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USE OF ULTRA THIN SEMICONDUCTIVE LAYERS AS PASSIVATION IN MICROSTRIP GAS CHAMBERS

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Abstract

We have investigated the properties of thin copper and germanium layers in view of their use in microstrip gas chambers. It was found that ultra thin germanium layers with thicknesses of about 100Å provide surface resistivities in the order of 10^{11}–10^{14} $\Omega/\square$. Such layers evaporated onto the micro structure of microstrip gas chambers manufactured on plastic or glass supports lead to a gain stabilization of these detectors up to very high particle fluxes.

The present study has been realized in the framework of the collaboration for the Development of Gas Microstrip Chambers for Radiation Detection and Tracking at High Rates (CERN Research and Development Project RD28).

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1 Introduction

Since the invention of the microstrip gas chamber (MSGC) [1] one has been confronted with the problem of short term gain instabilities during their operation, particularly if exposed to high particle fluxes [2] [3] [4] [5]. More recent investigations show that these variations can be divided in two types, local and global phenomena [6]. A global change of gain (usually a drop) can occur shortly after application of the high voltage. This effect is independent of the irradiation rate of the chamber and may be understood to be due to a polarization within the substrate material. An additional drop of the gain occurs locally in the area exposed to a particle flux. Here, the gain decreases and eventually stabilizes at a plateau the value of which is rate dependent. This phenomenon is due to the accumulation of ions generated in the avalanches on the surface of the insulating substrate.

It has been shown that the latter effect can be avoided using ion implanted glass substrates with decreased surface resistivity (10^{11}–10^{14} $\Omega/\Box$) [7]. The choice of electronicly conductive glass with low bulk resistivity (10^{9}–10^{11} Ωcm) also cures the problem of substrate polarization [6].

Microstrip gas chambers are very promising devices for application in transition radiation detectors (TRDs) due to their intrinsically good energy and spatial resolution. Efficient detection of soft X–rays in a multi–layer TRD, however, requires the use of low mass materials for the detector windows. The development of microstrip gas chambers on thin plastic substrates is therefore essential. Low Z high energy resolution detectors are also of interest in any environment where multiple scattering is of importance.

After the use of low resistivity glass has proven to overcome the charging up problem, the construction of microstrip gas chambers on plastic materials of comparable resistivities seems advantageous. The use of polymers with bulk resistivities in the order of 10^{9}–10^{11} Ωcm, however, is not possible. Bulk resistivities of polyimides, such as Kapton[1] or Upilex[2] are orders of magnitude too high ($\geq 10^{15}$ Ωcm). Resistivities of polymers on the other hand which possess intrinsic conductivity due to electron transport along the linked polymer chains (such as polypyroles or polyanilines) lack long-term stability due to thermal or radiation effects, oxidation or the existence of water in the bulk.

More recently, investigations have started to decrease the surface resistivity of polyimides by ion implantation. This method shows promising results and first test chambers are being constructed.

In this paper we present first studies on thin layers of copper or germanium evaporated on top of the microstrip structure etched on plastic or glass supports. At first we will present some results on the properties of such layers of different thickness and then show their ability to resolve the problem of charging up [8].

2 Resistivity behavior of very thin copper and germanium layers

In order to study the surface resistivity of ultra thin layers, we prepared kapton samples on which copper electrodes with 3000Å thickness were evaporated. On top of these samples thin copper or germanium layers were realized by electron beam vacuum evaporation. The electrodes allow direct measurement of the surface resistivity of the evaporated layer.

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[1] trade name of DuPont

[2] trade name of UBE industries

In this way, we have realized copper layers with thicknesses between 20 and 50Å. The resistivities showed steep rises by up to 9 orders of magnitude during the first 24 hours indicating surface oxidation (table 1). However, long term observations (fig. 1) show the resistivities to stabilize after about 150 days.

Analogous measurements were performed with germanium layers of thicknesses between 20 and 200Å. In order to accelerate the oxidation process, some of the samples were kept at a temperature of 70° C after the evaporation process. The resistivities show sharp rises by up to 3 orders of magnitude within the first 24 hours after the vacuum evaporation (table 2). On a longer time scale, the resistivities further increased, although more moderately (fig. 2), approaching a plateau after two months.

Germanium layers of thicknesses around 100Å, kept at room temperature after evaporation, show much slower resistivity rises as compared to the corresponding layers kept at 70° C. They also seem to stabilize at lower values (fig. 3). The three curves shown correspond to samples fixed at different positions in the evaporation oven, therefore constituting slightly different layer thicknesses.

These investigations show that surface resistivities in the interesting domain (10^{11}–$10^{14}\Omega/\Box$) can best be obtained by thin ($\leq$130Å) germanium layers. The use of copper layers is not suitable since thicknesses below 20Å would be required. Such layers are difficult to realize reliably, particularly on larger surfaces.

3 Application in the development of microstrip gas chambers

If we want to use thin slightly conductive layers in MSGCs, two possibilities are open. We may evaporate such layers on top of the microstructure imprinted on the substrate before. Thus, the manufacturing process of the structure can be kept, but the thin layer on top of the strips may alter the performance (i. e. the gain) of the chamber. We can also evaporate the thin layer first and then manufacture the microstructure. In the latter case, we will keep the gain characteristics. However, we risk, that different methods have to be developed to produce the microstrip structure on such fragile surfaces. For the sake of simplicity, we have chosen the first process.

In order to study the effect of such a thin layer on the performance of a MSGC, two detectors were constructed on different support materials, 300μm thick electronically conductive glass ($R\approx10^{13}\Omega$cm) and 50μm thick Upilex foil. Both detectors were operated with an 90:10 Argon-DME mixture and had the same geometry: Anodes and cathodes had a width of 25μm and 145μm, respectively, the strip thickness was 3000Å and the pitch 400μm. The chambers had a drift space of 5mm depth. The glass chamber was operated at a cathode voltage of V_c=–680V, a drift voltage of V_d=–1500V and a backplane voltage of V_b=–500V, resulting in a gas amplification of 440. The Upilex chamber was operated at the voltages V_c=–600V, V_d=–2000V and V_b=–320V. The gas gain in this case was 410.

The gain behavior of these chambers was investigated using 8KeV X–rays from an X–ray tube. Measurements were performed at low flux (around 40 Hz) immediately after application of the voltages ('flux0'–measurement) as well as at high fluxes of several 10000 photons/(s$\cdot$mm^2) (high flux measurement)[3]. The gas amplification of the Upilex chamber shows a small time dependence already at 'flux0' probably due to the polarization of the plastic material (fig. 4 (a)). The stable gain at 'flux0' of the glass chamber (fig. 4 (a)) corresponds to the electronic conductivity of the glass used. Increasing the flux, the gains

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[3] For a detailed description of this methode see [6]

of both chambers drop due to charging up of the high resistive surface (fig. 4 (b) and fig. 5 (b)).

After these investigations were performed, a 28Å thick germanium layer was evaporated onto the microstrip structures of these detectors. Immediately after the evaporation process, the chamber was closed and flushed with counting gas to avoid oxidation. Referring to table 2, a surface resistivity in the order of 10^{12} $\Omega/\Box$ was expected. Using the same voltage settings as before the detectors showed a gas gain reduced by $\approx$ 10% as compared to the original one (table 3). The effective surface resistivity could be obtained from the leakage current (also table 3).

Operating the Upilex chamber at 'flux0' (fig. 6 (a)) showed no time dependent gain behavior indicating a shielding of the polarization charge by the thin semiconductive layer. Furthermore, the reduced surface resistivity leads to a stabilization of the gain for both chambers up to photon fluxes corresponding to $2{\cdot}10^5$ minimum ionizing particles per second and square millimeter (fig. 6 and 7 (b)).

4 Conclusion

The resistivity behavior of very thin copper and germanium layers has been investigated. Vacuum evaporation of germanium layers with thicknesses below $\approx$130Å provides surface resistivities between 10^{11} and 10^{14} $\Omega/\Box$, which is an interesting result in view of applications in the development of MSGCs. Layers of 28Å germanium were evaporated on top of the microstructure of two microstrip gas chambers providing surface resistivities around 10^{12} $\Omega/\Box$. It could be shown that this leads to the desired stabilization of the gas amplification up to very high particle fluxes.

The measurements presented only constitute a first step. Germanium layers of 28Å thickness will undergo oxidation pushing up the surface resistivity above 10^{14} $\Omega/\Box$ after about 24 hours exposure to air. The long term stability of detectors with 100Å thick germanium layers has to be investigated also in view of possible chemical reactions between the organic compound of the gas and the germanium layer.

The present results however demonstrate the working principle of a solution to the charging up problem independently of the support material, which is of particular interest for the use of plastic substrates in microstrip gas chambers.

5 Acknowledgements

We thank L. Ropelewski (CERN) for his steady interest and his fruitful support. We are also indebted to F. Sauli (CERN), who gave access to his laboratory for the important high flux measurements. We would also like to thank R. Bouclier (CERN) and J. Zimmer (University of Heidelberg) for technical support. Finally we thank the Thin Film & Glass and Printed Circuit groups at CERN for manufacturing the microstructures as well as for the germanium and copper evaporations.

References

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[2] Bouclier et al., CERN DRDC 92–30, DRDC/P–41 (1992)

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[5] Bouclier et al., CERN–PPE/91–108 (1991), Presented at the 5th Pisa Meeting on Advanced Detectors

[6] Bouclier et al., CERN–PPE/93–04 (1993)

[7] Angelini et al., Nucl. Instr. and Meth. A315 (1992) 21

[8] This work was also presented at the 'Workshop on Progress in Gaseous Microstrip Proportional Chambers' in Grenoble (21–23 June 1993)

thickness[Å]	20	30	40	50
R_1[$\Omega/\square$]	$2 \cdot 10^{11}$	$2 \cdot 10^{9}$	273	77
R_2[$\Omega/\square$]	$3 \cdot 10^{10}$	$8 \cdot 10^{8}$	$7 \cdot 10^{9}$	$2 \cdot 10^{10}$

Table 1: Surface resistivities of copper layers immediately after evaporation (R_1) and 24 hours later (R_2). (The samples were kept at room temperature in air.)

thickness[Å]	20	25	50	100	120	200
R_1[$\Omega/\square$]	$4 \cdot 10^{12}$	10^{12}	$3 \cdot 10^{11}$	$5 \cdot 10^{9}$	$8 \cdot 10^{9}$	$8 \cdot 10^{9}$
R_2[$\Omega/\square$]	$> 10^{15}$	$> 10^{15}$	$3 \cdot 10^{14}$	$2 \cdot 10^{11}$	$9 \cdot 10^{10}$	$2 \cdot 10^{9}$

Table 2: Surface resistivities of germanium layers immediately after evaporation (R_1) and after 24 hours at 70°C (R_2). (The samples were kept in air, all resistivities were measured after cooling–down to room temperature.)

support material	R[$\Omega/\square$]	V_2/V_1
upilex	$1.5 \cdot 10^{12}$	89%
glass	$5 \cdot 10^{12}$	91%

Table 3: Surface resistivity R of the 28Å germanium layer and the ratio of gas amplification V_2/V_1 after and before evaporation of the layer.

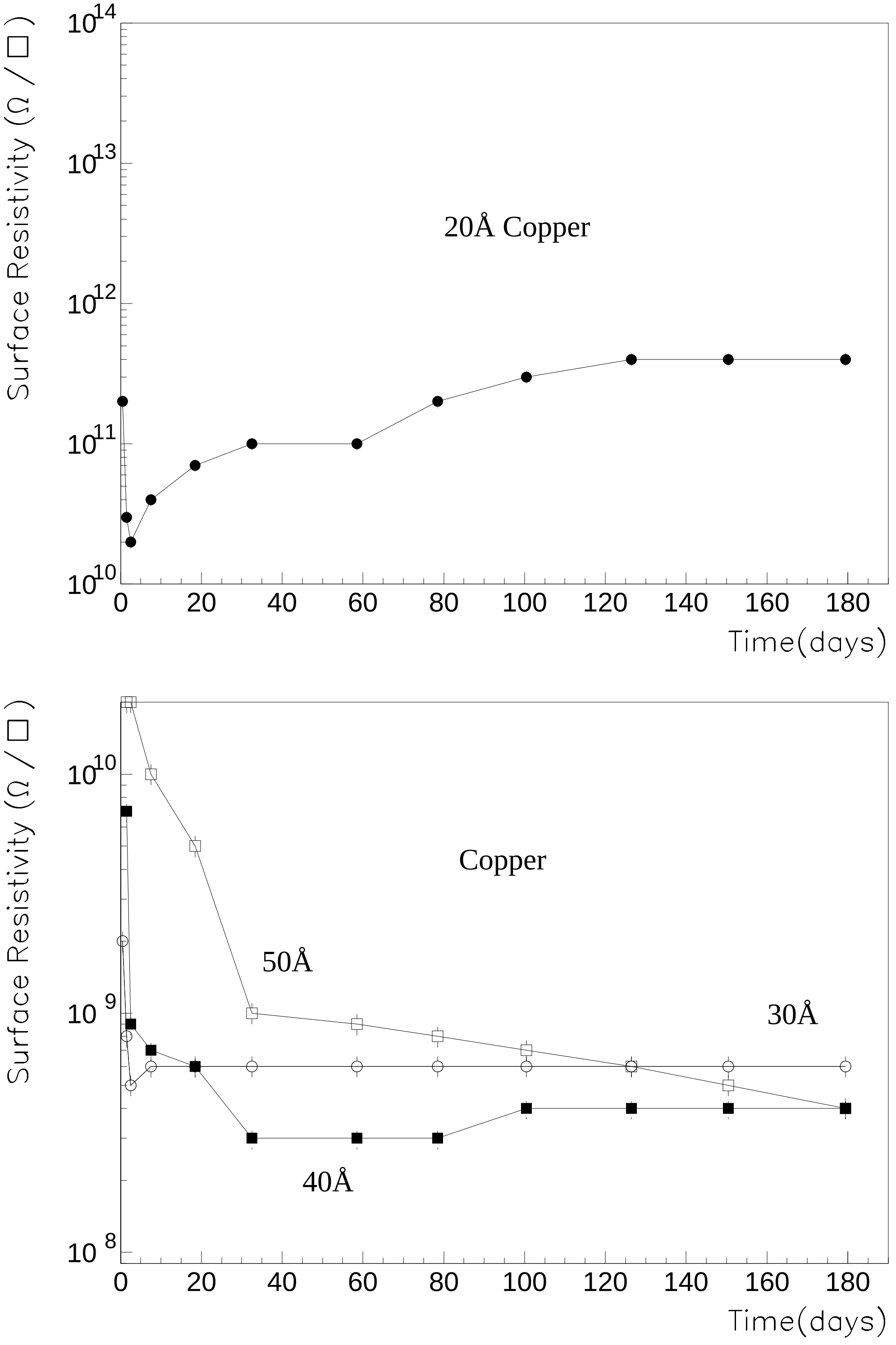


Figure 1: Time development of the surface resistivities of thin copper layers with thicknesses between 20 and 50 Å.

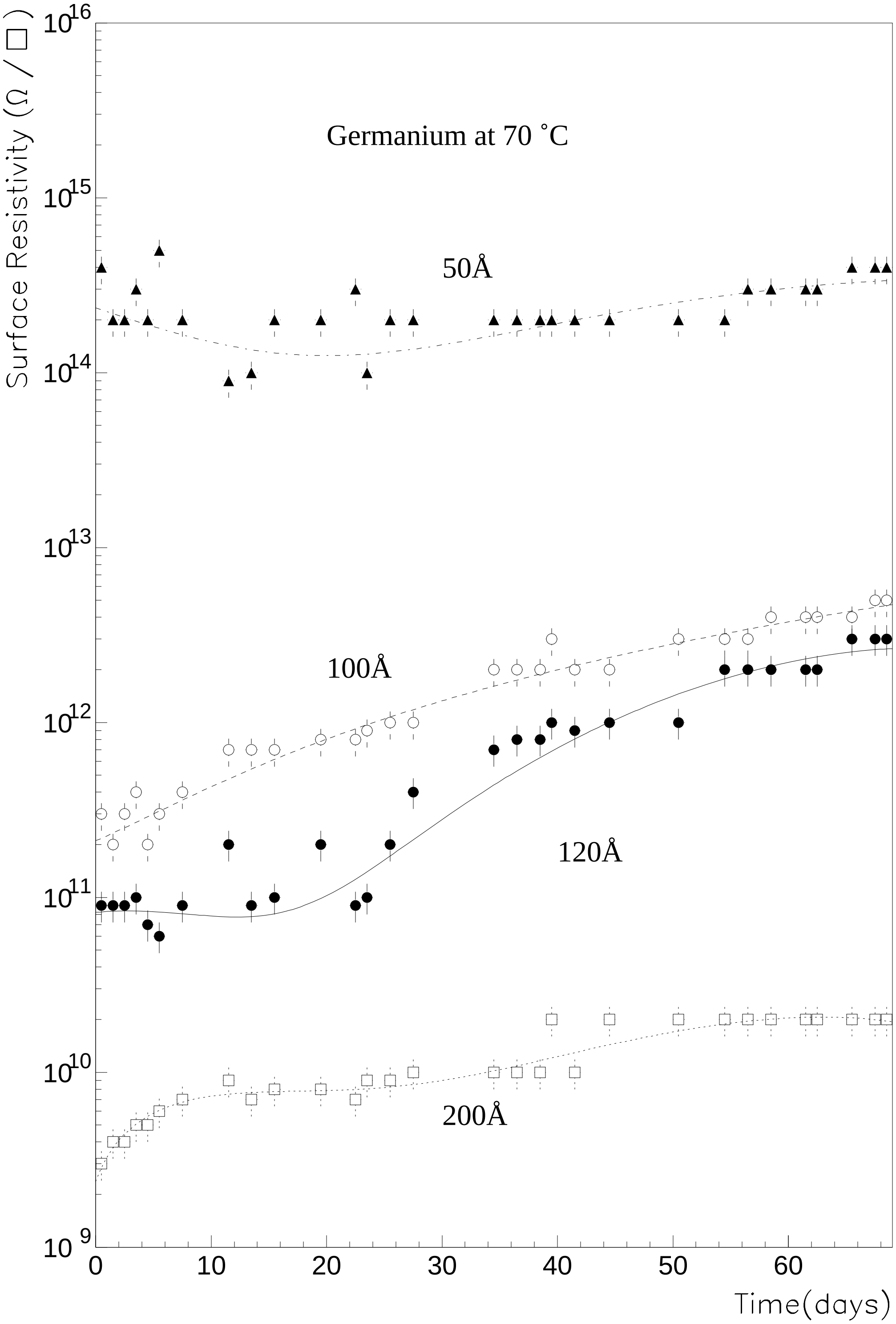


Figure 2: Time development of the surface resistivities of germanium layers with thicknesses between 50 und 200 Å at 70°C. (All resistivities measured after cooling-down to room temperature.)

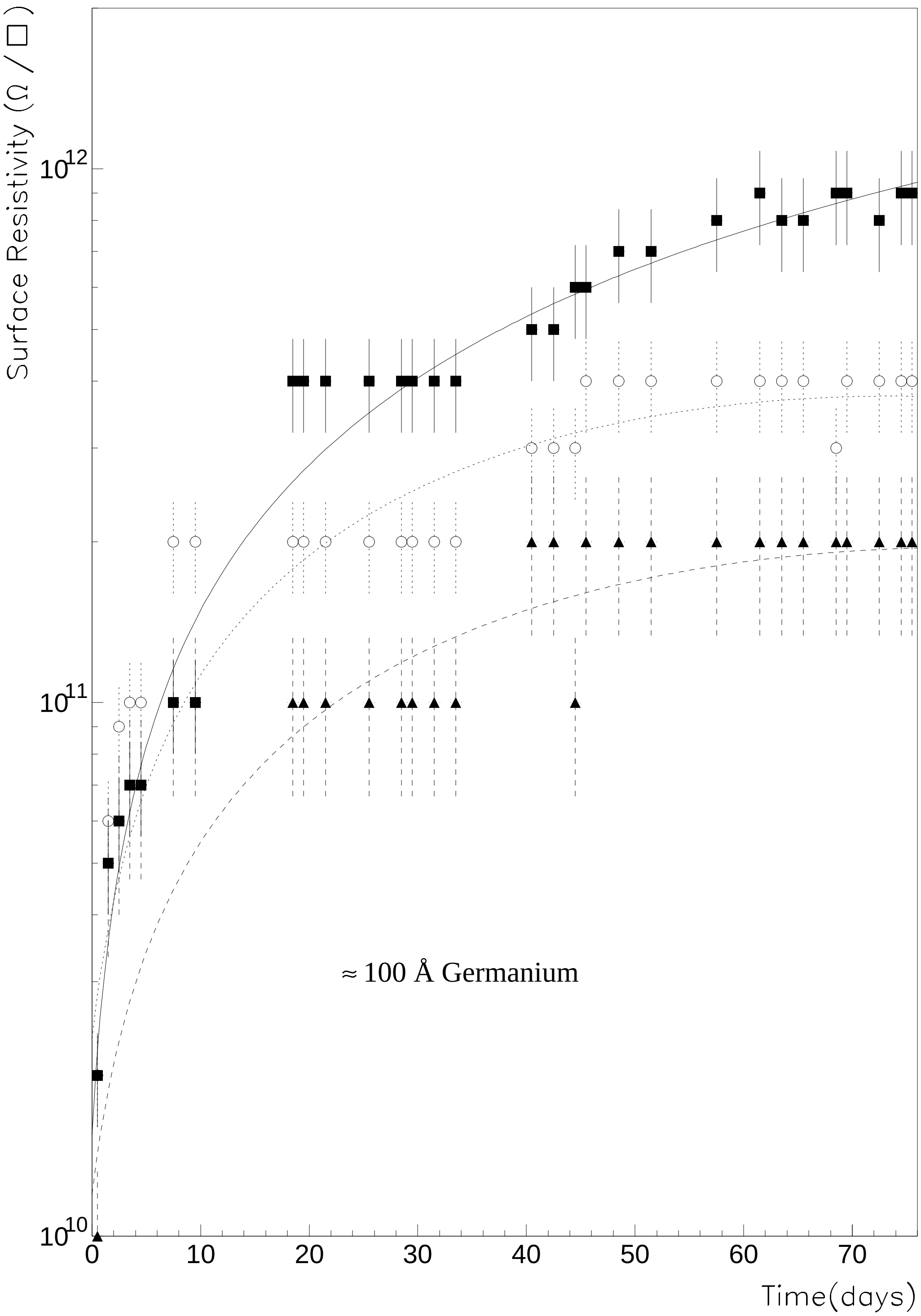
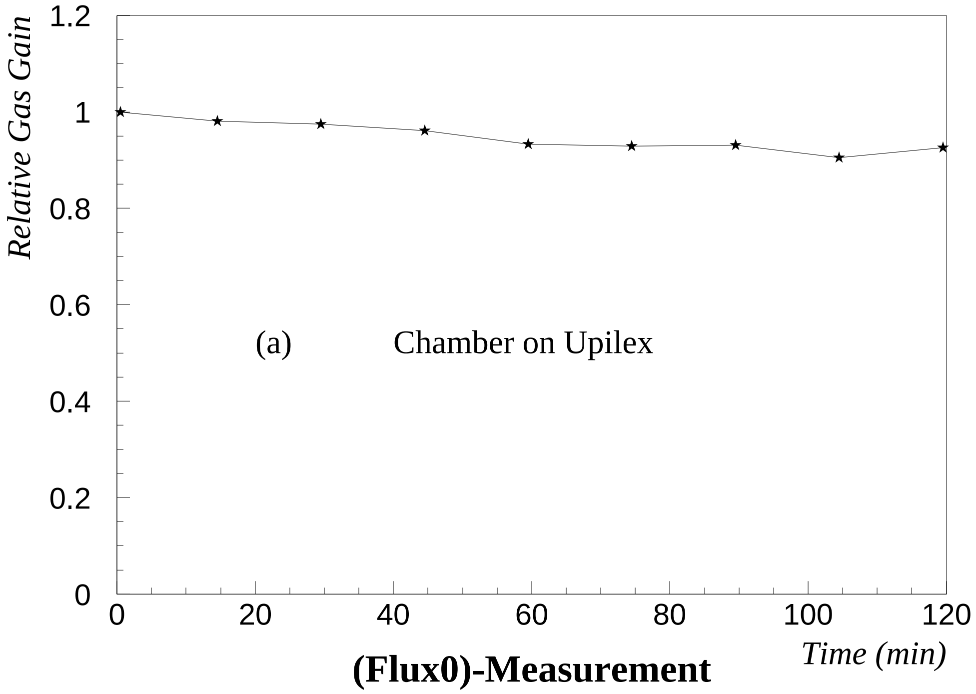
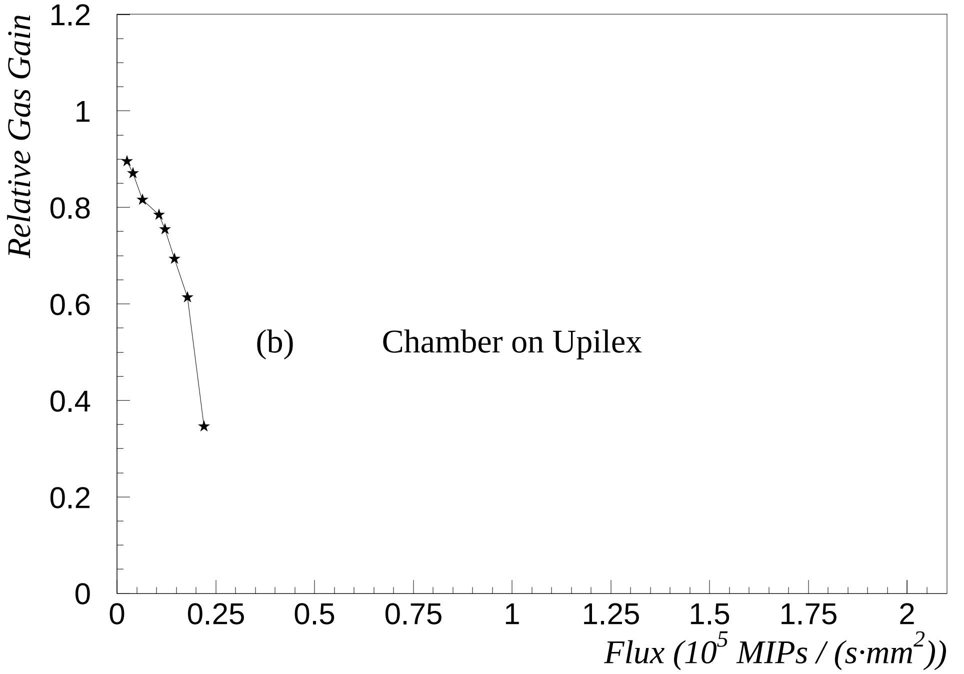


Figure 3: Time development of the surface resistivities of germanium layers with thicknesses around 100Å at room temperature.

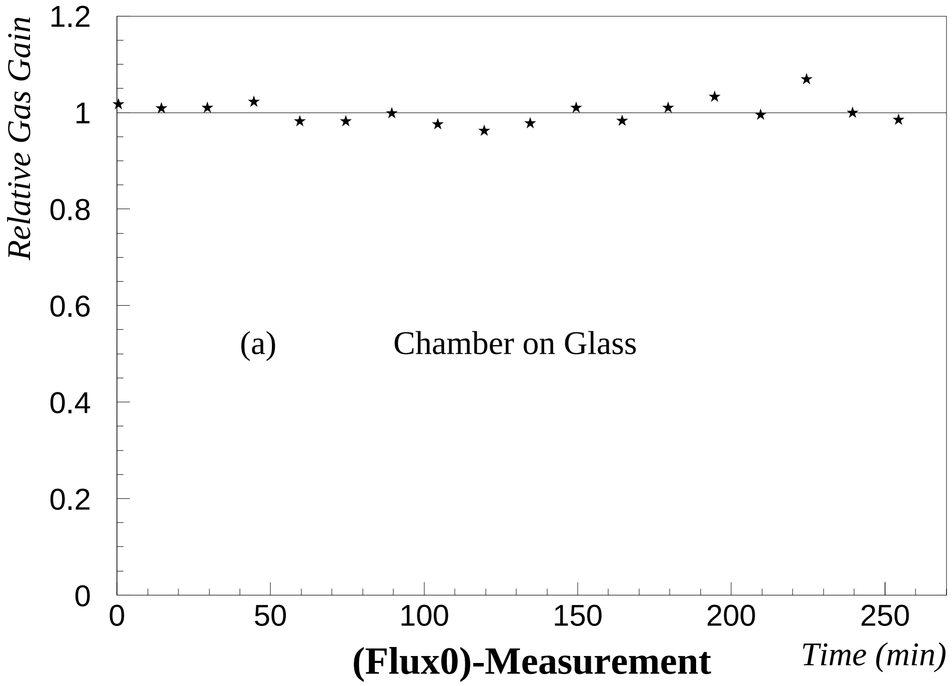


(Flux0)-Measurement

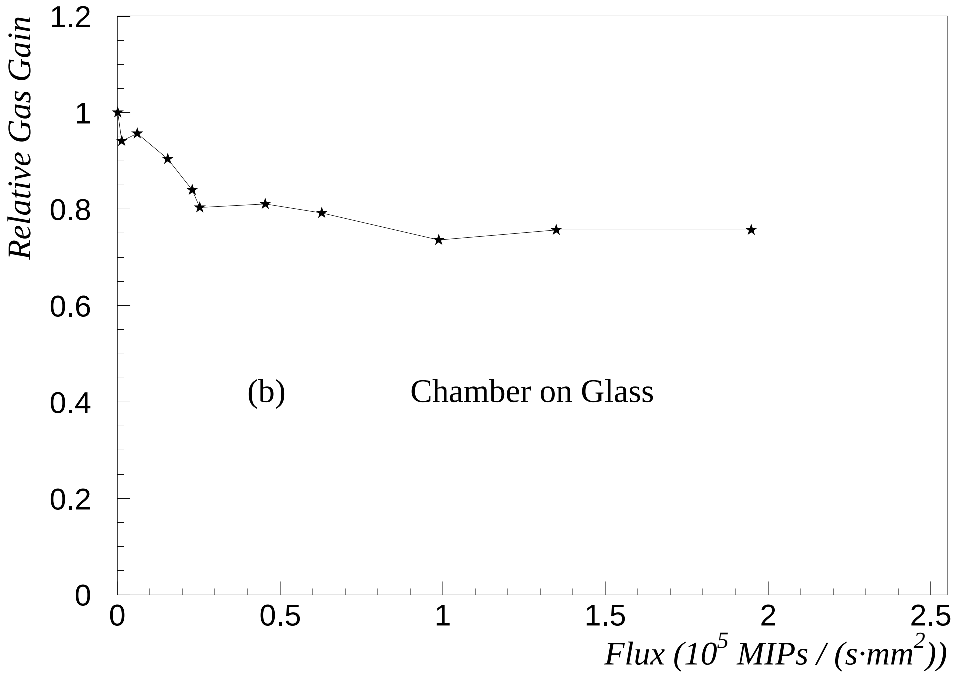


High Flux Measurement

Figure 4: (a) Time dependence of the gas amplification of the detector on Upilex substrate at 'flux0'.
(b) Flux dependence of the gas amplification of the detector on Upilex substrate.
For better comparison with future experiments the photon flux is expressed in units of minimum ionizing particles (MIPs).

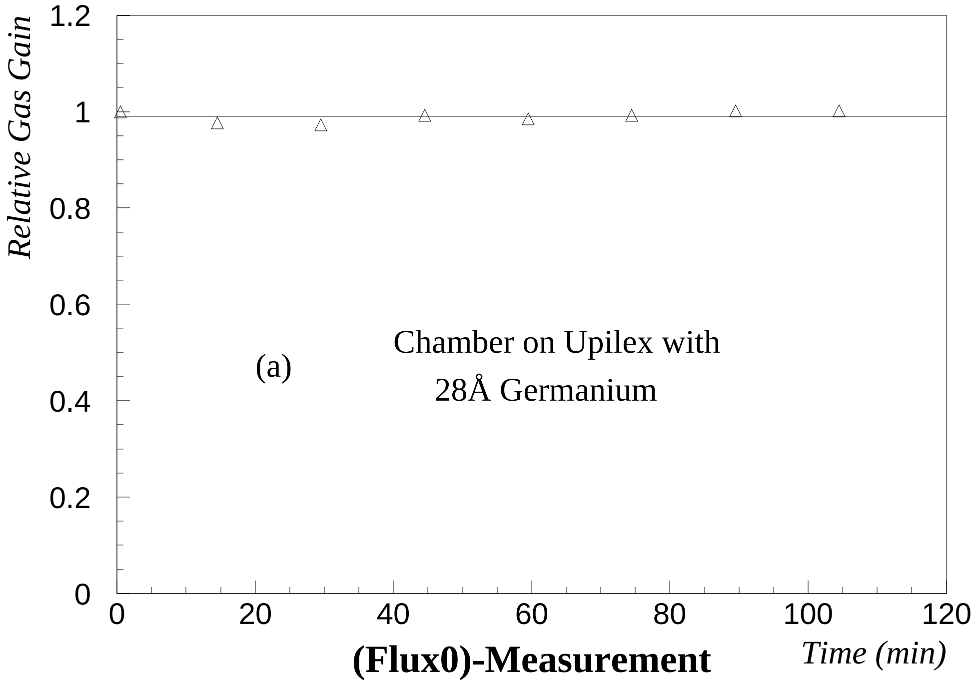


(Flux0)-Measurement

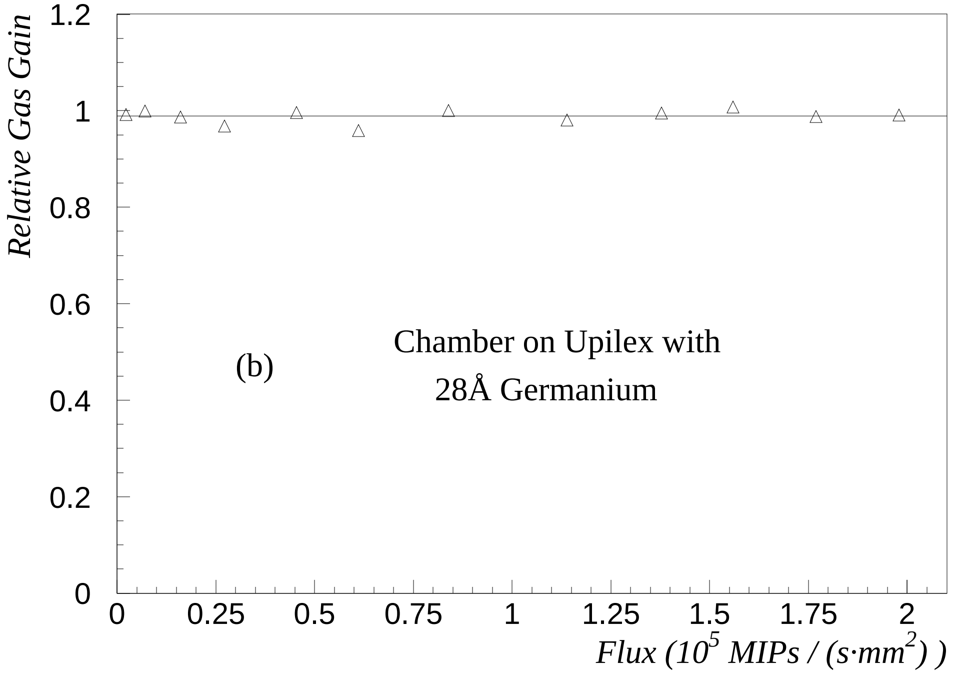


High Flux Measurement

Figure 5: (a) Time dependence of the gas amplification of the detector on glass substrate at 'flux0'.
(b) Flux dependence of the gas amplification of the detector on glass substrate.



(Flux0)-Measurement



High Flux Measurement

Figure 6: (a) Time dependence of the gas amplification of the detector on Upilex substrate at 'flux0' after evaporation of 28Å germanium.
(b) Flux dependence of the gas amplification of the detector on Upilex substrate after evaporation of 28Å germanium.

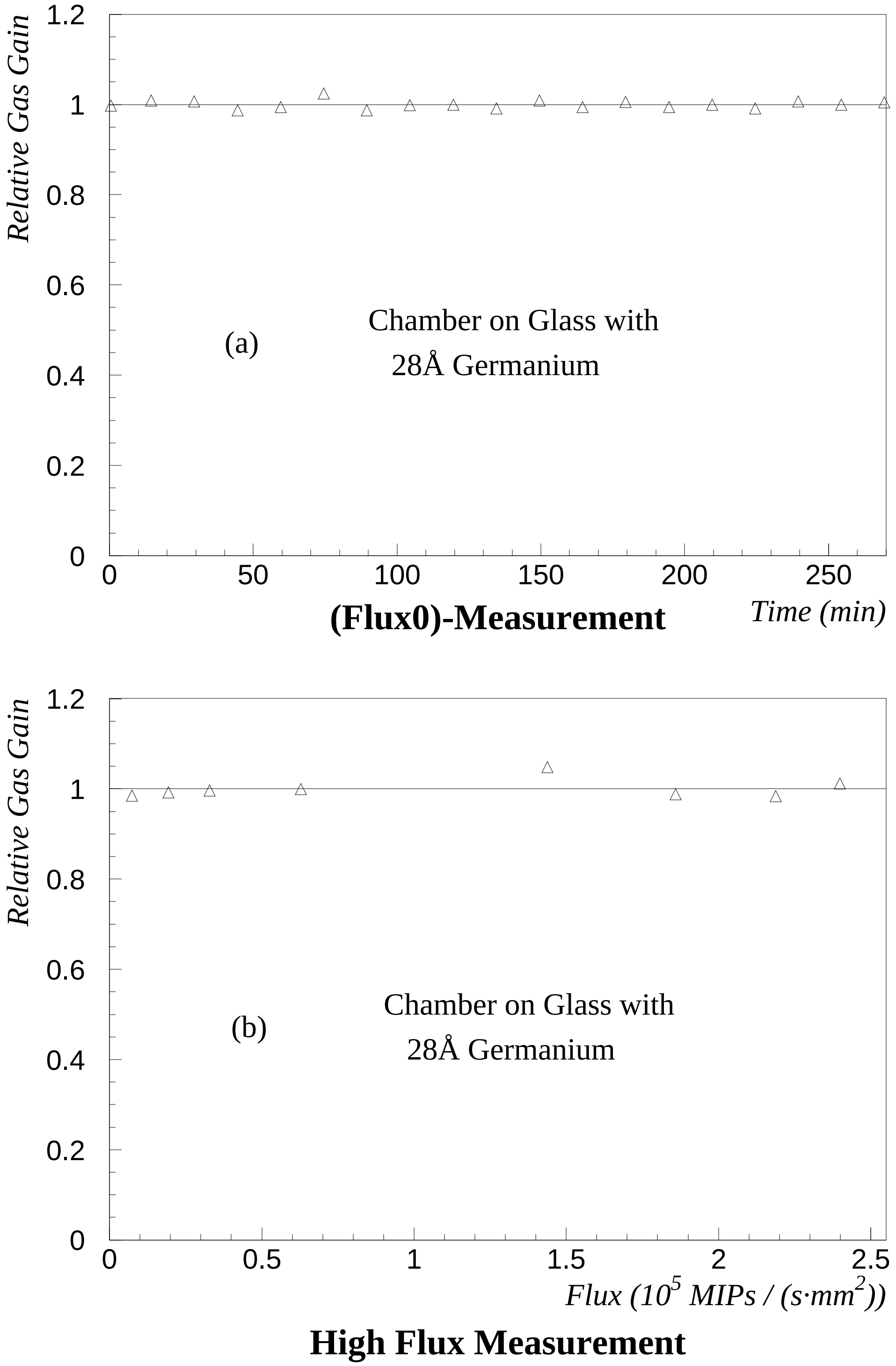


Figure 7: (a) Time dependence of the gas amplification of the detector on glass substrate at 'flux0' after evaporation of 28Å germanium.
(b) Flux dependence of the gas amplification of the detector on glass substrate after evaporation of 28Å germanium.