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A1_4 MCPs as hypervelocity impact detectors

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Abstract

In this paper we describe the current state of near-Earth environment dust models and suggest a method for measuring dust in the nanometre regime using a Microchannel Plate (MCP) based detector. The design for a novel detector and its possible applications are discussed.

Introduction

The near-Earth environment contains a substantial dust population including many very small dust particles, or nanometeoroids [1]. Currently data about this dust population comes from in-situ measurements and from statistical models such as the "Grün" interplanetary flux model [2] which is often used to calculate the dust flux at 1 AU. Despite the abundance of nanometre regime particles, current models have only been confirmed to the micrometre scale [3].

Previous Impact Detectors

Dust in low Earth orbit (LEO) has previously been detected by instruments using aerogels or free-standing foil plates, both of which require returning to Earth for analysis. Due to the nature of these detectors very small particles did not register impacts, for example, the free-standing foils, which must be of a certain thickness to support their own structure, are too thick to be penetrated by nanometeoroids.

An experiment flown on the International Space Station (ISS) featured several microchannel plates (MCPs) [4] covered with a thin (~60nm) layer of Aluminium foil. This experiment was initially intended to look at the thermal properties of filmed MCPs but when the foils were returned to the ground and inspected under a scanning electron microscope multiple impact features were seen [1]. These impact features were smaller than any previously seen in dust experiments making the filmed MCPs the most sensitive dust detector ever.

Model for a Novel Detector

The drawback of the filmed MCP detector described above is that, as a passive system, it still requires retrieval for analysis. If the dust models are to be confirmed and extended an active detector must be designed so it can be flown on unmanned missions.

The MCP detector above is the base for the novel detector proposed here. The filmed MCP is such a sensitive detector because it allows the film to be extremely thin as the MCP supports it. We suggest covering the MCP in 40nm Aluminium film as this is commercially available. For the detector to become an active system there must be some signal generated that can be read by a computer and transmitted back to Earth. MCPs are already used in space instrumentation as electron multipliers, that is, when a single electron enters one end of a channel it starts a cascade and many electrons are produced at the other end of the channel. We suggest using this effect to in conjunction with a nanofilm to produce and electrical signal from an impact.

To implement the new detector described above a detector body layout has been designed by the lead author, a sketch of which is provided in Figure 1.

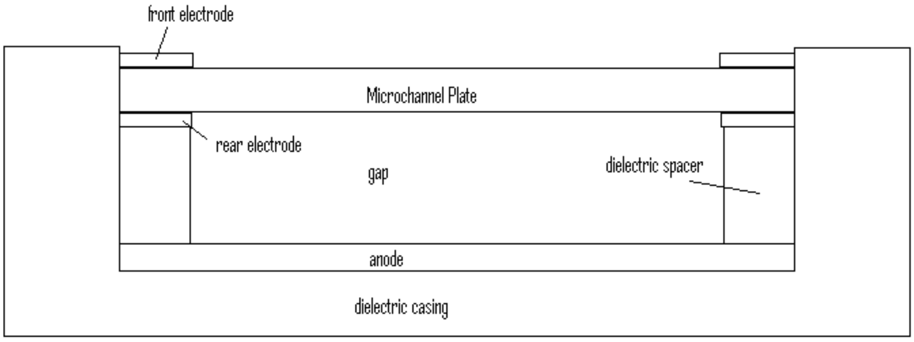

Figure 1: *Proposed MCP detector body design. For an introduction to MCP operation see [3].*

It can be shown by using the McDonnell and Sullivan formula (1) [5] that the minimum particle size we can expect to detect with this setup is ~19nm at a velocity of 20 km s^{-1} (avg. speed for micrometeoroids), an order of magnitude better than previous detectors [3]. This means that the suggested detector would be the most sensitive active dust detector ever flown by at least 1 order of magnitude.

$$\frac{F_{max}}{d_p} = 1.272 d_p^{0.056} \left(\frac{\rho_p}{\rho_{Fe}} \frac{\rho_{Al}}{\rho_t}\right)^{0.476} \left(\frac{\sigma_{Al}}{\sigma_t}\right)^{0.134} v^{0.806} \qquad (1)$$

where d_p is the diameter of the impacting particle, ρ_p is its density, ρ_t is the density of the foil and ρ_{Fe} *and* ρ_{Al} are the densities of Iron and Aluminium;σ_{Al} and σ_t are the tensile strengths of Aluminium and the target material respectively and v is the velocity of the impactor.

It can also be shown that an impact of this size would create ~50 000 electrons due to plasmarization of the Aluminium film [3]. This is considerably more than an x-ray event would cause which is what MCP detectors normal register, meaning these nanometeoroid would definitely be detected.

Conclusions

As MCP's are currently successfully used as x-ray detectors, this technology will definitely have the capability to function as a hypervelocity impact detector and already has proven space heritage. The calculations above (1) have shown that if this technology is applied to impact detection instead it would allow detection of smaller particles than ever before, producing data for regimes smaller than the current µm limit on models, thus extending our knowledge of the near-Earth environment. As the detector proposed is small and lightweight, there is also the possibility of this being an addition to almost any mission vastly increasing the sample area.

References

[1] **Carpenter, J. D., T. J. Stevenson, G. W. Fraser, J. C. Bridges, A. T. Kearsley, R. J. Chater, and S. V. Hainsworth** (2007), Nanometer hypervelocity dust impacts in low Earth orbit, *J. Geophys. Res.*, *112*, E08008, doi:10.1029/2007JE002923.

[2] **Grün, E., H. A. Zook, H. Fechtig, and R. H. Giese** (1985), Collisional balance of the meteoritic complex, *Icarus*, *62*, 244–272

[3] **Carpenter, J.D.**, Microchannel Plates In Astronomy and Planetary Science, PhD Thesis, Mar 2006

[4] **Wiza, J.L.,** MICROCHANNEL PLATE DETECTORS**,** Nuclear Instruments and Methods, Vol. 162, 1979, pages 587 to 601

[5] **Gardner, D.J., McDonnell ,J.A.M, and Collier I.** Hole growth characterisation for hypervelocity impacts in thin targets (1997), *Int. J. Impact Engng,* Vol. 19, No. 7, pp. 589~602,