Improvement directions of modern vacuum electron sources

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The progress of vacuum electronics is also driven by a continuous improvement of the emission capability of thermionic cathodes from the beginning of the 20th century till nowadays. In the last century, practically all the cathodes used have been thermionic cathodes, as can be seen in numerous reviews, e.g. [1,2]. A levelling off after 2004, especially of oxide cathode improvement, is mainly due to reduction of research efforts after the decline of the CRT era, but new applications are arising. Besides a reduction of the work function of thermionic cathodes and hence increased useable space charge limited current density, increased lifetime at the operating temperature and an increased emission uniformity over the emitting surface are further requirements. Most promising w.r.t. electron emission capability are Scandate cathodes, either as LAD top-layer Scandate cathodes as prepared by Philips [1], or nanometer size Scandia particle doped Ba dispenser cathodes (SDD) as introduced by BJUT in China [3]. Since lower work function in most cases implies a lower operating temperature and a higher gas poisoning sensitivity, ultra-high vacuum is needed in these electron tubes. Modern applications include microwave tubes, gyrotrons and Tera-Hertz generators with requirements of up to 200 A/cm^2 dc current density (eventually with beam compression). For high resolution electron beams for microscope and e-beam lithography applications high brightness cathodes are required. Currently either Schottky emitters (Zr-O on W), or LaB_6 hairpins or Os/Ru-I cathodes are used. Another type are photocathodes, which are applied in photo detectors e.g. in night vision, in photo-multipliers and as electron injectors in particle accelerators or in free electron masers. Typical materials are semiconductors such as Cs_2Te, Cs_3Sb, K_2CsSb. Improvement directions are high peak current densities in the pulsed beam of > 10^5 A/cm^2 and high beam currents of more than 1 mA. Despite ongoing research efforts, field emission cold cathodes have not been introduced in relevant commercial applications so far. Future perspectives of cathode improvements and promising applications will be discussed in more detail.

1. G. Gaertner, H. W. P. Koops, “Vacuum Electron Sources and their Materials and Technologies”, chapter 10 of “Vacuum Electronics, Components and Devices”, Ed. J. Eichmeier, M. Thumm, Springer 2008
2. G. Gaertner: „Historical development and future trends of vacuum electronics“, J. Vac. Sci. Technol. B, Vol. 30, No. 6, 060801 (2012)
3. Y. Wang et al. (BJUT = Beijing University of Technology), Terahertz Sci. Technol. 4, 50 – 58 (2011)