

Application Note Number 50: Advantages of an Electron Multiplier

Abstract: The Extorr electrometer is an extremely sensitive ion current measuring device. An electron multiplier can build on that sensitivity in two different ways. The electron multiplier can improve speed of data acquisition and ultimate sensitivity of the system. .

An electron multiplier is a device that transforms the charge of an ion into a swarm of electrons. It is a bent channel lined with leaded glass. A high negative voltage is placed on the funnel end, as shown in the figure below. It must be operated in a high vacuum and uses the following steps to transform a single ion into a swarm of electrons.

1. The positive ion is attracted to and hits the funnel portion.
2. Secondary electrons are accelerated into the bent channel by the bias field
3. Secondary electron emission produces gain at each electron collision with the glass wall
4. The resulting swarm of electrons is collected by the same Faraday cup previously used to collect the ions. Typical gain is about 10,000 to a million.

The immediate advantage to the electron multiplier is that we now have 10,000 times the charges to detect in our electrometer. This means that we need to dwell (read that as current integrate) for 1/10,000 of the time to achieve the same signal to noise ratio based on thermal or Johnson noise. This is not exactly true, since the multiplier itself adds a dark current to the noise, but it is close. For measurements which must be taken rapidly, this current multiplication is a great advantage.

Does the 10,000 gain yield a 10,000 gain in sensitivity? The answer to this is no. The sensitivity is ultimately limited by the shot noise due to collecting discrete charges in finite times. The uncertainty in collecting N ions in a given time interval is \sqrt{N} . So, practically speaking, the multiplier gives no more than a 100 to 1000 increase in sensitivity.

Here are several disadvantages to the multiplier. Unlike the Faraday cup, the multiplier has a finite lifetime. It also requires a good vacuum to operate. Operation at pressures above 10^{-6} torr decreases the useful lifetime of the multiplier. The multiplier gain must be calibrated against the faraday cup current and this calibration must be done throughout the lifetime of the multiplier. Multiplier gain can only be maintained by increasing the high voltage on the multiplier. The multiplier's lifetime has expired when it can no longer achieve the required gain at the maximum multiplier voltage setting.

Finally, all ions do not produce secondary electrons equally. In general, the higher the mass, the lower the multiplier sensitivity and this too depends on the magnitude of the multiplier voltage.

