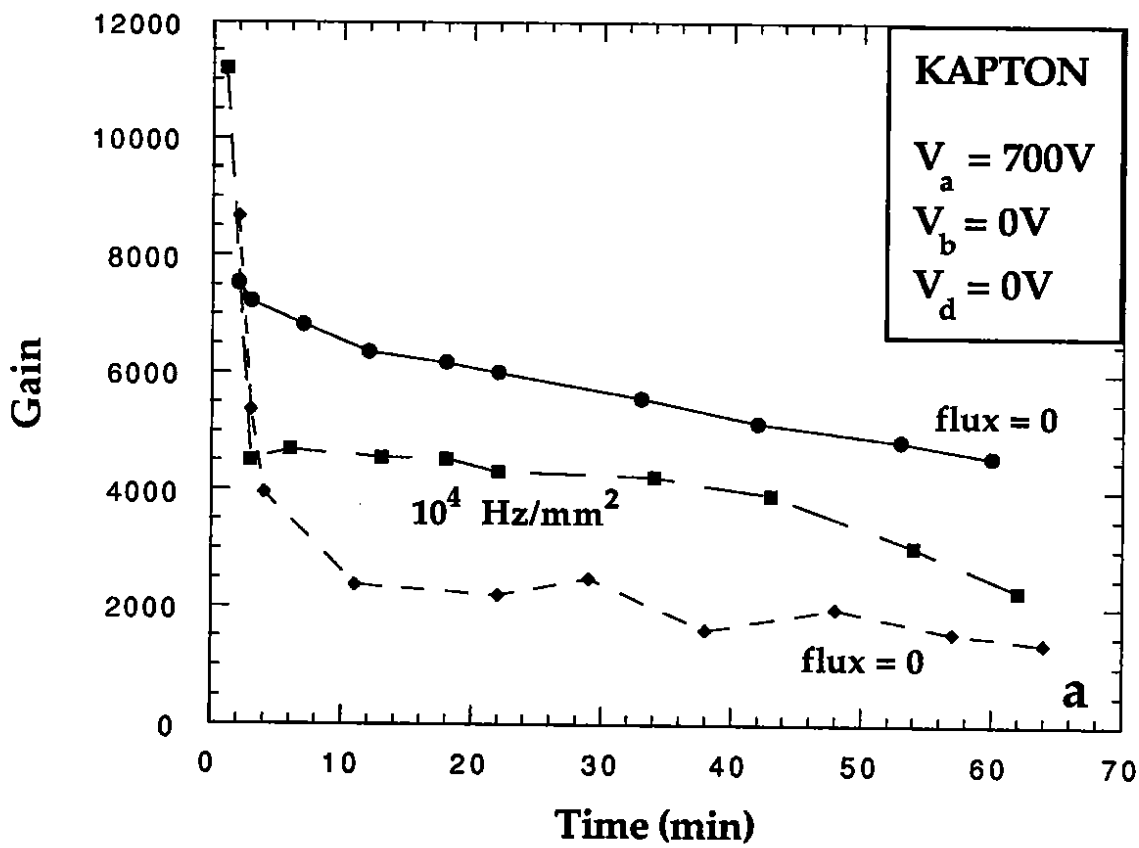


Fig. 6

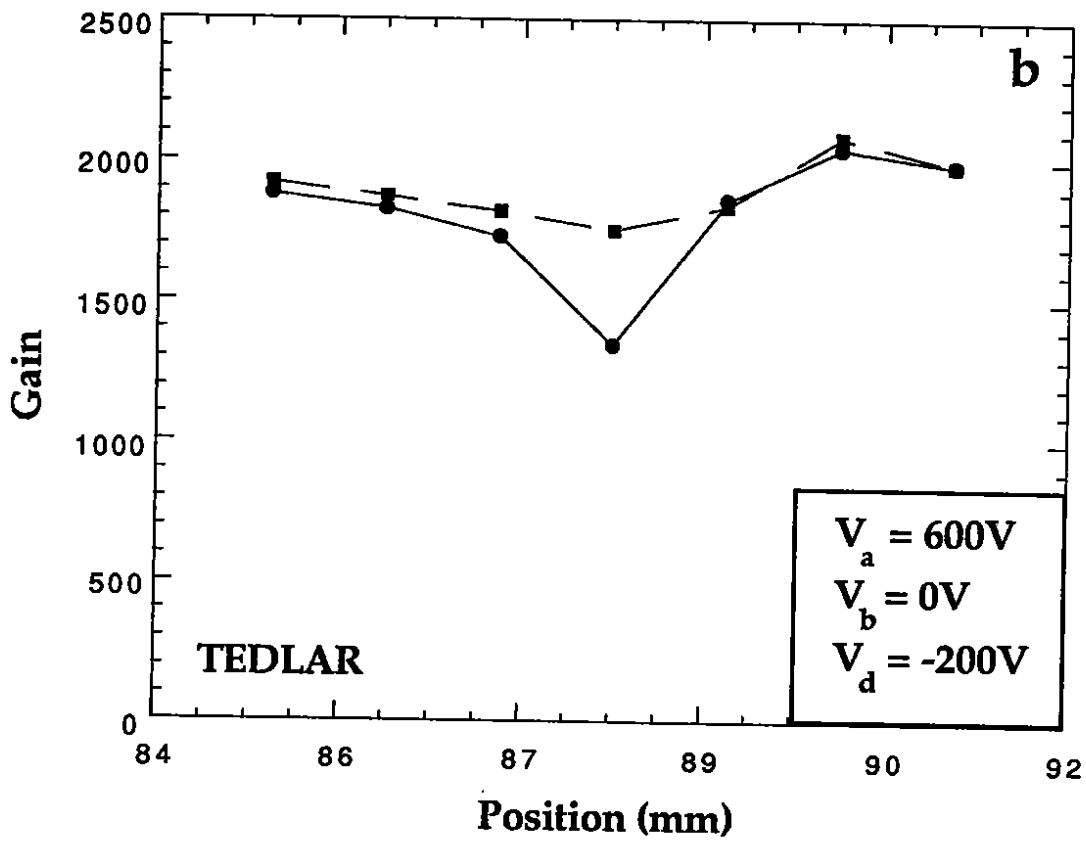
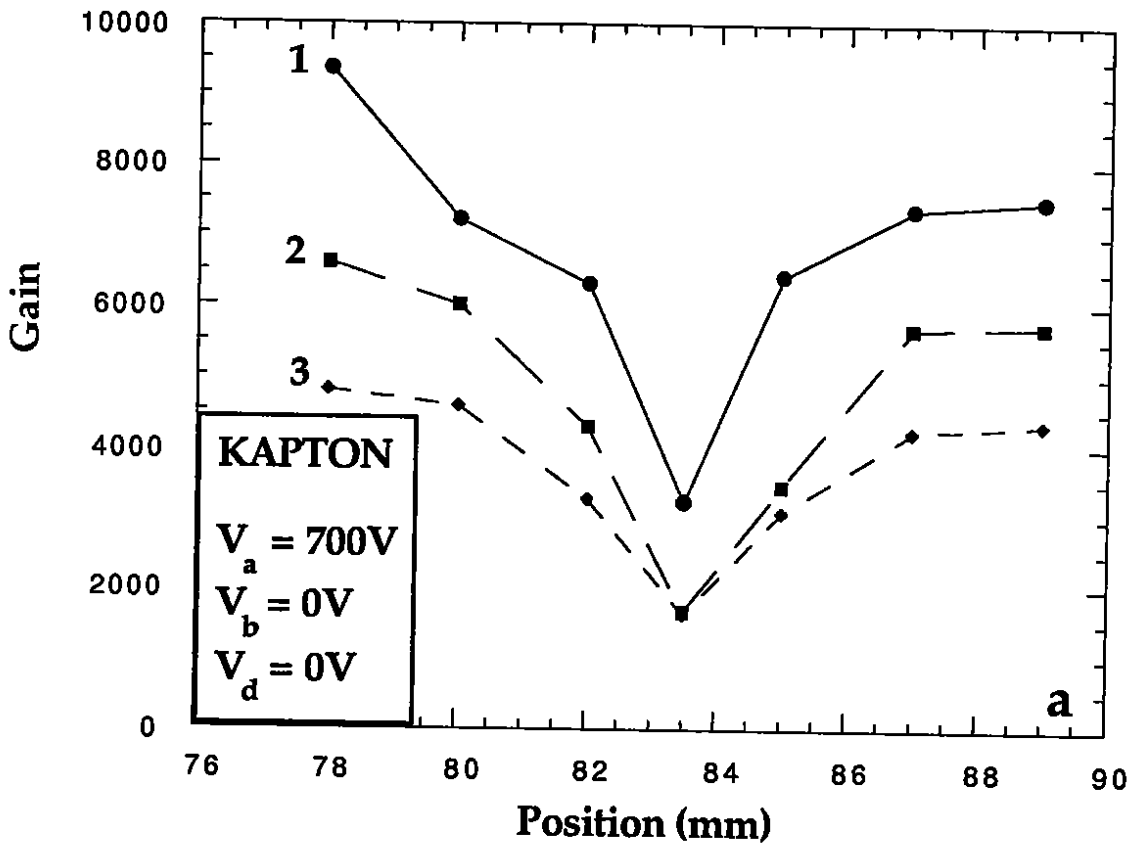


Fig. 7

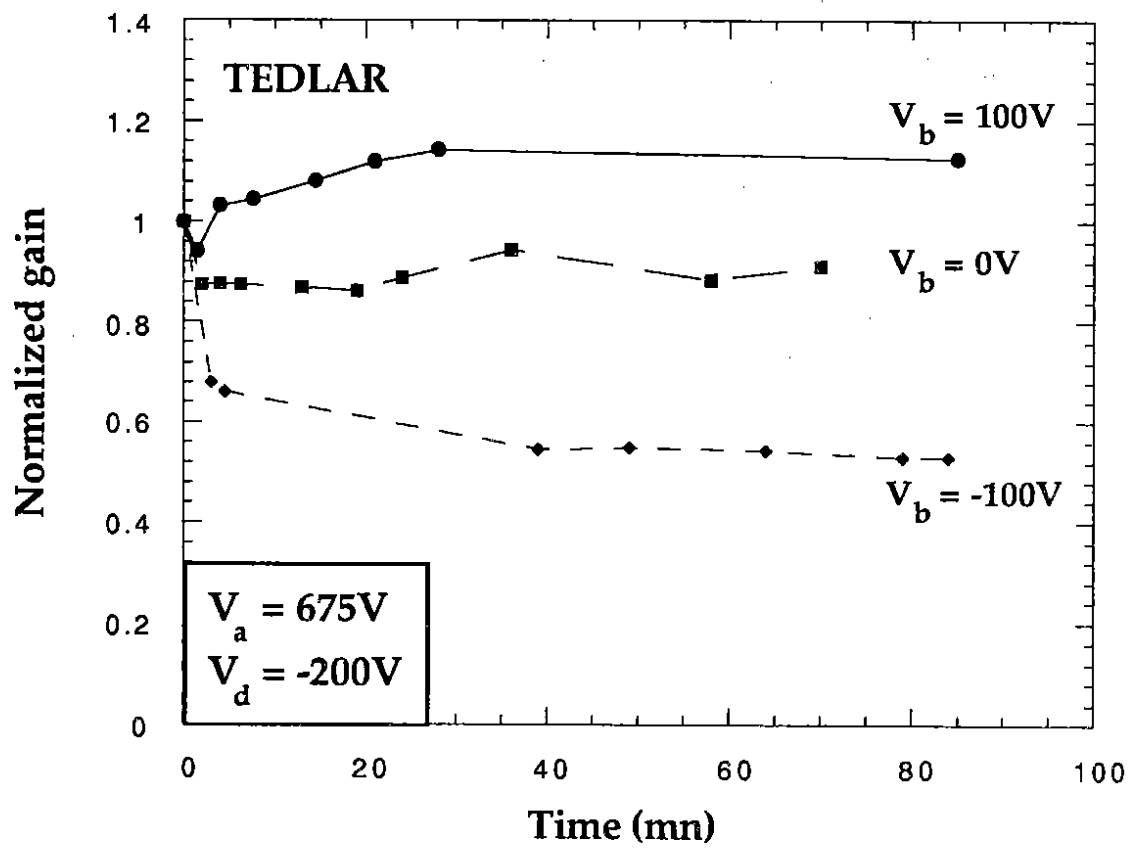


Fig. 8

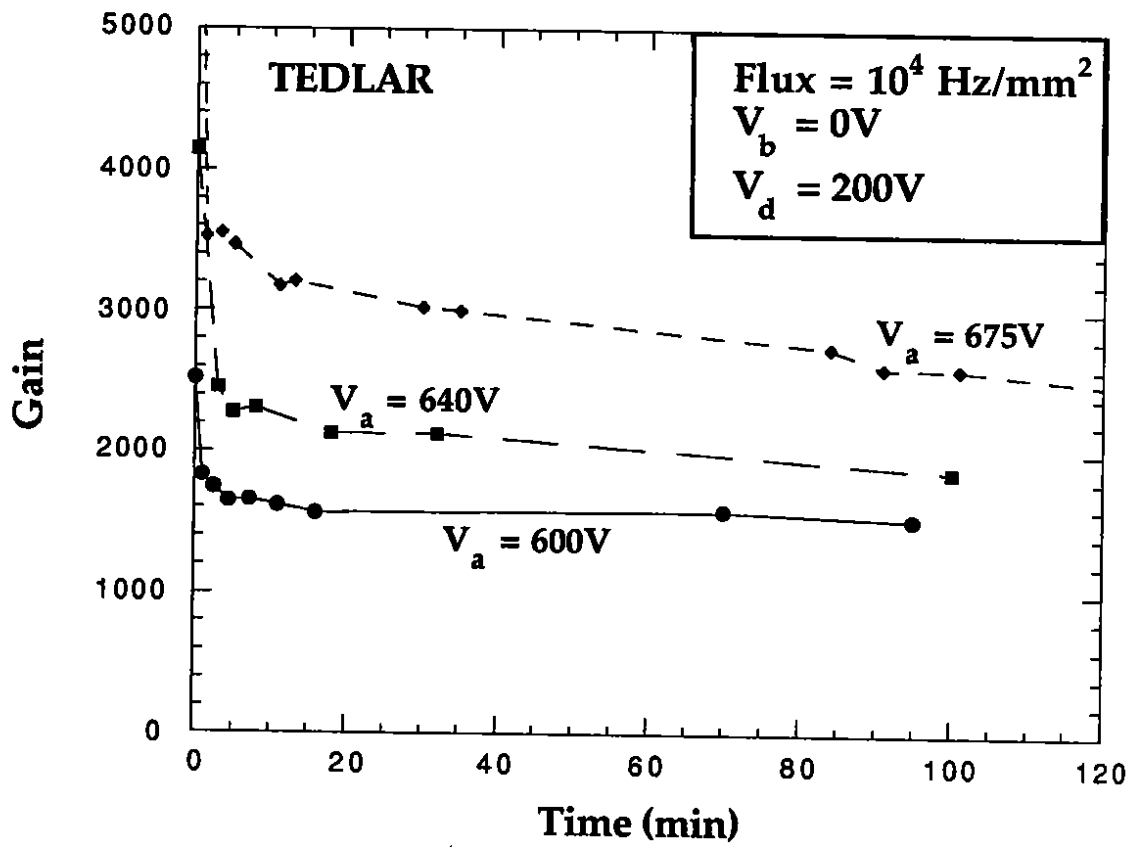


Fig. 9