X-Ray Detectors: Present and Future

Don Chernoff, Small World

If you want to collect X-rays on your SEM or TEM you have the choice of using an energy dispersive spectrometer (EDS) or a wavelength dispersive spectrometer (WDS). Which is better? That depends on what you want to do with it.

WDS is much more sensitive and has much higher resolution than EDS. Sensitivity means that WDS has a much lower minimum detection limit for trace elements. WDS can be up to several orders of magnitude more sensitive. This does not mean it is more accurate. Accuracy of analysis can be just as good for EDS as with WDS if the analyst takes the same care in sample prep, data gathering, and standardizing. Sensitivity simply means that WDS can detect much smaller amounts of a particular element than EDS. Why? Because the superior resolution provides much better signal to noise ratio than with EDS. Noise, in this case, is mostly contributed by background radiation from the sample. Because of its superior resolution, WDS can also resolve peak overlaps. If WDS is so wonderful why is it not found in more labs? There are several reasons:

1) It is more expensive than EDS,
2) It is slower than EDS,
3) It is harder to use than EDS.

New software and control systems in recent years have made WDS much easier to use. Some EDS manufacturers have even included WDS operation directly into the EDS software. This advancement should make WDS almost as simple to use as EDS. But reasons 1 and 2 are still with us. WDS detectors still have to mechanically scan a detecting crystal which takes time. WDS detectors are also approximately 2 to 4 times the cost of EDS detectors. EDS has become the popular way to do x-ray analysis for most samples by virtue of its simplicity, low cost, and relative ease of use. But EDS has not replaced WDS. There are still a lot of samples that can only be analyzed by WDS. Lets face it, if you need to completely resolve the titanium L line from the nitrogen K line in a sample containing titanium nitride you will not have much luck with EDS. Similarly if you are trying to determine the concentration of carbon in a steel sample you will not have much success with EDS. These applications need the sensitivity and resolution only WDS can provide.

The past few years have seen the introduction of germanium crystals to replace silicon in EDS detectors. These detectors show an incremental improvement in resolution over silicon. Typical resolution for a germanium detector is 115 eV for the Mn Ka peak Vs about 133 eV for silicon. This additional resolution proves useful for some marginally overlapped peaks but is not a big enough improvement to resolve severe overlaps. Germanium detectors also must be kept colder than silicon detectors which means they have been unable to take advantage of another recent development in X-ray detectors: no LN.

Detectors cooled by mechanical means instead of liquid nitrogen have become quite popular for one obvious reason, you don't have to add LN. For many labs the extra expense is worth the convenience. This is especially true in clean rooms. The first dry detectors used Peltier cooling to achieve near LN temperatures. They are not really dry since they use recirculating water to remove excess heat from the Peltier unit. The water is in a closed loop, however, so no maintenance is required. Newer designs have introduced remote refrigeration units which pump a refrigerant through the detector unit, also in a closed loop. The refrigerator stays on the floor where its vibrationdoes not interfere with the microscope. Peltier cooling cannot get quite as cold as liquid nitrogen so these detectors tend to suffer from increased noise at the low end of the spectrum. Refrigerator designs do not seem to suffer this problem. Neither method seems to get cold enough to be used in a germanium detector, however. Due to the additional hardware required, these cooled detectors will most likely always be more expensive than standard LN detectors.

Most of the improvements in detector design mentioned are evolutionary in nature. It seems there has not been a revolutionary breakthrough in X-ray detector technology since the EDS detector was invented. This may soon change. There is research being done on a new generation of ultra high resolution EDS detectors which may be on the market in a few years. These detectors rely on an extremely sensitive calorimetric device. That is, they detect the minute rise in temperature in a material when it is struck by an X-ray photon. The detection element of these devices are made of superconducting materials and must be operated very close to absolute zero. The hardware to do this is currently very expensive. The benefit of this type of detector is that a resolution of better than 10 eV at Mn Ka is achievable. This order of magnitude improvement in resolution would greatly expand the capabilities of EDS. Just think about it: no more peak overlaps! These detectors could also put WDS detectors into early retirement since they will have as good or better resolution. These detectors are still in the research labs and are predicted to be considerably more expensive than today's detectors. For some application the extra expense can be justified for the improvement in performance. For the rest of us, we can wait for the technology to get better, and hopefully, cheaper. ■

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