Poor Man's Faraday Cup*

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Frequently, the need arises for the measurement of the beam current in an electron microscope. For good quantitative analysis with either energy dispersive or wavelength dispersive spectrometers, the beam current is essential. The value of the beam current is used in quantitative microanalysis programs to equilibrate the production of X-ray generation between an unknown sample and a known calibration sample, i.e., a standard. Measurement of the beam current over time can also be quite helpful in determining problems with instrument stability. The following is a description of two very inexpensive methods for making a Faraday cup for measuring beam current in an SEM. It assumes that the microscope has a specimen current meter.

In a simplistic description, a Faraday cup can be described as a "Black Hole" for charged particles. What goes into the Faraday cup does not come out. In reality, it is a collector for all of the charges created due to the incident primary beam, which includes the primary electrons themselves, backscattered electrons, secondary electrons, and photoelectrons generated because of the generated X-rays striking the inside walls of the cup. The design of a good Faraday cup is such that the probability that any of these charges escaping and not being collected is very small. To do this, the entrance hole diameter for the primary electrons should have a small diameter and the point at which these induced charges are produced should be a long distance away, i.e., $d/l << 1$.

Design 1

Take a small block of aluminum (any metal) and drill a hole about 1-1.5 mm diameter relatively deep (5 mm or more). This metal block can be an SEM stub or the sample itself, if it is conducting and makes good electrical contact with the microscope's specimen holder. Select a Pt or Mo aperture with a suitable diameter hole. Apertures as small as 5 µm are available from any of the microscopy supply houses, but a 30-50 µm diameter will suffice.

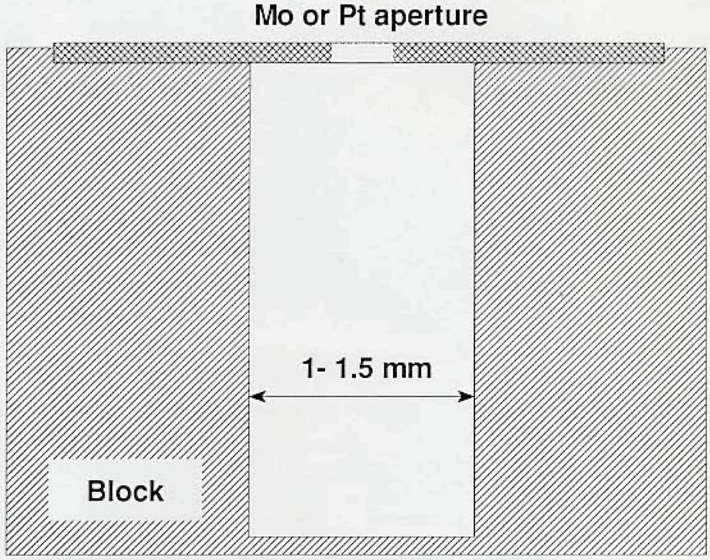

Figure 1: Schematic diagram of "Poor Man's Faraday Cup." Apertures are typically 2 or 3 mm in diameter. A 30 µm aperture with a 5 mm deep hole gives $D/L = 0.006$/

Drill a seat for the aperture (2 or 3 mm diameter) in the block and silver or carbon paint it in place (Fig. 1). a 1/8" end mill tool seats a 3 mm diameter aperture very nicely. With the small D/L ratio of this block, essentially all of the secondary, backscattered, and photoelectrons that are generated will be collected at the inside surfaces of the cup. In the SEM image mode, the hole should look black. Tilting his hole relative to the sample normal by a degree or two insures the capture of most of the electrons because of the strong forward scattering of the backscattered electrons at large tilt angles. In spot mode, with the beam inside the hole, the current that is measured with the specimen current meter will be the beam current.

Design 2

Another acceptable way to make a Faraday cup is to drill a very small wire size hole in the Al block relatively deeply. The smallest wire size drill that our machinist owns has a 0.0135" diameter (.34 mm). Tilt the hole as above. Although a much deeper hole must be drilled to obtain a D/L similar to the first design, a ¼ - ½" deep hole will suffice if the hole appears dark in the SEM. This is a common design for TEM sample holders in order to measure the beam current. In this case, the sample rod is isolated from ground and the absorbed current in the hole is measured with an electrometer.

Uses:

Now that you have the beam current, you can put this parameter into your X-ray microanalysis software package. Record the beam current for your calibration standards and unknowns. The software will make a calculation to adjust for differences in spectra recorded at different beam currents. Standardizing your measurements with a particular beam current is an excellent idea.

You can also use this setup to measure the stability of your microscope. Measure the beam current before and after collecting a typical spectrum. If it changes significantly in the time that you collected data, consider calling the service engineer.

I have also used a variation of Design 1 to measure ion beam current densities in a low energy, ion implantation system. In this system, the beam was spread out uniformly over an area with a diameter of about 12 mm. The aperture was at ground potential and isolated from the block by a thin insulator. With the beam entered over the aperture, the current density is the measured current collected in the block divided by the area of the hole, A. If $1/A = 10$, 100 or 1000 cm^{-2}, then the current density is given by moving the decimal point of the current measurement by 1, 2, or 3 places to the right. For my application, an aperture hole of 1.13 mm gave $1/A = 100\ cm^2$. ■

* Or "Poor Woman's Faraday Cup", as the user's gender dictates.