Extracting the Boersch effect contribution from experimental energy spread measurements for Schottky electron emitters

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For high-resolution work at low beam energies in e.g. SEM, and for HR-EELS, a low energy spread is required. In a practical system the total energy spread is a convolution of an intrinsic contribution from the emission process and a contribution from interactions between electrons that take place as soon as the electrons have left the emitter and travel through the column. The change in axial velocity resulting from these interactions causes a broadening of the intrinsic energy distribution; the Boersch effect[1]. It affects the system resolution via the chromatic aberration of lenses and deflectors. Because of the statistical nature of the Boersch effect it cannot be corrected for. It is therefore valuable to know in what way parameters such as tip and gun geometry and operating conditions affect the Boersch effect to be able to optimize the design and operation for minimal total energy spread.

This paper deals with the Boersch broadening due to electron-electron interactions taking place between emitter and extractor. Calculating the Boersch effect is challenging because of the low initial velocity at emission and the strong potential gradient in the tip vicinity. Experimentally, the correct way to determine the Boersch effect is to deconvolute the measured total energy spread with the intrinsic distribution that can be estimated from the operation parameters. Deconvolution is however sensitive to noise, which is often present in experimental data.

Experimental energy distribution data have been obtained for Schottky emitters of different radii and in different operating conditions with a filter lens retarding energy analyzer[2] behind the extractor. Theory tells us that the shape of the Boersch contribution is in between a Gaussian and a Lorentzian,[3] which can be characterized by a bell shape with two shape parameters [4]. We have extracted the Boersch contribution from the experimental data by assuming the bell function for the Boersch effect and fitting the convolution of the intrinsic contribution and the bell to the experimental data, with the two bell shape parameters as fitting parameters.

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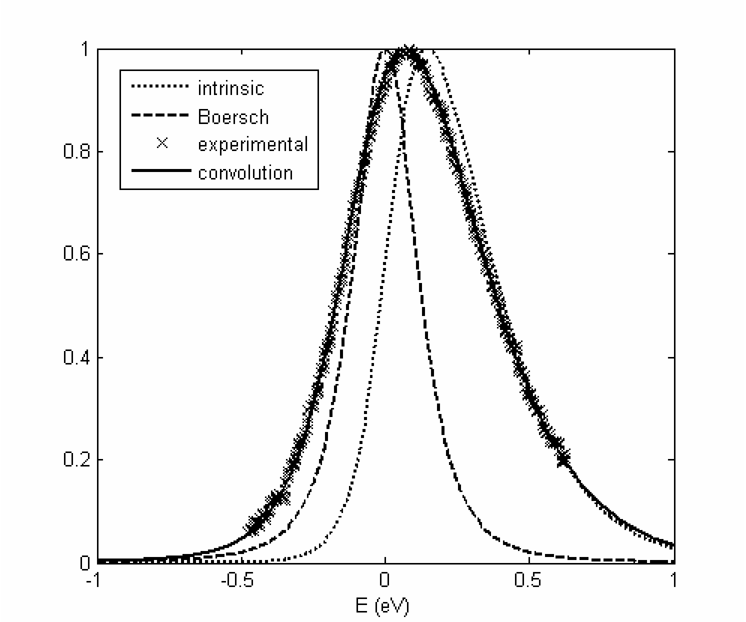

Fig 1. Typical fit result: experimental energy distribution for a Schottky emitter of 1.44 μm radius operated at an angular intensity of 0.5 mA/sr at 1800 K, and the fit result for the convolution of the intrinsic energy distribution and the 'Boersch bell'.

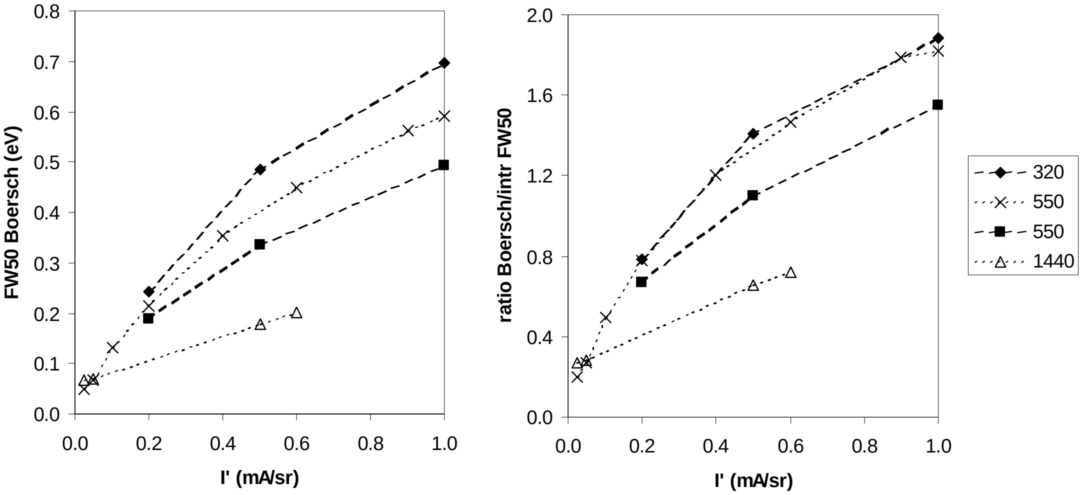

Fig 2. FW50 of the Boersch contribution and the ratio of the Boersch contribution and the intrinsic energy spread for Schottky emitters of different radii (nm) and operated at different angular intensities, at 1800 K. We suspect the different behavior of the two tips of 550 nm radius to be a result of a slightly different tip end geometry.