Triode-type MCP-based Compact Ion Detectors for High Pressure Operation in Miniature Mass Spectrometers

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Recent interest in fieldable mass spectrometry applications has spurred a great deal of research into the development of miniature mass spectrometers (MS). In order to retain the major advantage of portability, miniature MS systems typically use small vacuum pumps with relatively low pumping speeds, meaning the miniature MS has to be operated at relatively low vacuum levels (>1e-4 torr).

Conventional electron multiplier based detectors cannot be adapted to operate at high pressure because of ion feedback (IFB) which causes discharges and decreases in S/N. However the reduced dimensions of a micro-channel plate (MCP) detector, which can be less than the mean free path, make it suitable for operation at high pressure. The major source of IFB, which is a peculiar phenomenon of secondary electron amplification, was found to be the creation of ions from residual gas molecules between the MCP and anode. We concluded that controlling ions is more important than suppressing ion generation. In order to realize this idea, we introduced a triode structure to the conventional MCP detector.

A triode-type MCP detector has a mesh anode which is placed between a chevron stack of MCPs and a dynode. A miniaturized detector suitable for miniature MS was prototyped with an outer diameter of 8 mm and a height of 8 mm. It was confirmed that the detector was capable of high pressure operation using a novel bias configuration (MCP-in ≤ dynode < MCP-out < anode). In this mode, the dynode prevents IFB by capturing residual gas ions. The gain of the detector is maintained at 5×10^6 up to 10^{-2} torr without the appearance of IFB.

The prototype detector was also installed in a miniature ion trap system and operated at pressures up to 1 mtorr. The spectral quality and gain were observed to be consistent across the pressure range investigated. For comparison purposes, data was also collected using a conventional channel electron multiplier detector which showed pressure dependent gain response as well as arcing at the higher operational pressures.