Abstract

Research on new microelectromechanical systems (MEMS) for applications in nanometrology is becoming increasingly attractive. A challenge in MEMS technology is the fabrication of all elements using standard microelectronic processes. A tool enabling the prototyping of electronic nanocomponents is the scanning electron microscope (SEM) with a focused ion beam (FIB), as well as the helium ion microscope (HIM). Micro- and nanostructures are modified through milling, as well as a focused electron/ion beam induced deposition (FEBID/FIBID) processes. FEBID and FIBID technologies are additive material growth techniques – 3D printing at the nanoscale. The activities described in the dissertation focus on the *LabInSEM* concept developed at the Department of Nanometrology, which involves performing electrical, mechanical, and optical measurements of microstructures simultaneously during their modification by a focused electron/ion beam.

The goal of the dissertation was to investigate the phenomenon of field emission from needle-shaped electrodes. Consequently, the first tests of the tips were conducted using an atomic force microscope (AFM). Two methods of prototyping needle probes were applied. First, using a manipulator inside the vacuum chamber of the microscope, microparticles were transferred to the apex of the microcantilever. Then, through FIB milling, the particles were shaped into a tip-like form with a radius smaller than 30 nm. This process resulted in the creation of diamond and GaN tips. These microstructures were tested in topography and electrical conductivity mapping measurements to assess their wear resistance. The transfer technique was time-consuming, so attempts were made to fabricate Pt(C) nanowire tips using the second method – FEBID and FIBID. AFM measurements showed lower mechanical resistance, but the advantage was a one-step and fast production process. A series of studies were conducted to examine the Pt(C) material composition. Its electrical properties were analyzed in terms of post-process treatment.

In the final stage, the focus was on investigating the phenomenon of field emission from nanowires deposited by FEBID and FIBID, and developing a microcantilever deflection detector. SEM with FIB and HIM systems were used to prototype nanowire electrodes from Pt(C) and W(C) composites. Nanostructure growth calibration was performed. To reduce the field emission threshold voltage, efforts were made to create a cathode with the smallest possible radius (about 25 nm) while reducing the distance from the anode (about 120 nm). Nanowire field emitters were directly deposited onto MEMS microcantilevers. Field emission measurements were conducted in vacuum – the observed threshold voltage ranged from 45 to 70 V, depending on the configuration. Using Fowler-Nordheim theory, the effective electron emission area, field enhancement factor, and cathode work function were calculated. The functionality of the microcantilever deflection sensor was then tested – by bending the microstructure with a manipulator, the distance between the electrodes was reduced by 20 nm,

resulting in a 328 nA increase in the average electron emission current. The research conducted contributed to the development of vacuum microelectronics, while also highlighting the potential for creating operational nanowire field emitters integrated with any MEMS devices.

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