Methodology and control systems for charged particle beams in MEMS microsystems

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High interest in miniature electron beam devices can be observed in the world for a long time. For example, already in the 1950s, miniature stick tubes were developed in which the fragile and difficult to manufacture control grids were replaced with metal rods, which brought many benefits. Although the role of electron tubes, due to the use of semiconductors, is marginal in modern technology, work on miniature electron-beam or ion-beam devices is still being carried out. They usually focus on devices such as mass spectrometers, electron microscopes or systems for selective deposition or removal of material in a microscale. Thus, they concern systems in which the movement of charged particles in a vacuum is crucial for instrument operation and cannot be replaced by semiconductor devices. These works are often based on the use of the MEMS technique, which enables the production of virtually all components of the device, i.e. sources, control and detection electrodes and a vacuum-tight housing, using consistent technological processes. These processes can be easily automated and scaled from single lab units to low-cost mass production. Thanks to this, expensive and stationary measuring instruments (such as electron microscopes, mass spectrometers or X-ray spectrometers) can be supplemented with a cheap portable form. This allows for conducting preliminary analytical tests on site, without the need to secure samples and send them to a distant laboratory. The benefit of this can be seen primarily in the study of hard-to-reach and distant objects, even such as alien planets.

The purpose of this thesis was to develop systems and devices (electronic, micromechanical, automation and measurement systems) and software necessary for commissioning and testing the properties of electron and ion microsystems or their components. The main scientific aspect of the dissertation was to carry out research work aimed at characterizing and improving the operation of MEMS microsystems developed at the Wroclaw University of Science and Technology: a miniature X-ray source, electron microscope, mass spectrometers or their parts, as well as electronic systems constructed by the author.

The dissertation presents dedicated systems and devices, written software and experiments carried out using them, which allowed to assemble, run and characterize MEMS structures of a scanning microscope, selected types of mass spectrometers and an X-ray source.

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