**A.5.3. Galileo Microchannel Plates as Detectors of Ions having Atomic Masses from 1 to 181, Charge States from 1 to 44 and Energy Range from 0.5 to 150 keV/q**--*C. Fehrenbach, D. Fry, W. Mróz,* A. Prokopiuk* and M. P. Stöckli*

Micro channel plates, MCPs, are often used as ion and other particle detectors in different types of mass-spectrometers. Particles impacting MCPs emit secondary electrons, which are further multiplied, until a sufficient number of secondary electrons are produced to be measured and electronically analyzed. Each MCP is characterized by the electron current gain, $G_{ec}$, defined as the ratio of electron current at the output of the MCP and incoming electron current ($I_{out}$ / $I_{int}$), as a function of the bias voltage. In mass-spectroscopic measurements, the catalog parameter, $G_{ec}$, is not an especially useful parameter, because in general particles other than electrons are detected, for example: ions, neutral atoms, clusters and some time biological molecules. Each type of particle impacting the MCP emits different numbers of secondary electrons. The number of electrons emitted by a particle upon impact with the surface of the MCP is described by the secondary particle-electron emission coefficient, $\gamma_p$. The coefficients $\gamma_p$, in general are unknown. Their value is not needed for qualitative or comparative measurements, but if quantitative measurements are necessary, a calibration of the MCP should be done. When different particles are to be detected, e.g. when chemical composition is measured [4], it is more convenient to use the analog particle gain, $G_a$, defined as the ratio of the number of electrons at the output of the MCP to the intercepted number of particles, $N_{p\ int}$ (e.g. ions with charge state, q):

$$G_a = N_{out} / N_{p\ int} \equiv I_{out} / I_p/q = G_c\, q. \qquad (1)$$

The analog particle gain of MCPs is closely dependent on the secondary ion-electron emission coefficient, $\gamma_p$. Phenomena related to the ion-induced electron emission from solid surfaces can be ascribed to two different mechanisms: kinetic emission, which is denoted by $\gamma_{pk}$, and potential emission [24], denoted by $\gamma_{pp}$. Kinetic emission (KE) is caused by the transfer of kinetic projectile energy onto the electrons and atomic cores in the solid, or some adsorbates at the solid surface, which lead by a variety of physical processes to the ejection of electrons from the solid surface. In the KE processes the kinetic energy and mass of the projectile are of foremost importance. Other physical properties of projectiles such as their chemical configuration, charge state and electronic, vibrational or rotational state are usually of no concern. Naturally, this assumption is only justified at relatively high impact velocity.

Potential emission (PE) is the principal mechanism for electron emission if the kinetic energy of the projectile remains of less influence than its internal physical properties. For higher ionization states, as discussed in this paper, a significant influence on the electron emission is the charge state of incoming ions. The potential energy related to ion production from the corresponding neutral atomic or molecular ground state is carried by the ions toward the solid surface and deposited in it during recombination. Processes of recombination involve rapid electronic transitions which lead to electron emission. However, for higher impact velocity KE effects become significant.

For the measurements of the analog particle gains a detector assembly consisting of two 0.4 mm thick galileo MCPs with a 19.6 mm active diameter [2] was used. The 10 μm diameter channels have a bias angle of 5° and an open area ratio of 64%. The MCPs were matched for equal bias currents (3 μA at 700 V) and mounted in direct contact ("V-set" configuration. The operational pressure was a few times $10^{-9}$ Torr. Calibration measurements were performed with: H, C, O, F, Al, Fe [8], Ta [2,3] and Xe [7] ions. The energy range of the ions was varied from 0.5 to 150 keV/q. The maximum charge state of ions used for calibration was $Ta^{44+}$.

Figure 1 presents the measured analog particle gain as a function of ion impact velocity [2]. As is seen, the $G_a$ is almost independent on ion charge state (± 15 %) for ions with charges from q = 10 up to q = 20. In this range of charge states, $G_a$ depends mainly on the ion impact velocity. In the investigated range of ion velocities, $G_a$ rises strongly with the ion impact velocity due to the rise of the kinetic part, $\gamma_{pk}$, of the secondary ion-electron emission coefficient, $\gamma_p$. For the chosen ion impact velocity, $G_a$ begins to increase with the charge state of ions, starting from $q_t \cong 20$, due to the rise of the potential part, $\gamma_{pp}$, of the secondary ion-electron emission coefficient. This increase of $G_a$ with ion charge state, q, is higher for the lower velocities than for higher ones. With an increase in the velocity of the ion, the contribution of kinetic emission, $\gamma_{pk}$ , increases above the contribution of potential emission, $\gamma_{pp}$. The dependence of the analog particle gain of the investigated MCP detector as a function of the mass of the registered ions is shown in Fig. 2. These characteristics were obtained for low-charged ions [2,5], with the assumption that analog particle gain is charge state independant ($\gamma_{pp} \cong 0$). The $G_a$ of MCPs rises with the atomic mass of the registered ions [5,8]. For lower masses, from 1 to about 30 [amu] the rise is much quicker than for higher ones.

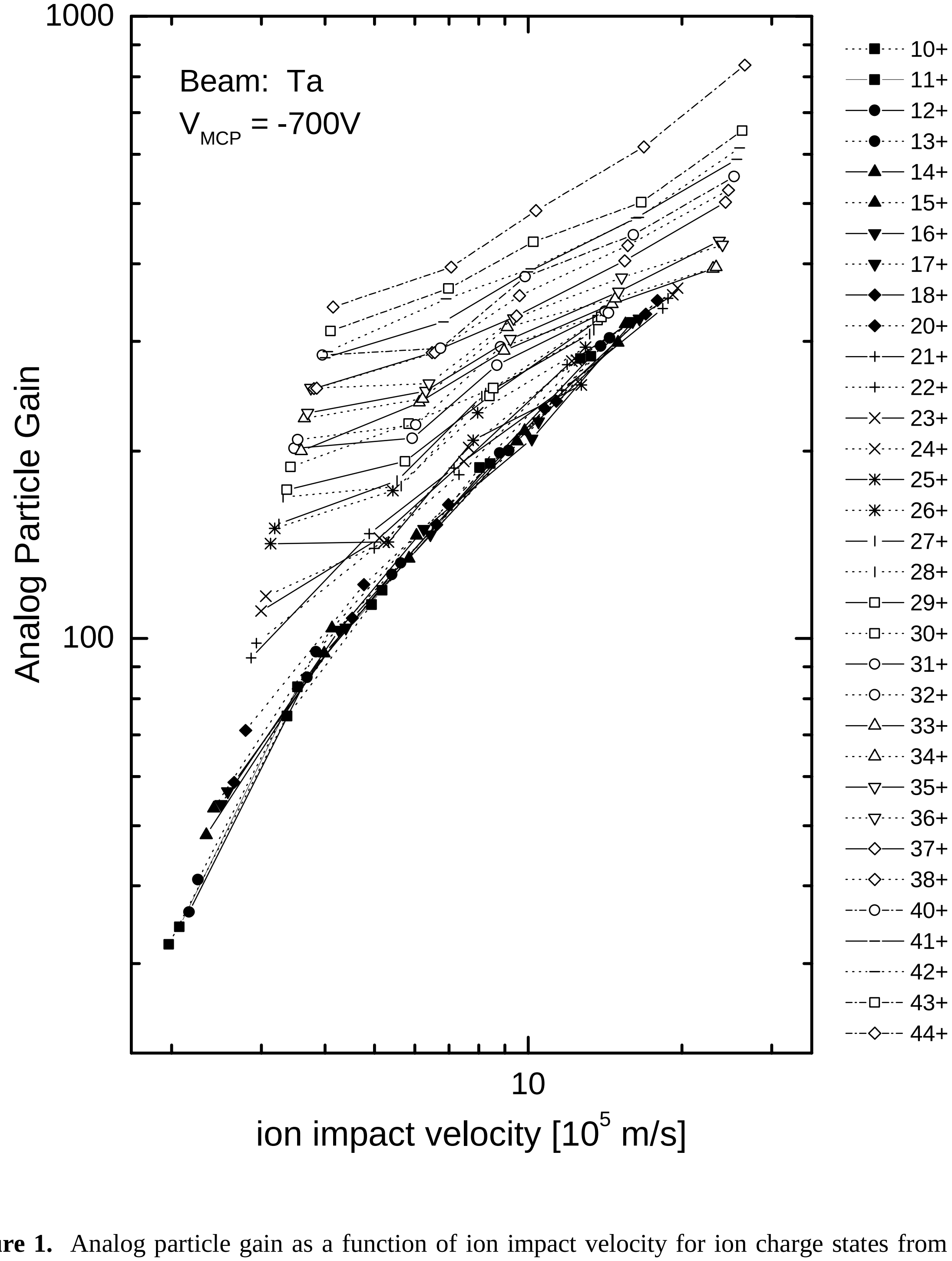


**Figure 1.** Analog particle gain as a function of ion impact velocity for ion charge states from q=10 to q=44.

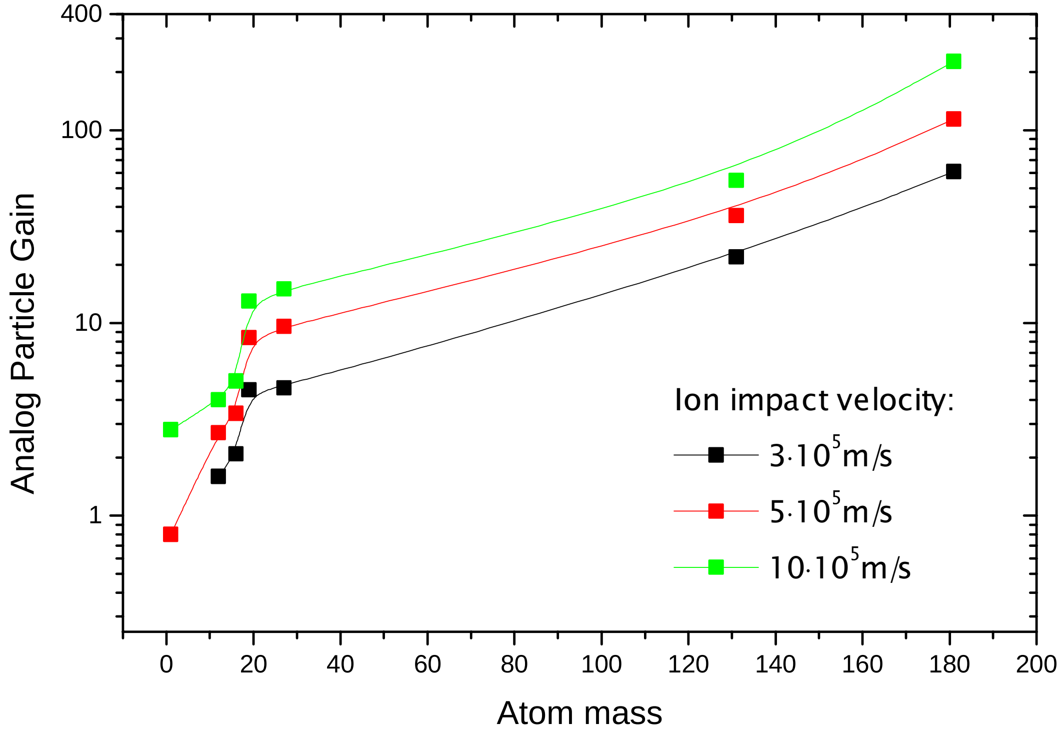


**Figure 2.** The dependence of the analog particle gain of investigated MCP detector as a function of the mass of registered ions.

Results of the experimental calibration of the two stage Galileo MCP assembly with the $Ta^{10+}$ - $Ta^{44+}$ ions having an energy range from 3.7 keV/q to 153.7 keV/q show that MCPs are very sensitive detectors of highly charged, high energy ions. In the investigated range of charge states and energies of tantalum ions, the analog particle gain, $G_a$, of MCPs is from tenths to hundreds of times higher than the given catalog current amplification, $G_c$, measured for electrons. The reason for this is the very high secondary ion-electron emission coefficient of the material which covers the channels of the investigated MCP. It was shown, that for ion charge states from q = 10 up to q ~20 kinetic emission dominates the process, but for higher charge states the mechanism of potential emission starts to be visible. At the entrance of MCP channels the high secondary ion-electron emission coefficient causes the appearance of a few hundred electrons, which after multiplication, characteristic for the MCP bias voltage used, give a total output current. As suggested by manufacturers the MCP bias voltage, 800 - 1000 V per plate, made it impossible to obtain proportional current gain of an MCP detector assembly for all ionization states and energies. The presented results of calibration with tantalum ions were obtained with the polarization voltage of the two-MCP detector assembly equal: U = -700 V, which gives a voltage per MCP lower than U = -350 V. This is a much lower voltage than the suggested voltage characteristic of MCP amplification. The detector also worked with bias voltage U = -600 V.

Results of the performed calibration shows that the MCPs are especially suitable for pulse counting mode operation, because they have a very small time response and high analog particle gain, increasing with the ion impact energy and charge states of registered ions. The operation of MCPs in almost proportional mode is also possible, especially when low energy (E ~ 1 keV), lowly charged ($\gamma_{pp} \cong 0$) ions are registered [5]. In such a situation, however, the measurements have to be carefully planned to obtain truly proportional gain of different ion fluxes. Control of the ratio of the total output current to the strip current, characteristic for the MCPs used, may be useful information about the regime of operation for MCPs. For proportional mode this ratio ought to be lower than 10%. For highly charged and high-energy ions, this criterion is insufficient. This situation is shown in the Fig. 3 [3]. Energy distributions of tantalum ions after correction for the analog particle gain of MCPs, have flat, nonphysical shapes, which suggests that the MCP worked in suppressed, nonproportional gain.

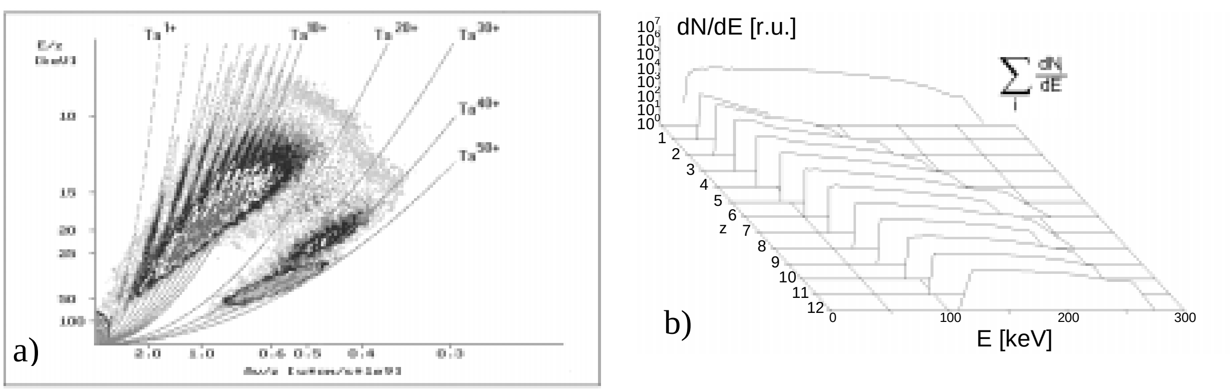


**Figure 3.** (a)-the registered and matched shapes of the tantalum parabolas, (b)- energy distributions of $Ta^{1+ - 12+}$ ions after correction for the analog particle gain of the MCP.

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*Institute of Optoelectronics, MUT, 01-489 Warsaw 49, Poland.

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