High Brightness Metal Coated Silicon Field Emission Electron Sources

F. A. Hill, R. Garcia, G. V. Lopez, M. Romero, K. Ioakeimidi,
Z. Marks, G. Delgado
KLA-Tencor, Milpitas, CA 94087
Gil.Delgado@kla-tencor.com

We present work on metal coated silicon field emission electron sources for high brightness applications. Presently, commercial high brightness electron sources include tungsten emitters that operate in extended Schottky emission mode or in cold field emission mode. Metal coated silicon electron field emitters are an alternative to tungsten emitters because of their demonstrated field emission at high current densities and long lifetimes. We report on the results of simulations and experimental brightness measurements that show that silicon emitters can have very high reduced brightness levels on the order of 10^{10} A/m^2/sr/V. The high brightness of these emitters exceeds the brightness of thermal field emitters by more than one order of magnitude.

The silicon emitters are microfabricated in arrays on silicon wafers. Each emitter is made of a pillar with a sharpened tip (Figure 1a,b), with an average tip diameter of 15 nm. After fabrication, the emitters are coated with a sputtered metal film and an optional diffusion barrier. STEM imaging and EELS analysis are used to study the atomic structure and elemental composition of the emission surface (Fig 1c,d).

Field emission experiments are conducted inside of ultra-high vacuum chambers. An externally positioned extractor is used to select and emit from a single emitter at a time. Field emission currents as high as 25 μA have been measured from individual emitters. A narrow aperture in the extractor allows a small probe current to pass through the extractor, and the beam properties are studied to measure the stability of the beam, the energy spread, and morphology of the emitting surface, the beam half angle, the angular current density and the reduced brightness. Field emission data have been collected and analyzed from silicon emitters with different metal coatings, including tungsten, molybdenum, platinum and ruthenium. The emitters have been tested under a range of different operating conditions, including variable chamber pressure, operating voltages, source currents and temperatures to study the effects of these conditions on beam stability, with a best demonstrated probe current stability $\langle \Delta I^2 \rangle^{1/2}/I$ of 5%. A knife edge aperture mounted onto a scanning stage above a Faraday cup detector is used to measure the beam profile in order to obtain the angular current density and reduced brightness of the beam and compare the measurements to theoretical calculations (Figure 2). These data demonstrate the great potential of metal coated silicon emitter array sources for high brightness applications.

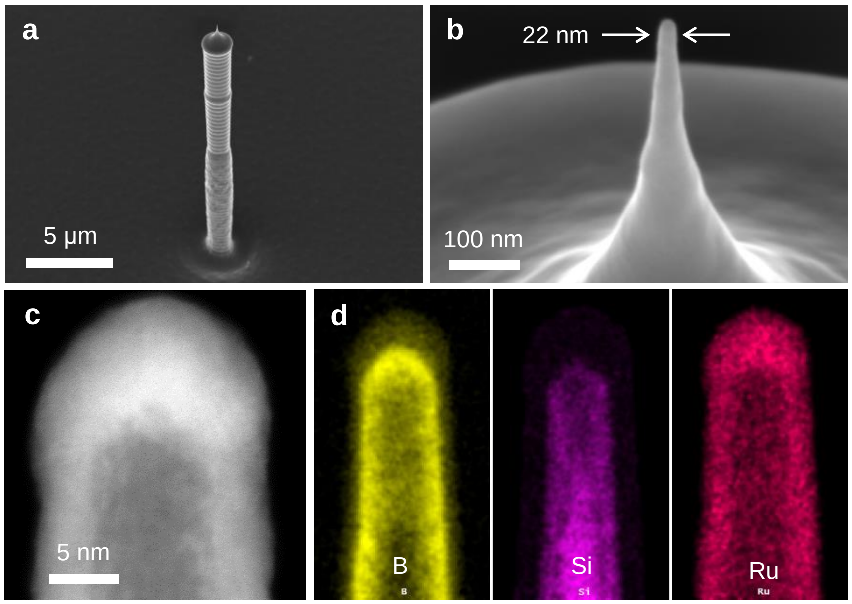

Figure 1: (a) SEM image of a microfabricated silicon emitter, (b) high magnification SEM image of an emitter tip coated with 5 nm of molybdenum, (c) STEM image of the tip of a silicon emitter with a coating of 5 nm ruthenium on 1 nm of boron carbide, and (d) elemental analysis of the silicon tip shown in (c).

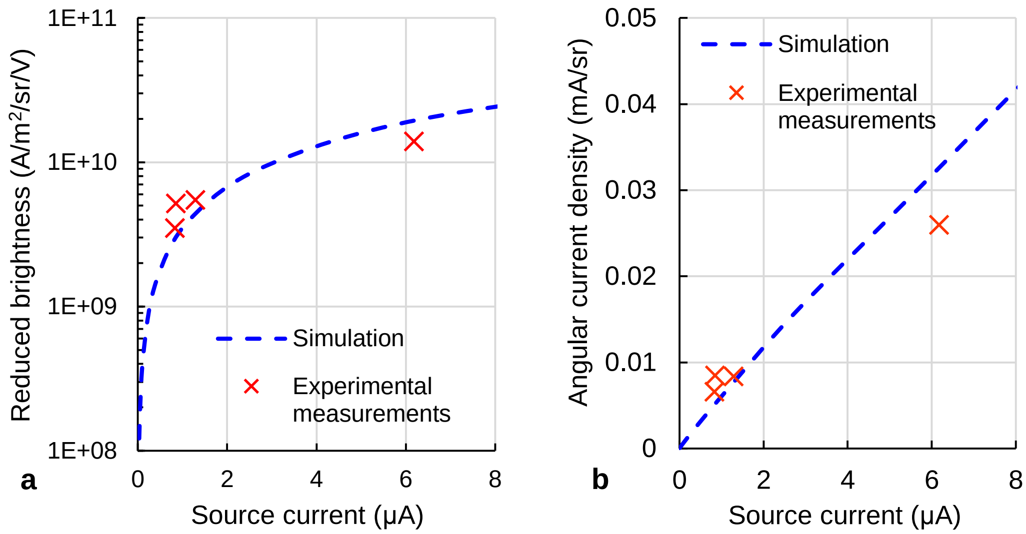

Figure 2: Theoretical simulation results and experimental measurements for (a) reduced brightness and (b) angular current density of the probe current as a function of total emission current from silicon emitters coated with 5 nm of molybdenum.