The Micro Sphere Plate: A novel electron multiplier

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Introduction

A Microsphere Plate (MSP) is a compact electron multiplier with temporal and spatial resolving power. It consists of glass beads 20 to 100 mm in diameter, sintered to form a thin, porous plate. The surface of the glass beads is covered with partially conductive, secondary-electron emissive material. The two faces of the plate are coated with conductive electrodes. Voltage applied between the two electrodes enables secondary electron multiplication in the gaps and passages between glass beads (See Fig.1).

MSPs are used in vacuum systems for the detection of charged particles. Applications include particle-imaging, time-of-flight mass spectroscopy, particle counting, ion-beam monitoring, and electron microscopy. MSPs are also used for UV and X-ray imaging and in photomultipliers. MSPs are available in a variety of standard sizes and mounting configurations. The unique manufacturing process of MSPs makes it possible to fulfill almost any requirement for non-conventional size or shape.

MSP Operating Principle

The MSP is coated on both sides with conducting electrodes. A voltage of several thousand volts between the two electrodes establishes an electric field with an average direction normal to the faces of the plate. Primary electrons, ions or photons hitting the lower potential face of the MSP produce secondary electrons. These secondary electrons are accelerated by the electric field through the passages around the glass beads until the electrons hit a surface of a glass bead. In the collision more secondary electrons are generated. Each collision multiplies the number of electrons so that a large number of electrons emerge from the output side for each primary electron. The strip current, namely the flow of charge on the partially conductive surfaces of the glass beads, compensates for the electric charge drawn by the secondary electron emission process. The operation principle of MSPs is similar to that of Microchannel Plates (MCPs) except that the tortuous passages among the glass beads strongly inhibit ion feedback. Thus MSPs can operate at lower vacuum and provide higher gain.

MSP Characteristics

Vacuum requirements

MSPs operate in a wide range of vacuum conditions, from 10^{-4} to 10^{-12} Torr. Ion feedback noise is not observed even under poor vacuum conditions.

Thickness

Single thickness (0.7 mm) MSP is suitable for analog measurements. It is also suitable for the measurement of pulses that include several particles (Time of flight mass spectrometry). The maximal operating voltage for a single thickness MSP is 3.0 kV. For pulse counting and for single particle detection, double thickness (1.4 mm) MSP is used. The maximal operating voltage for a double thickness MSP is 3.5 kV.

Amplification

Current amplification exceeds 10^6 and 10^7 for single and double thickness MSPs, respectively (See Fig. 2). At fixed voltage, the output current is generally a linear function of the input current. High output current, exceeding 10% of the strip current, results in gain saturation and deviation from linearity (See Fig. 3).

Pulse counting

For pulse counting applications and single particle detection, double thickness (1.4 mm) MSPs are preferable. Gain saturation in the passages among the glassbeads results in a well-pronounced peak in the output pulse height distribution (PHD), as shown in Fig, 4. The Pulse Height Ratio (PHR), defined as the peak FWHM divided by the peak value, is about 55% at bias voltage of 3.2 kV [Ref. 1, 2]. The noise PHD at 3.2 kV is exponential, with an average noise pulse charge of about 2 pC. At this voltage, the average signal pulse charge (for a single incoming electron or photon) is about 15 pC. The width of the pulses is less than a nanosecond. Time resolution of less than 200 psec can be achieved.

Resistance

The resistance of single thickness MSPs ranges from 0.5 to 1.5 GigaΩ cm, whereas the resistance of double thickness MSPs ranges from 1.0 to 4.5 GigaΩ cm. The resistance is a decreasing function of the bias voltage and the temperature.

Aging

MSP aging causes gain reduction when operating at fixed voltage for a long time. Typically the gain is reduced to half its initial value after accumulated output charge of about 0.01 C/cm^2 emerges from the MSP. Fixed gain may be maintained for long periods by incrementing the MSP voltage.

Detection efficiency

MSPs are relatively insensitive to the incident angle of the detected particles (See Fig. 5). The incident angle is measured with respect to the MSP normal. No change in the PHD is observed at incident angles within this range [Ref. 1, 2]. For electrons, the maximal detection efficiency is obtained at 500 eV, as can be seen in Fig. 6.

Spatial resolution

The spatial resolution of MSPs is about 2 line-pair/mm. When a phosphor screen is positioned next to the MSP, the MSP pulses generate light spots on the screen (See Fig. 7). Single electrons generate 0.4 and 0.7 mm diameter light spots with single and double thickness MSP, respectively. The avarage lateral shift between the incident point of the incoming particle andthe center of the light spot is 100 mm [Ref. 3].

Figure captions

1. Schematics of MSP multiplication chain
2. MSP amplification
3. MSP saturation characteristics
4. Double thickness MSP: Signal and noise PHD at 3.2 kV
5. MSP Sensitivity vs. Incident Angle of UV photons.
6. MSP sensitivity to electrons
7. Single electrons hitting an MSP, as seen at the phosphor screen

References

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