Optically Actuated Nanostructured Electron-Emitter Arrays

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High-density, optically actuated electron emitter arrays may facilitate the development of time-resolved electron microscopy, diffraction, and spectroscopy, as well as that of compact coherent x-ray sources. [1,2] These optically actuated electron emitters can operate in a pulsed configuration with shorter pulse durations than can be achieved via DC field actuation. [3] Consequently, electron emitter arrays may be integrated with pulsed laser actuators to study physical and chemical processes that occur on the femtosecond timescale. Additionally, development of a compact coherent x-ray source may facilitate accelerated development of commercial phase-contrast x-ray imaging.

Optically actuated electron emitter *arrays* will allow demonstration of optical field emission guns with higher total average current than analogous, isolated emitters. Additionally, longitudinal surface plasmon resonance modes present in Au nanorod arrays, result in local electric field enhancement that may allow, further increased, electron emission yield.

Here, we outline the design, fabrication and testing of nanostructured plasmonic Au electron emitter arrays and sub-10 nm Si electron emitter arrays. Figure 1 shows SEM images of Au nanorod arrays partially embedded in a 10 nm SiO_2 film, and Si electron emitter arrays with sub-10 nm tip diameters.

Figure 2 displays the simulated local electric field strength at Au nanorod emitter apices. The electric field was simulated numerically for both Au and Si emitters using a finite element method via *COMSOL Multiphysics*. Periodic boundary conditions have been employed in other simulations to investigate the effects of emitter layout, geometry and density, on local electric field enhancement so as to optimize electron extraction from the nanostructure arrays by the incident coherent, 1 GVm^{-1}, 800 nm wavelength, radiation.

Figure 3 displays the electron emission yield from an array of Au nanorods. Electron emission has been measured from both Au and Si emitter arrays as both a function of incident laser power, and the energy of the emitted electrons.

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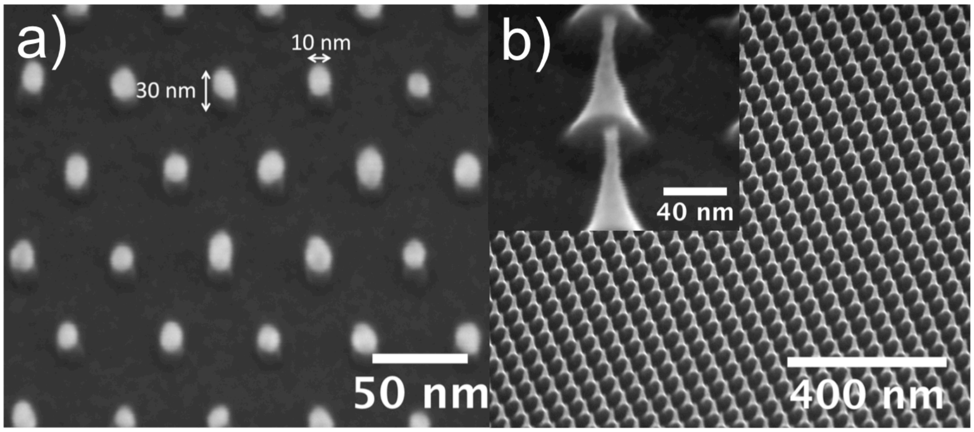

Figure 1*: (a) SEM micrograph of Au nanorod array. The nanorod geometry is tuned to match a longitudinal surface plasmon mode of Au, which is excited by 800 nm light. (b) SEM micrograph of a Si nanoemitter array. The micrograph shows a 50 nm pitch, square array of n-Si electron emitters with sub-10 nm tip diameters. Inset, SEM micrograph of two individual Si emitter tips within a square array of 100 nm pitch emitters.*

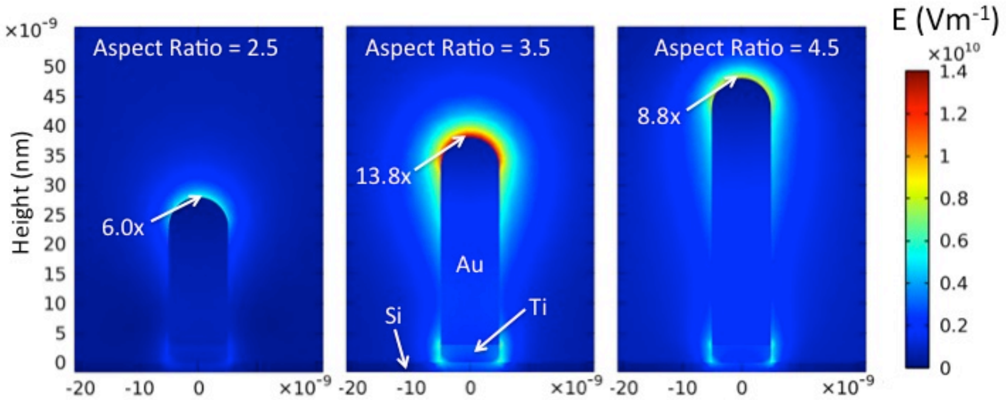

Figure 2*: Simulated electric field strength in the vicinity of Au nanorods of various aspect ratios. Simulation results demonstrate the geometry dependent longitudinal surface plasmon modes in Au nanorods.*

Figure 3*: Plot of emission current against laser pulse energy for a 600 µm × 50 µm array of Au nanorods at 100 nm pitch, illuminated by 35 fs pulses of 800 nm light at a repetition rate of 3 kHz. The laser beam diameter was 90 µm (FWHM) at the sample surface and was oriented at 6° with respect to the surface.*