Integrated field emission electron source analysis

The electron beam is used in many fields and devices. The first televisions operated on the basis of an electron beam bombarding the surface of a phosphor screen, and the first computers operated on the basis of electron tubes acting like today's transistors. After the development of semiconductor transistors and the associated industrial revolution, the electron beam is still necessary in science, e.g., in electron microscopy, for examining and imaging materials with very high resolution, in field emission displays, in the generation of X-rays, and even in the travel of spacecrafts for charge neutralization in ion drives. All these new applications of the electron beam require research on the fabrication and characterization of modern electron emitters, thanks to which progress in the development of these devices is possible. To accurately describe and characterize the operation of electron emitters, accurate measurement tools are necessary.

The INFASCOPE project is an international cooperation that focuses on developing innovative experimental methods and measurement procedures aimed at detecting electrons from field emission emitter arrays and single electron sources. Our research is an integral part of the field known as vacuum nanoelectronics, which focuses on the study of production techniques, operation, and applications of field emitters.

The main goal of the project is to understand how the different emission sites on the cathode surface interact with each other and with the residual gas when operating in vacuum. This requires detailed knowledge of the role of individual matrix emitters in generating the emission current and how their characteristics change over time. To achieve the generation of a high-current electron beam, it is important to distribute the emission evenly over the field cathode area. Even with precisely made emitter arrays, the emission phenomenon involves only a few dominant emitters, which unfortunately undergo premature degradation. Even minor changes in the shape of a single emitter can significantly affect its output current.

Currently available experimental methods do not offer sufficient opportunities to observe the operation of field emitter arrays, which makes it difficult to understand the uniformity of emission and the impact of conditioning processes on this uniformity. Therefore, it is necessary to develop new experimental methods that will enable in-depth study and understanding of the behavior of modern field cathodes. Our goal is to improve their performance and create more advanced theoretical models based on the results of these experiments.

In our project, we propose an innovative approach that eliminates the limitations of commonly used indirect electron detection methods. Instead of using digital cameras to observe scintillators bombarded with electrons, we propose using a CMOS sensor to directly measure the current emission current distribution in the emitter arrays. A CMOS sensor is a semiconductor device that generates and records electrons in its structure, allowing signals to be collected from individual pixels in the matrix. Our new method has the key advantage of a large dynamic range that can be adjusted to the exposure time. Thanks to this, we are able to detect multiple emitting sites with different emission currents, enabling near-real-time observation. This innovative approach opens new opportunities for researchers, enabling a precise understanding of the operation and improving the efficiency of field cathodes.