International Journal of Mass Spectrometry 421 (2017) 234–237

Contents lists available at ScienceDirect

International Journal of Mass Spectrometry

journal homepage: www.elsevier.com/locate/ijms

Short communication

Gain regulation of the microchannel plate system

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ARTICLE INFO

Article history:
Received 9 May 2017
Received in revised form 24 July 2017
Accepted 25 July 2017
Available online 29 July 2017

Keywords:
Microchannel plate
Gain
Saturation

1. Introduction

Microchannel plate (MCP) are specifically designed to multiply signal in the ranges of detection [1–14]. The mechanism of MCP electron multipliers is that an incident particle impacts the input surface of MCP detector and produces one or more secondary electrons [15]. These electrons are subsequently accelerated through a MCP channel by a channel electric field and ejected from the channel surface because of the photoelectric effect, producing more secondary electrons [16]. This growing electron will initiate an avalanche propagating through the microchannel and is detected at the output current of the MCP electron multipliers. According to the gain value, MCP electron multipliers are obtained and balanced. The gain of MCP is the ratio of output current to input current [17].

The gain of any microchannel plate can determine the application field of MCP electron multipliers [18]. For better applications, therefore, it is important to know exactly how monitor gain increases to the desired value to establish maximum operational electron multiplication ratios, as well as the levels of MCP photomultiplier tubes. The gain can then become an important design parameter of detection and amplification of photons and particles in a growing number of applications. On a rather more fundamental level, the gain of microchannel plate might give some insight into the mechanism of the electron multiplication system.

The voltage of some electron multiplication system determines the gain of the microchannel plate. Once the multiplied current signal in the microchannel plate at given voltage increases up to a significant current value and reaches a limited level, resulting in a gain saturation of the microchannel plate. Because the phenomena of MCP electron multipliers in conditions of gain saturation is not uncommon, it would be very important to study the original input signal to avoid a measured saturated output. Therefore, the problem of the gain saturation in these devices need to further continues to be investigated. Giudicotti [19] have developed a simple model describing the saturation of the gain in MCP electron multipliers.

To study gain mechanism of MCP experimentally, we monitor input current, work and screen voltage into the construction of the flexible and reliable microchannel plate system. The key factor is to establish a dynamic voltage-controlled system, where working voltage could tune the gain by altering the ratios of output current and input current. In this system, fiberglass membrane is used to make cylindrical symmetric microchannel for the electron transport. The microchannel surface obtains lead through H_2 reduction and forms a continuous dynode. They have the ability of detecting diverse ray and particles. In photomultiplication system, the particle transporting activity is controlled by voltage. Herein, we demonstrate two two-dimensional array of microchannel plates, which are consist of a mass of paralleled single channels (Fig. 1). Meanwhile, because of every single channel is an electron multiplication system, the multipores microchannel system emerges electron avalanche. Now the microchannel plates have attracted wide interests in the fields such as optical spectroscopy, space science and imaging.

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http://dx.doi.org/10.1016/j.ijms.2017.07.017

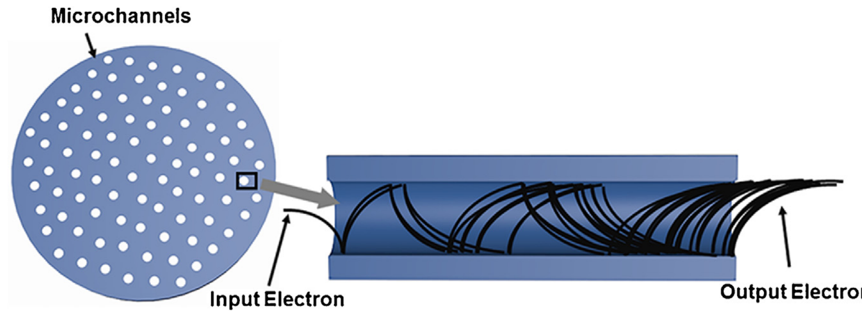

Fig. 1. The scheme of the microchannel plate, and electron avalanche in the single channel. An incident particle impacts the input surface of a MCP detector and produces one or more secondary electrons in the microchannel.

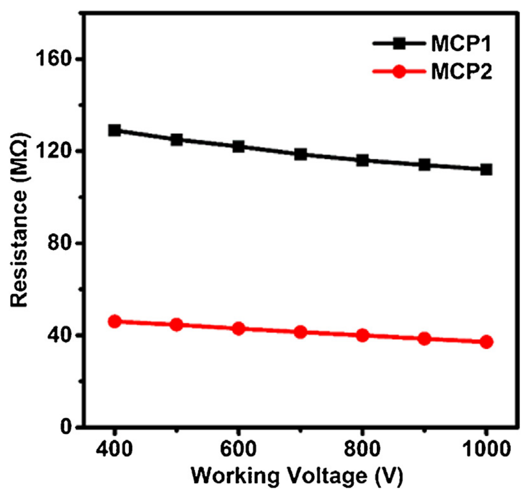

Fig. 2. The resistance of the MCP 1 and MCP 2 at voltage controlled from 400 V to 1000 V. As voltage increasing, the resistances decrease, showing a linear declining resistance-working voltage behavior.

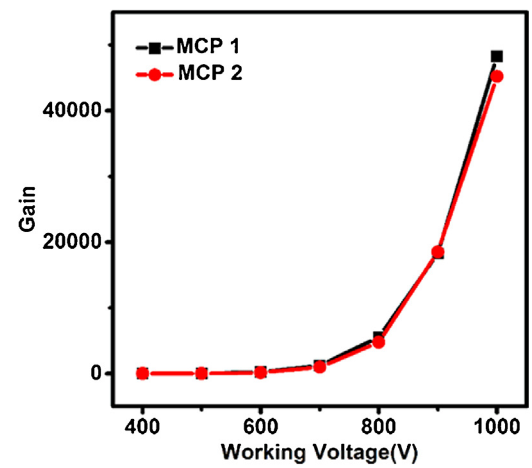

Fig. 3. The gain of MCP 1 and MCP 2 increases, as increasing working voltage from 400 V to 1000 V. The gain of MCP 1 is higher than one of MCP 2 when voltage turn from 400 V to 1000 V.

2. Material and methods

2.1. The fabrication of the microchannel plate

The microchannel plate devices are fabricated by glass fiber, and then produced through H_2 reduction and coating [20]. The pores (~6 μm) of the microchannel were observed by scanning electron microscopy (SEM, Fig. S1). The channel length is 300 μm, the bias angle is 6°. The diameter of the MCP is 26 mm. The elements of MCP were verified by X-ray photoelectron spectroscopy (XPS). The appearance of signals on MCP reflects the base property of MCP. Prior to coating, Na1s, Ba3d5, K2p, Cs3d5, C1s, Bi4f5, Pb4f, Si2p and O1s signal are detected (Figs. S2 and S3). After coating, the appearance of Ni2p and Cr2p signals on MCP surface confirms the successful coating (Fig. S4).

3. Results and discussion

Resistance is the basic parameter of the MCP. The resistance is detected by the resistance-voltage (R-V) measurements, shown in Fig. 2. The vacuum is 4×10^{-4} Pa. The resistance (MΩ) of MCP 1 is higher than that of MCP 2 at working voltage controlled from 400 V to 1000 V. Meanwhile, the system's resistances decrease, as the working voltage increase, showing a linear declining resistance-working voltage behavior, which is attributed to a behavior of negative temperature coefficient of glass MCPs. When the voltage increases, a larger amount of joule heat is generated, and then the temperature of MCP rise. Increased temperature leads to the reduction of MCP resistance due to negative temperature coefficient of resistance [21–23]. Meanwhile, working voltage cannot be reduced for MCPs since it determines the gain value of the microchannel plate. In this system, MCP has a relatively good stabilities and repeatable resistance properties at voltage between 400 V and 1000 V, and thus it is expected to be a good electron multiplication system in this voltage range.

The gain is very significant performance parameter to the MCP electron multiplication system. The gain of MCP is the ratio of output current to input current. Here, MCP demonstrate the different gain of high and low states switched by working voltage. The gain of MCP 1 increases from 0 to 48300, and the gain of MCP 2 increases from 0 to 45200, when voltage turns from 400 V to 1000 V (Fig. 3). The gain of MCP 1 is higher than one of MCP 2 throughout this voltage range from 400 V to1000 V. The gain-working voltage curves in the increasing of voltage are similar in MCP 1 and MCP 2, which testified that the gain increase was controlled by the working voltage indirectly.

It's worth to note that the system's input current is essential. The input current of MCP affect the gain effectively on the given condition. Fig. 4 shows the gain-input current curve. An irregular wave characteristics curve can be seen, when the input current is controlled from 5 pA to 70 pA per 5 pA, cathode voltage set as −200 V, screen voltage is 2000 V, and work voltage is 800 V. The gain of MCP 1 system is much larger than that of MCP 2, which also testified that the gain was controlled by the materials.

Considering voltage controlled capability in this MCP system, the working voltage, screen voltage and cathode voltage can be coordinated with input current to investigate the gain regulation of MCP. The below are the boundary conditions in this system: the input current is controlled from 5 pA to 70 pA per 5 pA, cathode