Overview

Testing of nanofilm functionalized MCP devices is accomplished using the test configuration shown below left, wherein a UV light source (Penray lamp) is projected thru an aperture onto an MCP (electron source) generating photoelectrons through the interaction of UV light with the NiCr metallization. These photoelectrons produce an operation within 0.03C/cm² extracted charge vs. the typical 0.3C/cm², at a higher fraction of initial gain (80% vs 40%) as compared to state-of-the-art MCP devices.

ALD provides the flexibility to engineer, at the sub-nanometer level, functional films to optimize MCP performance in applications such as mass spectrometry (MS).

Introduction

A mass spectrometer (MS) consists of a mass analyzer and a detector - typically a lead-glass based microchannel plate detector (MCP) or channel electron multiplier (CEM). Current lead-glass technologies utilize fiber optic manufacturing processes, which remain fundamentally unchanged since the 1970s. Functionalization of the detector relies on a high temperature hydrogen reduction of the surface film to simultaneously form the conductive and secondary electron (SE) emissive layers. These devices lack the capability to independently optimize mechanical, resistive and emissive properties, which contributes to limited dynamic range, device variability, dark noise and lifetime degradation. This technology restricts MS performance due to gain variation, noise, dynamic range and response time limitations.

Method

ALD is used to precisely control the composition, emissivity, conduction and ion barrier properties of the functional nanofilms. ALD is a low temperature, thin film growth technique that relies on two sequential, self-limiting surface reactions between gas-phase precursor molecules and a solid surface in a moderate vacuum. The self-limiting nature of the reactions precisely and conformally coats high aspect ratio structures (>500:1) and complex, large area, geometries (e.g. MCP) with smooth, dense films. ALD can deposit a variety thin films including oxides, nitrides, metals and combination of these materials in complex nanostuctures. It is possible to achieve layers consisting of high secondary electron yield (SEY), pure materials, at required conductivity to meet timing and dynamic range requirements. The purity and barrier properties of the ALD films can be selected to inhibit the release of ions from the film or bulk material, limiting ion feedback and improving device performance.

Results – Testing Alumina Dynode

A commercial MCP was coated with a nanofilm using the test configuration shown below left, wherein a UV light source (Penray lamp) is projected thru an aperture onto an MCP (electron source) generating photoelectrons through the interaction of UV light with the NiCr metallization. These photoelectrons produce an amplification cascade in the source MCP which provides a well controlled and uniform flux of input electrons for the MCP, under test whose response is measured on the anode. Typical gain vs. voltage response is shown in the middle figure below for a commercial MCP (black) and the Al₂O₃ nanofilm (or D2) functionalized MCP (red) which shows nearly an order of magnitude higher gain due to the engineered nanofilms secondary electron emission response. MCP lifetime (gain stability with extracted charge) is compared in the top right graph below, which depicts significantly less time to gain stability at a higher percentage of initial gain for the engineered nanofilm. Finally, the ion feedback response (graph bottom right) shows an order of magnitude reduction in ion current as compared to the commercial plates.

Results – Magnesia Dynode

MgO has a high dielectric constant (8-10), a wide band gap (7.8 eV) with potential applications as: gate insulator, buffer layer for superconductors and ferroelectrics, and high SEY film for plasma displays. MgO has been deposited via ALD using a variety of precursors. MgO in conjunction with Mg(OH)₂ has also been shown to successfully inhibit the release of ions from the film or bulk material, limiting ion feedback and improving device performance. MgO and Mg(OH)₂ films grown at 225 – 275 °C show nearly an order of magnitude increase in SEY over film grown at 150-180 °C. MgO film thickness of 10-20 nm shows nearly an order of magnitude increase in SEY over film grown at 10-15 nm. MgO thin films were deposited using Trimethylaluminum (TMA) at 105-118 °C direct dose 150cc bottle and Bis(Disecbutylacetamidinate) at 225 – 275 °C direct dose 150cc bottle.

Conclusion

MgO modification of the emission properties of the MCP pore surface has demonstrated significant performance improvements in: gain (~5x times) and lifetime (achieved stable operation within 0.03C/cm² extracted charge vs. the typical 0.3C/cm², at a higher fraction of initial gain ~50%) as compared to commercial MCP devices. ALD is used to precisely control the thickness, composition, emissivity, conduction and ion barrier properties of the functional nanofilms resulting in the self-limiting nature of the surface reactions conformally coating the complex, large area, geometries of MCPs with smooth, dense films. ALD allows for the exploration of a variety thin films: oxides, nitrides, metals and combination of these materials in complex nanostuctures. It is possible to achieve layers consisting of high SEY, pure materials, at required conductivity to meet timing and dynamic range requirements. MCP performance of MgO-based nanofilms has been described, using a novel liquid precursors. Magnesium Bis(Disecbutylacetamidinate), developed specifically for Arradiance. Negative electron affinity materials, such as MgO, are of interest for MS applications due to the high SEY and energy distributions which are independent of the type of incident particle. ALD brings this capability to MCPs and MS allowing for nanofilm engineering to further enhance the surface response to ions.

More generally, application of the nanofilm technology to mass spectrometer (MS) whereby independent optimization of MCP mechanical, resistive and emissive properties, can improve dynamic range, device variability, dark noise and lifetime performance.