Nanoscale Photoelectron Emission Using C-shaped Nanoapertures with Cesium Bromide Photocathode

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We developed photoelectron sources with C-shaped nanoapertures to generate sub-20 nm light/photoelectron sources using surface plasmon resonance as sources for multiple beam electron beam lithography. Previous work has shown that C-shaped nanoapertures are capable of focusing 980 nm light to a subwavelength scale[1]. Last year, we presented the design of C-apertures resonant at UV wavelengths using finite-difference time domain (FDTD) simulations and predicted that C-apertures would be able to focus light to sub-20 nm spots at 257 nm[2]. We also demonstrated that 20 nm characteristic size C-apertures were successfully fabricated with sub-5 nm precision using focused helium ion beam milling (Zeiss ORION® PLUS).

Fig. 1(a) shows the helium ion microscope (HIM) image of such C-apertures (20 nm characteristic size) milled in a 90 nm thick aluminum film on a fused silica substrate with a focused helium ion beam. Our FDTD simulation shows that light energy can be concentrated at the metallic ridge and above the surface of the C-aperture at 257 nm. By depositing a thin CsBr photocathode over the aperture, the concentrated light is able to excite photoelectrons at the same sub-20 nm scale in the vacuum. The structure of the nano-photoemitter is shown in fig. 1(b).

This year, we experimentally demonstrated the photoemission of the C-aperture nanoscale photoelectron source by applying a negative bias across the C-aperture photocathode and an anode collector and illuminating the C-aperture with a focused 257 nm laser. Using a piezo stage to scan the C-aperture photoemitter

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[1] J. Leen, P. Hansen, Y. Cheng, A. Gibby, and L. Hesselink, Applied Physics Letters **97**, 073111 (2010)
[2] Y. Cheng, Y. Takashima, J. R. Maldonado, D. Ferranti, W. Thompson, L. Hesselink, and R. F. Pease, EIPBN 2011.

relative to the focused laser spot, we obtained a map of photocurrent from three C-aperture photoemitters (fig. 1(c)) and pulled 230 pA (compared to the background noises) of each C-aperture nanoscale photoelectron source, on average. According to the FDTD near-field optical spot, the current density is approximately 55 A/cm^2 and is higher than that of most of the thermionic electron emitters. We are continuing to develop the multiple electron beam lithography system using C-aperture photoemitters.

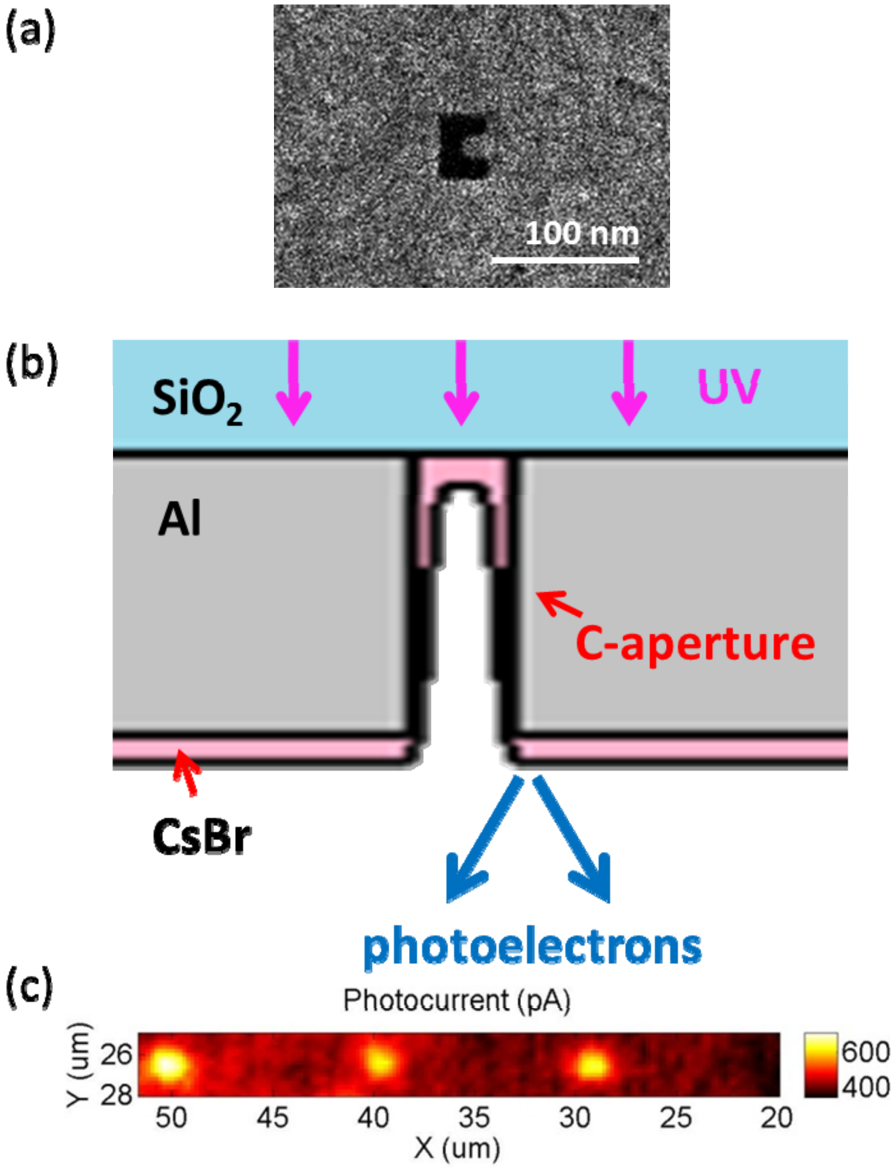

Figure 1: (a) C-shaped nanoaperture, with a 20 nm gap, fabricated with focused helium ion beam. (b) The structure of the nanoscale C-aperture photoemitter. (c) A scan of photocurrent from the C-aperture photoemitter. The spots map the shape of diffraction-limited focused laser, not the sizes of real photoelectron sources.