The "AGING" Mechanism in Electron Multipliers and Operating Life

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Presented at the 42nd ASMS Conference on Mass Spectroscopy and Allied Topics
May 29-June 3, 1994, Chicago, Illinois

INTRODUCTION

The objective of this study is to determine the primary cause(s) of electron multiplier degradation with use over an extended time, with a view toward optimizing detector lifetime in mass spectrometry applications.

An understanding of the "aging" process in electron multipliers is a necessary precursor to developing a very-long-life mass spectrometer detector. By studying the dynode surfaces of an ETP ACTIVE FILM Multiplier™, we have isolated the major factors influencing the deterioration of electron multiplier performance.

Analysis of the dynode surfaces was performed on a discrete-dynode device; however, these results may be generalized for any type of electron multiplier detector.

TEST CONDITIONS & RESULTS

Tests were carried out on a 20-stage ACTIVE FILM Multiplier™ operated in a vacuum of 3x10-6 mbar, pumped by a 'Diffstak' diffusion pump. A constant current of N2 ions was directed into the multiplier aperture and the multiplier high voltage dynamically adjusted so that its gain was held to a constant 1x107 over the 20 hour test. The multiplier output current was held constant at 25μA.

After accelerated aging for 20 hours, the multiplier was disassembled for analysis. Each dynode of the multiplier was numbered to identify its position in the chain, beginning with the dynode closest to the multiplier input.

Using computer simulation techniques to closely model the operation of a discrete-dynode multiplier, we can estimate the total dose of electrons incident on the surface of each dynode (figure 3).

As would be expected, the dynodes closer to the output of the multiplier are exposed to much greater doses of secondary electrons than those dynodes closer to the input. The shape of the curve in figure 3 is very close to that seen in figure 1.

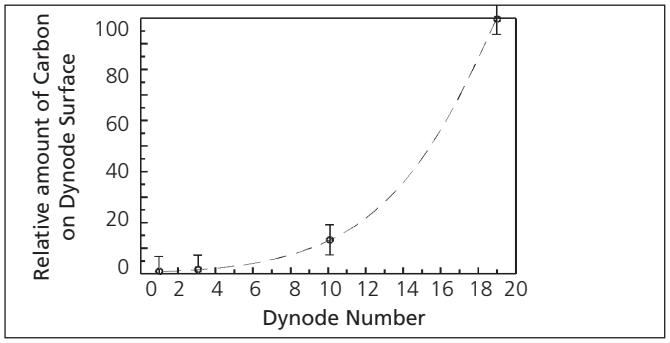

Figure 1. Relative level of carbon contamination on dynode surfaces (dynode #20: last dynode).

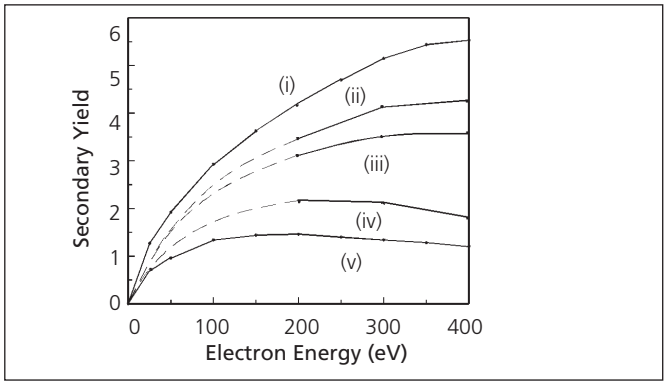

Figure 2. Secondary electron yield from (i) a new dynode surface of an active film Multiplier and those of an aged multiplier (ii) dynode 3, (iii) dynode 10, (iv) dynode 19, and (v) the surface of a specially prepared heavily contaminated dynode covered with a very thick carbon layer (for comparison).

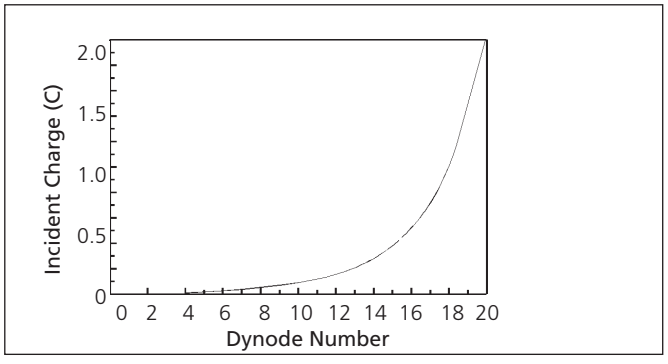

Figure 3. Theoretical calculation for the total electron dose incident on each dynode.

ETP electron multipliers

Analysis of the dynode surfaces was conducted using Auger Electron Spectroscopy (AES). The main contaminant observed on the dynode surfaces was carbon. Contaminant levels increased dramatically on the dynodes nearer to the output end of the multiplier (figure 4).

All the dynodes of the multiplier were exposed to the same environment for the same time interval. The only difference between the dynodes is the dose of secondary electrons they received during the accelerated aging process. This leads us to conclude that the dose per unit area of secondary electrons irradiating the dynode surface is the dominant factor governing the rate at which the dynode surface is contaminated.

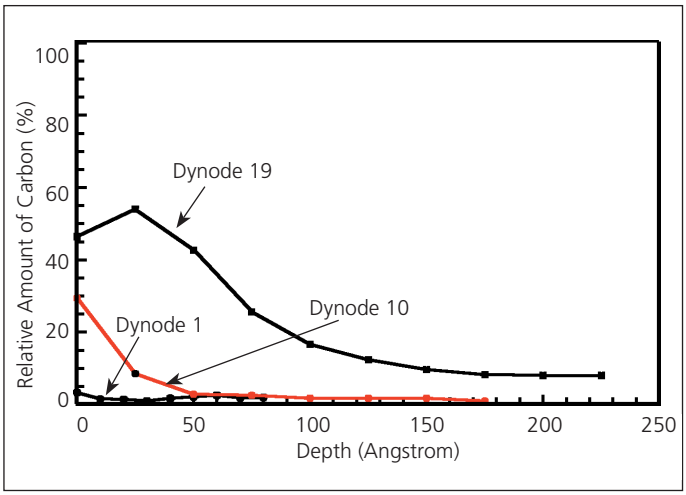

Figure 4. Depth profiles, taken using Auger Electron Spectroscopy (AES), of the relative amount of carbon contamination on the dynode surfaces of a heavily used multiplier. Dynode 1 corresponds to the first dynode and dynode 19 is the near output.

CONCLUSIONS

- The amount of carbon deposited is directly related to the total accumulated dose of electrons per unit area on the dynode. (Not simply the time the multiplier is exposed to the environment in the vacuum chamber, even though the vacuum environment plays a major part in determining the overall life of the detector).

- Incident secondary electrons on the dynode surface cause a carbon in the residual gas to become bonded to the dynode surfaces, reducing the secondary yield. (This is a process very similar to electron beam stitching, where the presence of incident electrons is used to facilitate the adhesion of molecules to a surface, and would account for the extreme difficulty of cleaning a contaminated multiplier.) Figure 4 shows a depth profile of the surface layer of a heavily contaminated dynode. Note the oxide layer, still intact, buried beneath a thick layer of carbon contamination.

- Since the process of aging is directly related to the total accumulated charge of electrons per unit area on a dynode surface, an obvious way of increasing the useful life of a multiplier is to increase the surface area of the dynodes. This spreads the electron dose out over a larger area, reducing the accumulated charge per unit area on the dynodes. This is particularly true for the dynodes in the latter third of the dynode chain where the secondary electron currents are much larger.

The increased life of ACTIVE FILM Multipliers™ seen in mass spectrometry applications can in part be attributed to their relatively large surface area (>1000mm2) compared to 100-150 mm2 for a standard Channel Electron Multipler (CEM).

ETP electron multipliers

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