Studies and Optimization of Field Emission from Si Nanowires on Micro Tubes

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Black silicon structures on etched pillars have proven to be a reliable and long-term stable geometry for field emission arrays [1, 2]. Recently, linear arrangements of high aspect silicon nanowires have shown improved field emission performance compared to black silicon emitter arrays of same chip area [3]. In this paper, we show that up to two orders of magnitude higher emission currents can be obtained from a cathode array with otherwise the same geometry as a black silicon reference sample. For this new emitter type both the geometry of the emission structures as well as the doping of the substrate material was optimized.

Several field emission cathode samples with an 50x50 array of Si-pillars with a spacing of 50 µm were fabricated. The pillars have an outer diameter of 5 µm, a height of approximately 40 µm and consist of n-type silicon with a resistivity of <0.005 Ωcm and <100> orientation.
In a first step, the pillars were hollowed out to realize thin-walled tubular structures. This leads to a reduced shielding of the individual tips on top of the pillars and a shape more similar to the nanowires described in [3] is obtained. The wall thickness of the tubes at the top is less than 300 nm. The resulting structures exhibit both reduced onset voltage as well as higher emission current compared to the reference black silicon sample from the same material.

A new set of emitters were fabricated with the same thin-walled tubular geometry as described above but using n-type silicon with a resistivity of 1-10 Ωcm and <100> orientation. These emitter type showed even lower onset voltages and higher emission currents, while exhibiting stable emission currents during long-time operation. A detailed discussion of the comparison of the measurement results and on the causes for the observed behaviour will be presented at the conference.

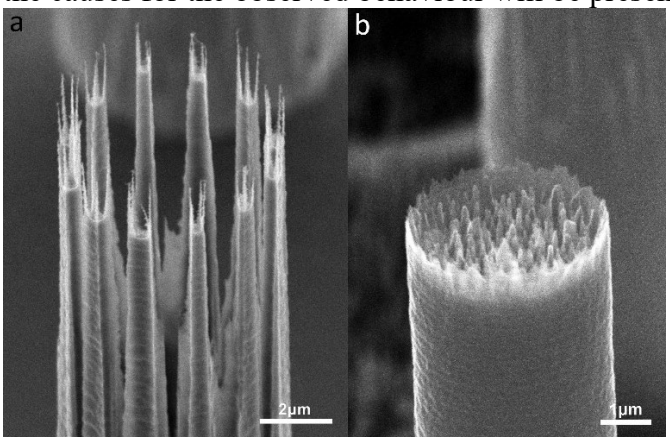

Figure 1. SEM images of a typical emitters (a: Si-nanowire Emitter, b: Black silicon emitter). The emitters are about 40µm high and have a diameter of about 5µm.

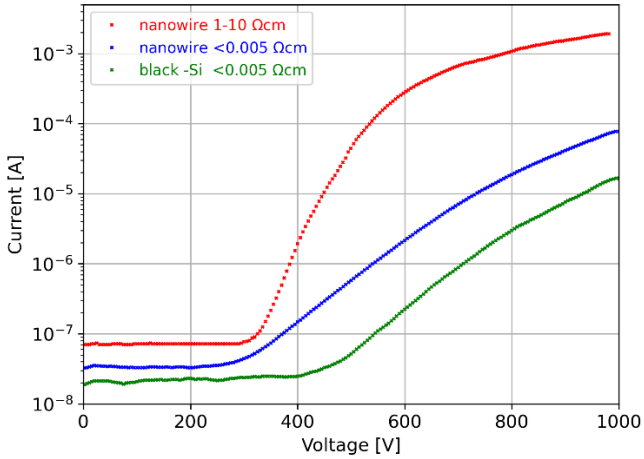

Figure 2. Emission characteristics for all three mentioned emitter types in an identical setup with an array size of 50x50 tips measured at a pressure of 10^{-9} hPa.

References

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[3] M. Bachmann et al.; „High current silicon nanowire field emitter arrays", Journal of Vacuum Science &Technology B **40**, 010605 (2022); doi:10.1116/6.0001639