CMOS-Sensor Calibration for the Measurement of Field Emission Electron Currents

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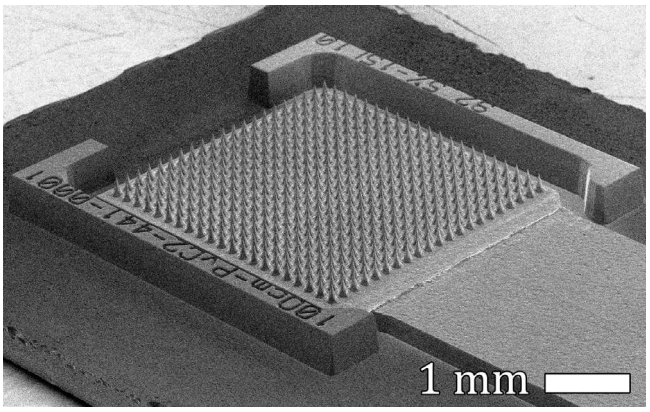
ABSTRACT

The use of field emission electron sources (FES) in X-ray sources or ionization vacuum gauges is still uncommon due to the restricted lifetime of field emission arrays (FEAs), often caused by high current loads. In [1], we showed that the lifetime-limiting effects (degradation) can be significantly reduced by distributing a total emission current across multiple FES-Chips. Similarly, the lifetime of a single FEA-chip depends on the emission distribution across its individual emitters.
However, it was found that the emission current of a FEA is usually distributed very inhomogeneously [2]. To investigate current distribution and its temporal behavior, we developed a CMOS-based imaging method capable of resolving current distributions on FEAs quantitatively over several orders of magnitude by mapping shares of spot signal intensities onto the measured integral current [3].
The mathematical description of the image sensor signal presented in [3], derived from a modified version of Kramers' law [4], has now been extended by a calibration constant C_C, enabling the determination of individual field emitter currents from the raw optical spot signal S_{Raw0}:

$$S_{Raw0} = C_C \cdot t_E \cdot I \cdot U^b \quad \rightarrow \quad I = \frac{S_{Raw0}}{C_C \cdot t_E \cdot U^b}$$

Here, t_E denotes the exposure time of the image sensor, I the cathode current, and U the cathode's extraction voltage or the electron's acceleration voltage respectively. The voltage exponent b is a simplified linear approximation, describing the electron-photon conversion of bremsstrahlung [4], as well as additional absorptive effects [3]. If C_C is known, an emission current I_S can be calculated from S_{Raw0} and compared with the electric emission current I_e. For a n-doped FEA-chip (5-10 Ωcm, Fig. 1a) this comparison is presented in Fig. 1b. The results show that the image-signal-derived current I_S matches the actual emission current I_e with an average accuracy of approximately 2 % over 5 min and a standard deviation of 3 %



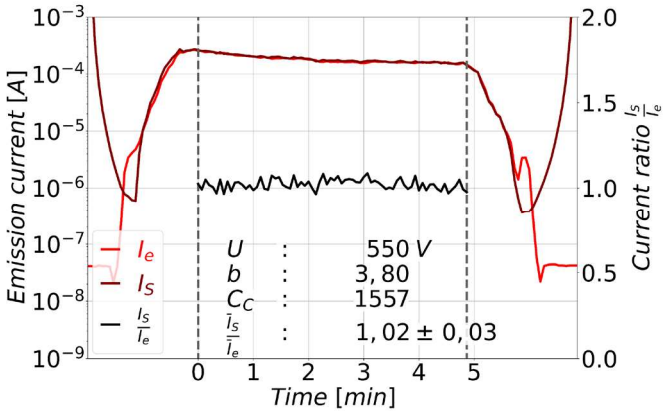


Fig. 1: a) SEM image of the Si-FEA. b) Comparison of the calculated signal current I_S vs the emission current I_e.

References

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