Performance Evaluation of Bipolar TOF Detectors Using Lead-Free ALD-Functionalized MCPs Compared to Standard MCPs

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INTRODUCTION

The performance of lead-free MCPs and standard MCPs in a BPTOF detector are compared for the first time.

MCP (Microchannel Plate)

- Enables detection of single-ion events in TOF Mass Spectromtry

Standard MCP Behavior

- Electrical properties and amplification properties are created in the same process of reducing a lead-silicate glass
- Gain evolves with use ("conditioning" or burn-in)
  Increasing voltage required to maintain constant gain over time

Lead-Free MCP Functionalized using ALD

- ALD functional layers control electrical properties and electron emission behavior and can be applied independently
- Designed to operate in a conditioned gain state from initial use and to maintain that performance with use over long periods of time
- Lead-free substrate does not require the existing MCP exemption to be compliant with European RoHS regulations

The electrical and amplification properties of Lead-Free ALD functionalized MCPs can be tuned independently

CONFLICT OF INTEREST

The authors declare the following competing financial interest(s): All authors are employed by Exosens who manufacture and sell MCP-Scintillator-PMT TOF detectors like those described in this work.

METHODS

BPTOF Detector (Bipolar Time-of-Flight)

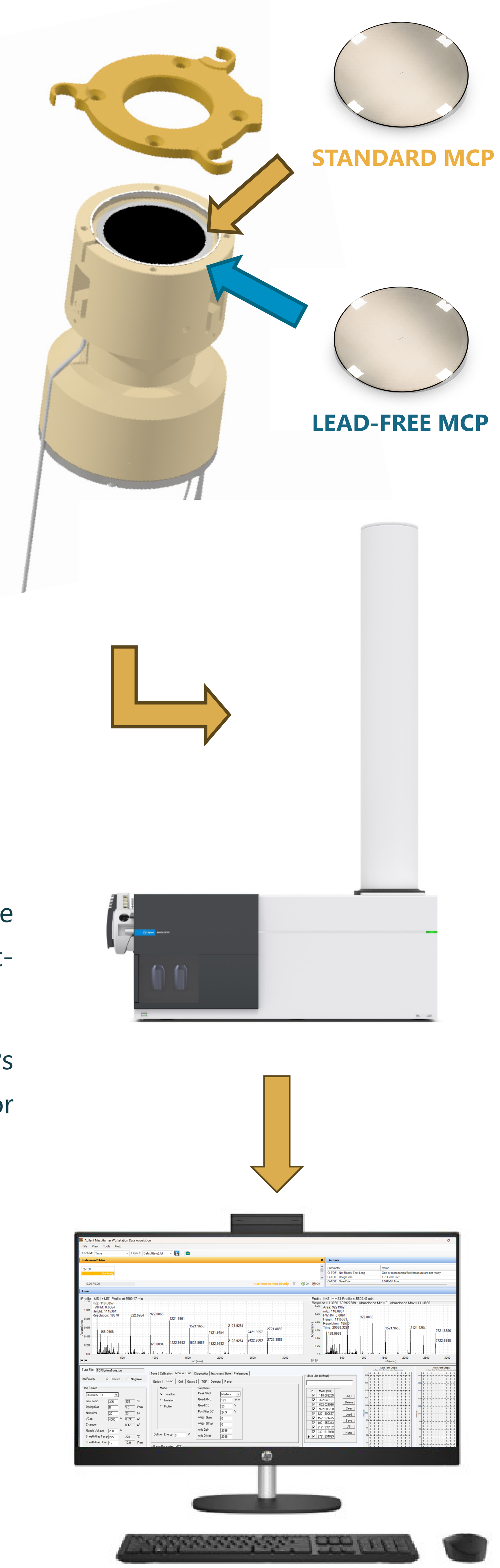
- Generates and amplifies the electrical signal that will provide high-resolution mass spectra

Role of the MCP

- The MCP converts incoming ions into electron cascades, providing the initial detection and gain
- The operating gain is relatively low in this configuration, with the MCP primarily setting the starting signal level
- The MCP defines the initial signal — its stability directly impacts long-term detector performance.

Downstream Signal Processing

- Additional detector elements (e.g., scintillator and photomultiplier) provide the majority of signal amplification
- Final signal characteristics are determined by the combined detector system



Performance Measurements

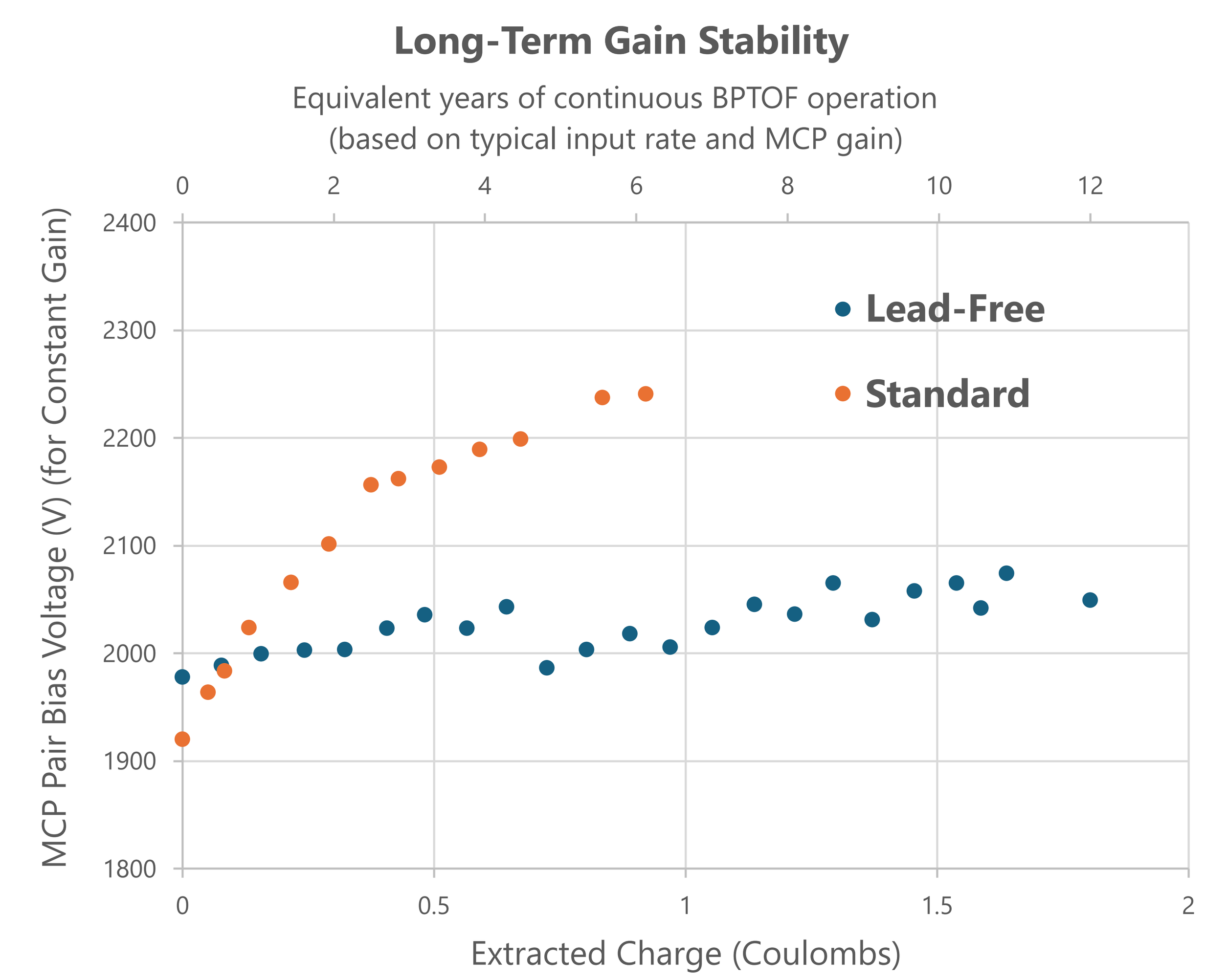
- Mass resolution values and optimal detector MCP voltage values were determined using the instrument tune sequence in the MassHunter software auto-tuning an Agilent 6546 QTOF
- Resolution and tune voltage values for the Standard and Lead-Free MCPs were obtained by installing the MCP under test in a B380 BPTOF detector keeping all other components the same.

Gain Stability Measurement

- To accelerate lifetime evaluation, the MCPs were operated in an MCP-pair/chevron detector configuration for this measurement, increasing extracted charge rate while preserving the underlying gain-drift behavior.
- The values for the years of operation in a bipolar detector axis were calculated from extracted charge values based on the typical gain of an MCP in the bipolar TOF detector (~1000) and a constant input of thirty million ions per second, which is roughly 5pA.

RESULTS

m/z (Da)	Mass Resolution	
	Standard MCP	Lead-Free MCP
118	38,668	38,173
622	68,452	69,644
922	76,510	74,451
1222	80,490	81,737
1522	82,826	82,737
1822	84,148	84,732
2122	87,993	92,554
2422	90,857	90,985



A lead-free MCP can be a direct replacement for a standard MCP, but with dramatically improved long-term gain stability