Electron Sources: Past, Present, and Future

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The electron source is the most important component of the Scanning Electron Microscope (SEM) since it is this which will determine the overall performance of the machine. The gun performance can be described in terms of quantities such as its brightness, its source size, its energy spread, and its stability and, depending on the chosen application, any of these factors may be the most significant one. The task of the electron gun in a SEM is, in fact, particularly difficult because of the very wide range of operational parameters that may be required, e.g. a variation in probe size of from a few angstroms to a few microns, and a probe current which may go from less than a pico-amp. to more than a microamp. This wide range of operating parameters makes the choice of the optimum source for scanning microscopy a difficult decision.

Historically, the first step up from the sealed glass tube 'cathode ray generator' was the simple, diode, tungsten thermionic emitter. With the addition, in the 1930's, of the Wehnelt control-grid cylinder to form a triode gun, the thermionic emitter was able to reach its theoretical brightness limit and a source size of a few tens of microns[1]. With the relatively poor lenses, vacuums, and detectors that were then available this level of performance was adequate and permitted significant advances to be made in the application and understanding of the instrument itself. However, with the development in 1959 of the Everhart-Thornley secondary electron detector it became clear that the potential of the SEM for high spatial resolution imaging would only be achieved with better electron sources. Two types of improvement were investigated. Firstly, the 'pointed ' filament, developed by Fernandez-Moran and other workers, was designed to minimize the effect of space-charge on the cathode and to produce a smaller source size[2]. Although pointed filaments do have a brightness which is 2 to 3 X higher than that of a conventional tungsten emitter, the fragility of the device, its susceptibility to mechanical and thermal damage, and its consequent shortened life-span, made it unsuitable for most purposes. Secondly, the LaB_6 cathode, originally proposed by Laffery, was turned into a practical reality by the work of Broers and others[3]. The LaB_6 emitter gives an increase in brightness of from 3 to 5 times over a tungsten thermionic emitter, a reduction in source size of typically from 50 μm down to about 5 μm, and only half the energy spread coupled with (in the case of the modern indirectly-heated LaB_6 cathode) a long lifetime (>1000 hours) and stable emission.

The event which took the performance of the SEM to the next level was the development of practical field emission (FE) sources. Field emitters were not new, for example Zworykin and collaborators had used one in the prototype SEM in the 1940's, but two major problems had to be overcome before they were anything more than laboratory curiosities. The first was the provision of practical, reliable, and clean, ultra-high vacuum systems in which to run the emitter. This goal was met by the late 1960s, through improvements in the technology of demountable metal gaskets, bakeable vacuum systems, and in ion and getter pumps, which made the attainment of ultra-high vacuums a relatively routine matter. The second was the development of an electron gun design which would allow the full potential of the field emitter to be realized. Here the work of Crewe and his group provided a design which minimized the effect of gun aberrations on the brightness of the emitter while providing convenient and flexible electron-optical properties[4]. Their design, which forms the basis of most of the current generation of high resolution SEMs, was so effective that just the gun alone could form a probe a few angstroms in diameter containing sufficient current for high resolution imaging and microanalysis. Further they were able to demonstrate that a comparable level of performance could be obtained even at accelerating voltages of only one or two kV, so opening a new field of SEM investigation. Most recently still, the work of Vu Thien Bihn and others had led to the concept of nano-FE tips which achieve a brightness two orders of magnitude higher than that

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COMING EVENTS

✓ June 6/10 '94: **Polymer Microscopy.** (Univ. of Michigan). Ann Arbor, MI. (313)764-8490.

✓ June 7/9 '94: **1994 International AFM/STM Conference.** Natick, MA. Samuel Cohen: Tel.: (508)651-4578, Fax: (508)651-5104.

✓ **LEHIGH MICROSCOPY SHORT COURSES**
June 13/17 '94: **Basic Course:** SEM and X-ray Microanalysis
June 20/24, 94: **Advanced Courses:**
Advanced Scanning Imaging
Quantitative X-ray Microanalysis
Microcharacterization
AFM, STM and other Scanned Probe Mi croscopes
June 20/23 '94: **Analytical Electron Mi croscopy**
For registration & other information, contact Dr. David B. Williams: Tel.: (215)758-5133, Fax: (215)758-4244

✓ June 15/17 '94: **Surface Analysis '94.** (AVS/ASTM). Burlington, MA. Joseph Geller: (508)535-5595.

✓ June 15/17 '94: **First European Microbeam Analysis Workshop.** Helsinki, Findland. Erkki Heikinheimo: Tel: +358-0-4512759.

✓ June 16/18 '94: **Current Trends In Immunocytochemical Protocols.** Geo. Washington Univ. Medical Ctr. Washington, DC. Fred Lightfoot: (202)994-2881.

✓ June 26/30 '94: **10th Annual Molecular Microspectroscopy Short Course.** (Miami Univ.) Oxford, OH.)513)529-2873.

✓ June 21-24 '94: **5th Conference on Frontiers of Electron Microscopy in Materials Science.** Oakland, OH. (513)529-2873.

✓ June 24/25 '94: **IEEE Workshop on Biomedical Image Analysis.** IEEE Computer Scoiety and MAMI Technical Committee. Seattle, WA. Dimitry Goldgof: Fax: (813)974-5456.

✓ June 26/July 1 '94: **4th European Congress of Cell Biology.** Praha, CR. Dr. Z. Drahota, Tel.: 2-4721151, Fax: 2-4712253.

✓ June 27/July 1 '94: **Computer Simulation and Processing of HRTEM Images.** NCEM Workshop & School, Berkeley, CA. Michael A. O'Keefe: (510)486-4610.

✓ July 11/15 '94: **Freeze Fracture Course.** Colorado State Univ., Fort Collins, CO. Eileen Dieperbrock, (303)491-5847.

✓ July 11/15 '94: **41st International Field Emission Symposium (IFE '94).** Rouen, France. Prof. D. Blavette and A. Menand. Tel.: (33) 35 14 66 51, Fax: (33) 35 14 66 52.

✓ July 17/22 '94: **13th International Congress on Electron Microscopy.** Paris, France. Secretariat ICEM 13, Case 243 - Universite Paris VI, 4 place Jussieu, 75252 Paris Cedex 05, France. Tel.: (33)144272621, Fax: (33)144272622.

✓ July 18/21 '94: **INTER/MICRO-94.** McCrone Research Institute. Chicago, IL. Nancy Daerr: (312)842-7100, Fax: (312)842-1078.

✓ July 31/Aug 5 '94: **MSA/MAS Conference.** New Orleans LA. (800)538-3672, Fax (508)548-9053.

✓ August 15/17 '94: **Site-Specific Cross-Section.** Arizona State Univ. Short Course. Tempe, AZ. Sharon Willson (602)965-4544.

✓ August 18/19 '94: **Materials Ultramicrotomy.** Arizona State Univ. Short Course. Tempe, AZ. Sharon Willison (602)965-4544.

✓ August 18/20 '94: **Stereology Course.** Yale Univ. School of Medicine, New Haven CT. Paul Webster: (203)785-5072, Fax (203)785-7226.

✓ August 22/26 '94: **Immunocytochemisty and Cryosections Practical Course.** Yale Univ. School of Medicine, New Haven CT. Paul Webster: (203)785-5072, Fax (203)785-7226.

✓ Sept 8/9 '94: **ImmuonGold Wet Workshop.** Univ of Bristol. (31)-8370-97676 or Fax: (31)8370-15955.

✓ Sept 12/15 '94: **MICRO 94 - International Microscopy and Image Analysis.** London, UK. RMS (U.K.): (0865)248768 Fax: (0865)791237

✓ Sept 21/23 '94: **Microscopy/Photomicrography Workshop.** American Type Culture Collection. Rockville, MD. (301)231-5566.

- REGIONAL MSA/MAS EVENTS -

✓ May 13/14 '94: **Pacific NW EM Society Spring Meeting.** Seattle, WA. Mike Rock: (206)685-7073.

✓ May 26 '94: **Minnesota Society Spring Symposium.** St. Paul, MN. Gib Ahlstrand: (612)625-8249.

of a regular FE source by starting from a source of atomic dimensions[5].

Despite the advances discussed briefly above there is still not one single choice of electron source which is optimum for all applications and instruments. The best electron source for conventional electron beam microanalysis needs quite different properties to those found in a source optimized for ultra-high resolution imaging, or to those for a source designed for application in electron beam lithography, and so the scanning microscopist will continue to have to deal with a variety of electron guns. ■

References

1. M.E. Haine and P.A. Einstein, (1952), Brit. J.Appl.Phys., 3,40
2. H. Fernandez-Moran, (1966), Proc. 6th Int.Cong. on EM, Kyoto, 27
3. A.N. Broers, (1969), J.Phys. E., 273
4. A.V. Crewe at al, (1968), Rev. Sci. Instr. 39,576.
5. Vu Thien Binh and N. Garcia, (1991), J.Phys. I., 1, 605

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