Concentric Ring Metal-Dielectric Structures for Surface Electromagnetic Wave Assisted Compact Photoelectron Source

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Electron-beam lithography offers the advantages of high-resolution and mask-less direct writing. However, existing systems cannot match the throughput required for high volumes. The usable writing current for a given resolution is ultimately limited by Coulomb interaction in the beam, or by limited ability of the source to supply the desired current. One proposed method for overcoming this limitation is to distribute the current over multiple beams[1,2]. Realization of such multi-beam systems hinges on the availability of a massively parallel multi-beam electron source. To this end, we propose a novel compact photoelectron source, composed of a concentric ring metal-dielectric structure used to excite *Compound Diffracted Evanescent Waves* (CDEW)[3].

A sub-wavelength groove on a metal-dielectric surface scatters and diffracts incident light, which generates CDEW and carries away some of the incident energy along the surface as evanescent electromagnetic waves. An array of such grooves has the capacity to efficiently generate and collect CDEW when designed with optimal dimensions. This allows transmission of optical power incident over a broad area through a sub-wavelength slit/aperture in a metal film. Previously published results of 2D computer simulations[4] demonstrate the ability to transmit optical energy through a sub-wavelength slit with significant enhancement of optical power-per-area (over 10x) when surrounded by a linear metal-dielectric grating. Similarly, periodic concentric rings of grooves can guide CDEW to a sub-wavelength aperture at the center of the rings that transmit the optical energy to the opposite side of the film. Circular geometry allows the optical enhancement to be independent of the incident light polarization.

This method is efficient in collecting optical energy incident on a broad area on one side of the film and focusing it to a sub-wavelength spot on the opposite side. Furthermore, it can stimulate photoelectron emission over a sub-wavelength area from a suitable material with relatively low work function. Our 3D simulation results (fig. 1) indicate 36x enhancement of the optical power density at the exit side of a 90nm central aperture (fig. 2) from a structure optimized for 266nm incident wavelength (185nm period, 10 ring structure) composed of quartz and aluminum. Specifically, this structure can be utilized to drive photoemission from a magnesium film which has a work function (3.6eV) lower than the photon energy at 266nm (4.6eV). Quantum efficiency for a magnesium film of 15nm thickness was measured at 2×10^{-5} (fig. 3), which predicts a single source current of 0.3nA when combined with the concentric ring structure driven with a 100mW laser. We are currently in the process of measuring the photoelectron current and the virtual source size from a completed source, along with the use of quantum dots composed of low work function materials for enhanced photoelectron emission and decreased source size. These efforts will provide insight into the feasibility of a massively parallel multiple electron-beam lithography system.

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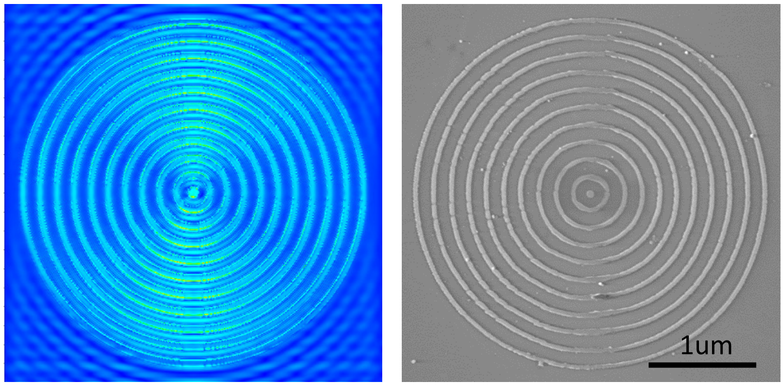

Fig. 1: 3D simulation result (**E**-field amplitude) of the concentric ring structure optimized for 266nm radiation, composed of quartz and aluminum (left). eSEM image of the etched quartz structure prior to aluminum film deposition (right).

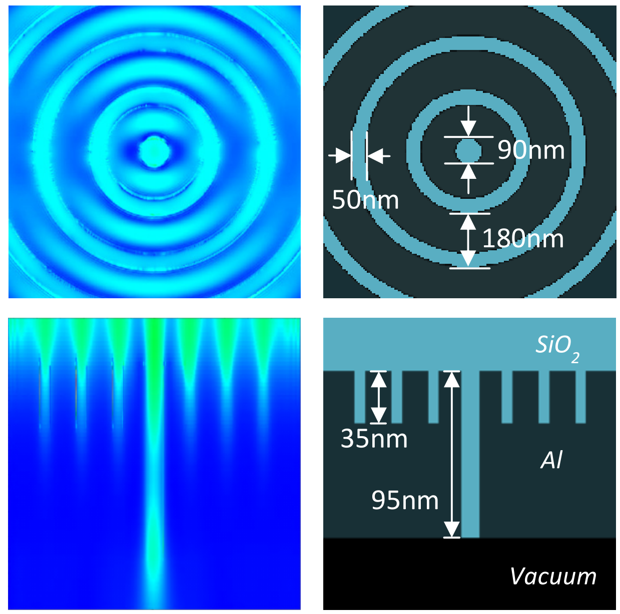

Fig. 2: Top-down (above) and cross-sectional (below) view of the concentric ring structure near the central aperture. 3D simulation result (**E**-field amplitude) demonstrating the 266nm radiation, at normal incidence on the grating, generating CDEW and being focused to the vacuum side of the central 90nm diameter aperture (left). Optimized dimensions and materials for 266nm incident radiation (right).

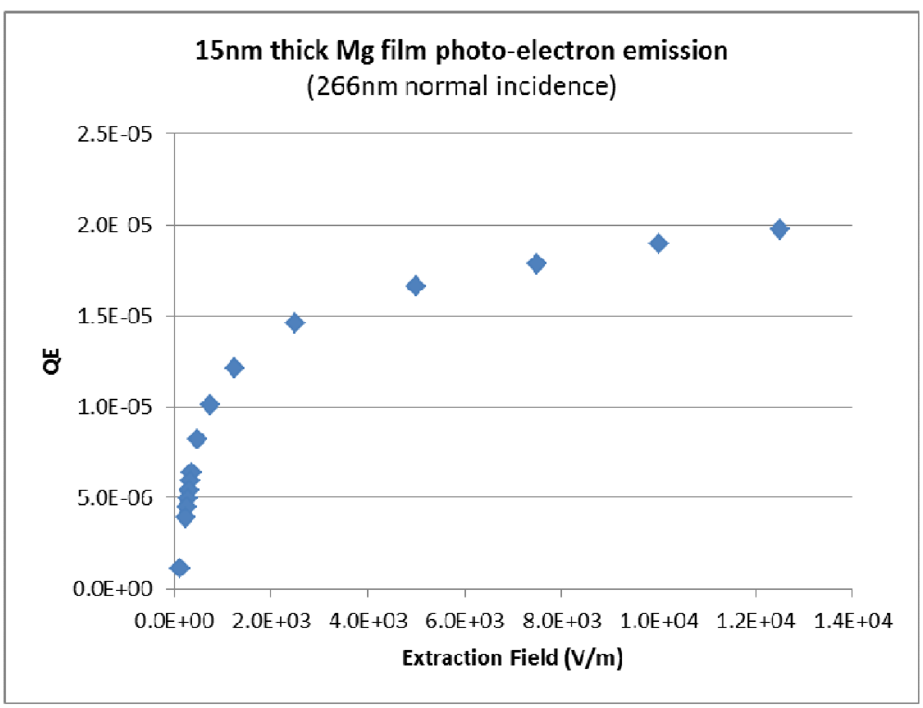

Fig. 3: Quantum efficiency (QE: # of electrons emitted per # of photons incident) measurement for 15nm thick magnesium film irradiated with 266nm radiation at normal incidence for various extraction electrical field values.