# More than One Ever Wanted to Know about X-Ray Detectors Part VII: More Alternate Semiconductors for Detectors

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Where did the term "Energy Dispersive Spectroscopy" come from? In the beginning (that would be about 1965) there was only "x-ray spectroscopy," which meant "wavelength dispersive x-ray spectroscopy." When semiconductor detectors came on the scene there was a possibility of confusion, so the new method had to have a new name. Very soon there were a variety of names, including "nondispersive spectroscopy," "energy analyzer," "pulse height spectroscopy," "semiconductor counter spectroscopy," and "semiconductor x-ray spectroscopy," as well as "Si(Li) [and Ge(Li)] spectrometers." Of course no one was going to try to raise money to manufacture "Si(Li) spectrometers"; they would be laughed at! (This business is only slightly silly.)

About 1972 the term "energy dispersive spectroscopy" was gaining prevalence, and people had started to rename the Bragg reflection spectrometers "wavelength dispersive." There was some resistance because the Si(Li)-based spectrometer does not disperse, it just detects. Semiconductor detectors are energy-sensitive spectrometers. Likewise, Bragg spectrometers do not "disperse" in the same way that a prism or grating disperses visible light, since only one wavelength is reflected at a time. You could say that a shotgun disperses shot, but not a rifle; a crowd could disperse, but not an individual. Bragg spectrometers are "wavelength sensitive" spectrometers. However, the purists lost the battle, and the slightly cockeyed definitions took over.

Last month I discussed small band gap semiconductors and their potential advantages. There are also semiconductors with larger band gaps than silicon and germanium, and a lot of research is being put into them. Wide band gap semiconductors include diamond, silicon carbide, cadmium telluride, gallium arsenide, mercuric iodide, and lead iodide.

The biggest advantage that a wide band gap semiconductor could give to x-ray detection is operation at room temperature. At room temperature even the highest resistance silicon and germanium have leakage current due to thermal ionization of carriers. The forbidden band gap is small enough that some room-temperature electrons can jump it. So silicon and germanium must be cooled to liquid nitrogen temperatures to prevent this. As the band gap gets larger the probability that an electron will jump it becomes less and less, until at band gaps of a couple of electron volts there is no thermal leakage current at room temperature.

As I discussed last month, a large band gap detector will produce less charge when it absorbs an x-ray. This gives more statistical noise and less resolution. On the other hand, a room temperature detector could be made smaller, lighter, cheaper, and more portable than a liquid nitrogen cooled detector. There are many applications in which high band gap detectors would work well.

The only single-chemical-element semiconductor with a wide band gap is diamond. The band gap of diamond is 5.5 electron volts. This is much higher than is needed for a room temperature detector, so the statistical noise is high. Diamond has great electron mobility, however, and successful radiation detectors have been made with it. Unfortunately, carbon is a light element and you need a lot of it to stop your typical x ray. The only diamonds that are perfect enough for x-ray detection are those that are perfectly colorless and transparent. Large, clear diamonds are in great demand for boring applications such as body adornment. Diamond x-ray detectors will probably not hit the market any time soon.

This leaves us with compound semiconductors, a number of which are available. The problem with compound semiconductors is that they are very hard to make perfect. Even though the band gap may be high enough for high resistivity at room temperature, lattice defects, impurities, and surface problems can also induce leakage current. A number of high band gap compound semiconductors have been studied, but most have had leakage current that prevented their use at room temperature. The two that have been useful are mercuric iodide ($HgI_2$) and lead iodide ($PbI_2$). These seem to have a mechanism to self-compensate defects and impurities, and so have high resistivity. Both $HgI_2$ and $PbI_2$ have been used to make good x-ray detectors and will soon make a splash in the marketplace.

In Part VI I mentioned that one way to get a desired band gap is to make an alloy or compound of two or more group IVA elements. For example, silicon and germanium form a continuous series of solid solutions, and the band gaps of their alloys are also continuous between those of the pure elements. Unfortunately a detector made of such an alloy would not have much advantage over one of pure silicon or pure germanium. It would have a lot of escape peaks, though!

An alloy of silicon and carbon would be nice, allowing flexibility to exactly define the trade off between operating temperature and resolution. Of course there are no alloys of silicon and carbon, only one compound--silicon carbide. Silicon carbide is hard to make in a big chunk because it has a high melting temperature and crystal phase transformations between the growth temperature and room temperature. Small wafers of SiC have been made by vapor transport, but they are too low in resistivity to make x-ray detectors.

In conclusion, silicon will continue to be used for most x ray detectors. Germanium is now being introduced as a high-performance option. $HgI_2$ will soon be introduced as a moderate resolution detector for low cost and portable applications. ■

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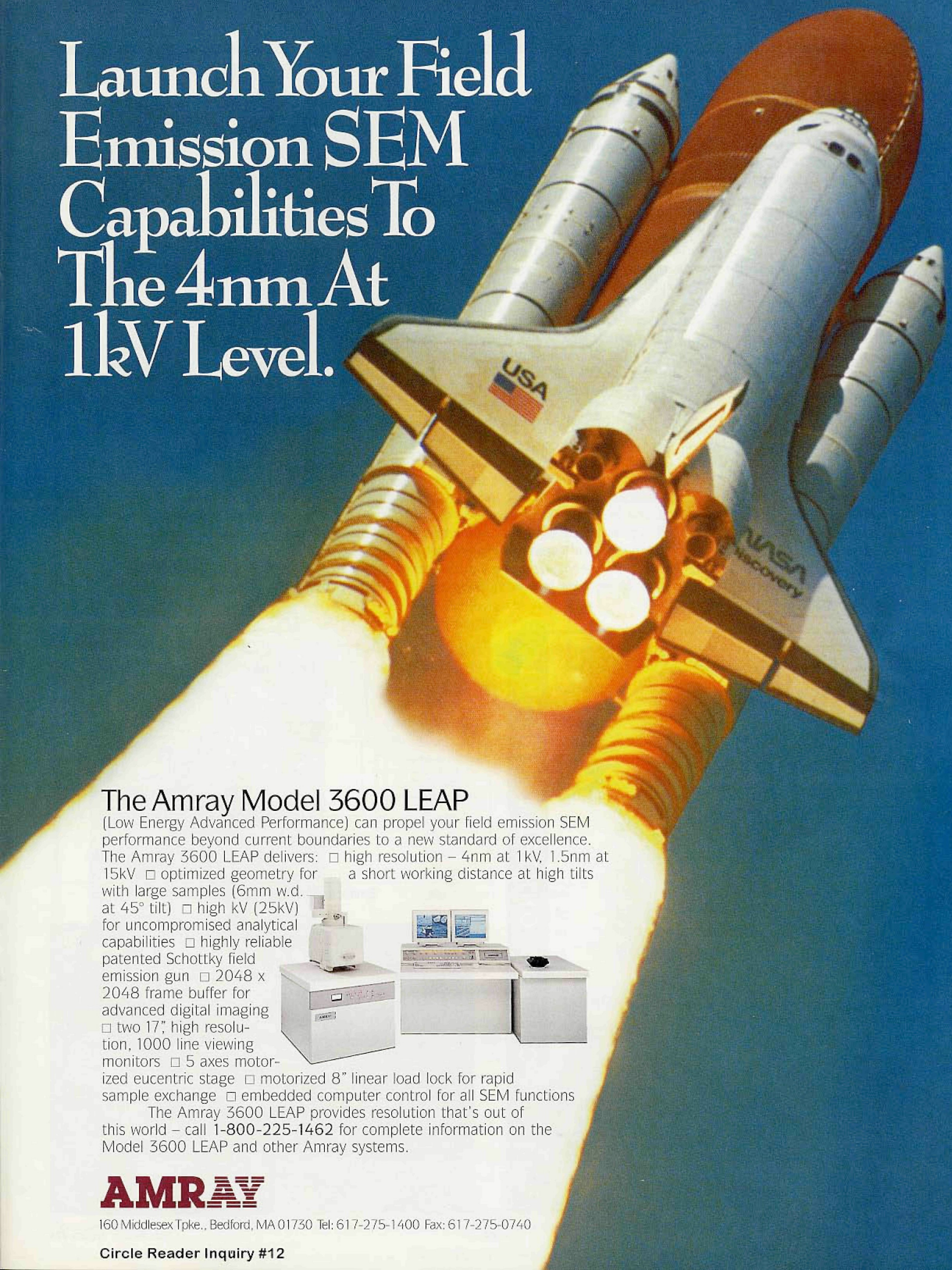


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