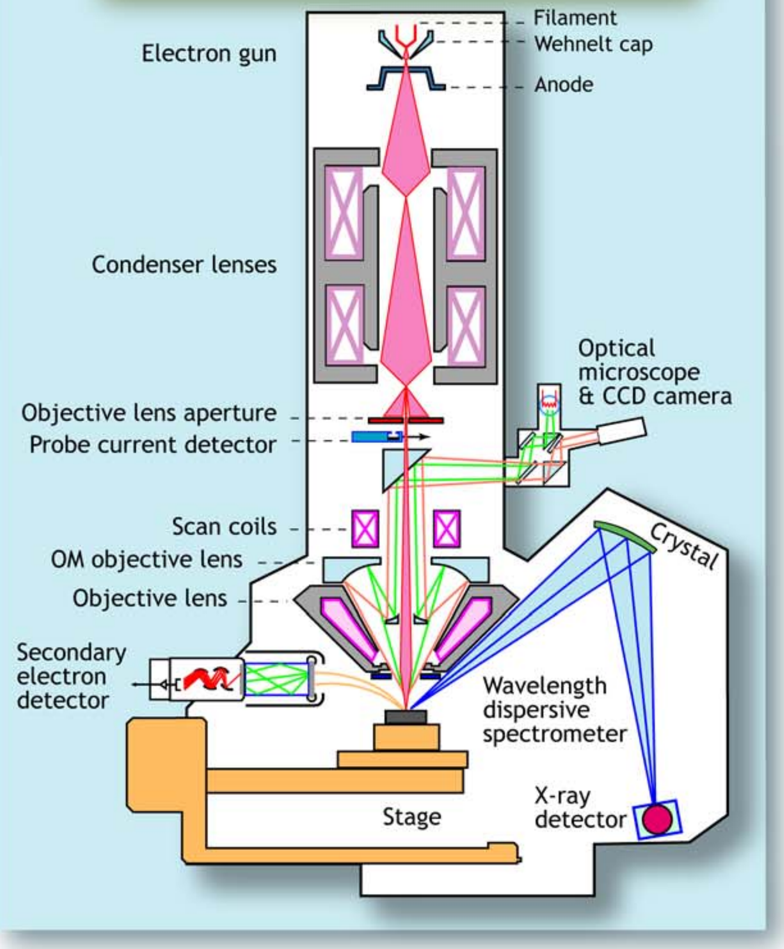
# WDS vs EDS

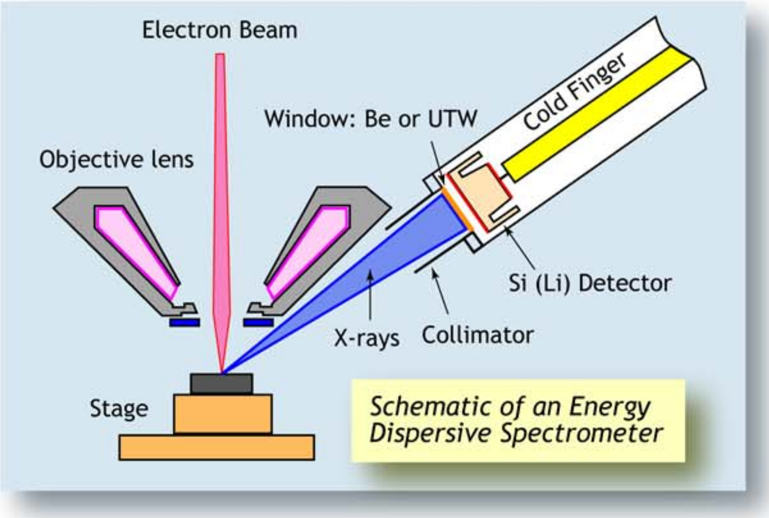
Electron microprobes (also referred to as electron probe microanalyzers or EPMA) have been around for many decades. They differ from scanning electron microscopes in that they are configured with wavelength dispersive spectrometers (WDS).

Each element produces a unique set of characteristic X-rays when bombarded with electrons. Each X-ray will have a specific energy and wavelength. Energy dispersive spectrometers (EDS) sort the X-rays based on their energy; while wavelength dispersive spectrometers (WDS) sort the X-rays based on their wavelengths.

WDS systems use X-ray diffraction as the means by which they separate X-rays of different wavelengths. The spectrometer consists of an analyzing crystal and a detector. Those X-rays that hit the crystal and diffract will enter the detector. Whether an X-ray photon will diffract depends on its wavelength, the orientation of the crystal, and the crystal's lattice spacing. Only X-rays of a given wavelength will enter the detector at any one time. To measure X-rays of another wavelength, the crystal and detector are moved to a new position. Since a specific WD spectrometer can measure only one X-ray wavelength at a time, it is important that a WDS system has an array of spectrometers in order to work efficiently. Electron microprobes typically have up to five WD spectrometers, allowing them to measure five elements simultaneously. Each spectrometer typically has between two and four analyzing crystals, each with a different lattice spacing, because each type of crystal can diffract only a given range of wavelengths.

*Schematic of an Electron Microprobe with a Wavelength Dispersive Spectrometer*



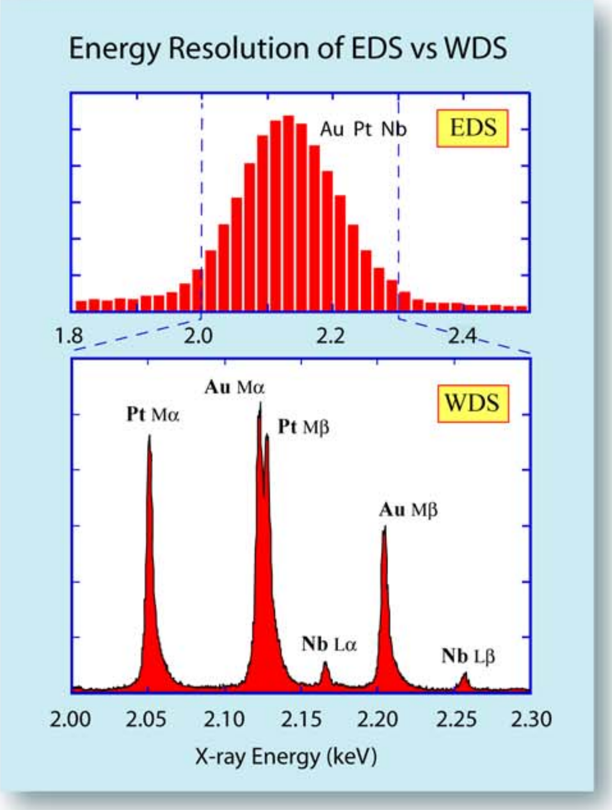


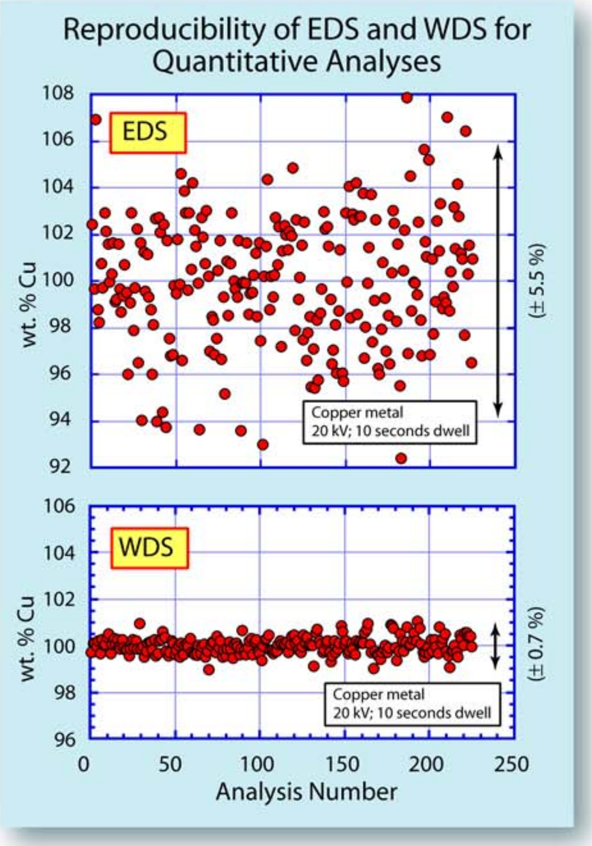
*Schematic of an Energy Dispersive Spectrometer*

Energy dispersive spectrometers (EDS) work on a completely different principle than WDS. The central component of an EDS system is a solid-state detector, consisting of a semiconductor. As each X-ray photon hits the detector, a very small current is produced by knocking out electrons from the semi-conductor. Each electron ejected from a silicon electron shell consumes about 3.8 eV of energy from the X-ray. Therefore an X-ray photon starting with 7,471 eV of energy (Ni $K\alpha$) will produce a current of about 1,966 electrons. By measuring the amount of current produced by each X-ray photon, the original energy of the X-ray can be calculated. An EDS spectrum is essentially a histogram of the number of X-rays measured at each energy.

There are advantages and disadvantages to both EDS and WDS systems. One of the main advantages of the EDS system is that the user can quickly collect a full spectrum with the push of a button. Using a WDS system the user must use multiple spectrometers to get the entire periodic table, and has to mechanically scan the spectrometers from one limit to the other.

However, the most significant difference between WDS and EDS systems is their energy resolution. A Mn K$\alpha$ X-ray line on an EDS system will typically be between 135-150 eV wide. On a WDS system, this same X-ray line will only be about 10 eV wide. This means that the amount of overlap between peaks of similar energies is much smaller on the WDS system. To the right is a comparison of spectra collected from a Pt-Au-Nb alloy on a WDS compared to an EDS system. On the WDS system six X-ray lines can be identified, with an overlap occurring only between the Au M$\alpha$ and the Pt M$\beta$ lines. It would be very straightforward to identify the elements present and to quantify their abundance without resorting to an elaborate deconvolution procedure. On the EDS system, the broad nature of the X-ray lines mask each other and they appear to be a single peak. It would be impossible to reliably deconvolute this peak into the individual X-ray lines.


Energy Resolution of EDS vs WDS


Reproducibility of EDS and WDS for Quantitative Analyses

The second major problem with EDS systems is their low count rates and poor reproducibility. Typically a WDS system will have a count rate about 10x that of an EDS system. There are some EDS systems that can collect at a higher count rate, but they sacrifice even more on the energy resolution — their peaks are even wider.

To the left is a comparison of the reproducibility of an EDS system and a WDS system. The data were collected simultaniously, so the conditions under which they were collected were identical. The plots show that the EDS data had almost 8x the scatter of the WDS data. For serious quantitative analyses, the EDS data would not be acceptable. The spread on the EDS data could be reduced by counting longer, but that would also improve the WDS data.

Another advantage of the WDS system includes a lower detection limit. Most elements on the periodic table can be measured into the 0.01 weight percent range on a WDS system and into 0.1 weight percent range on the EDS system. Also, much better performance can be obtained for light element analyses (Be, B, C, N, O and F) on a WDS system. The count rates will be much better, peak overlap problems will be fewer, and reproducibility will be much improved compared to EDS.