Plasmonic Waveguiding in Pd Nanowires Enables Unexpected Deep-UV Photoresist Exposure

Michael Jung[1]
School of Engineering Mechanics and Materials, University of Georgia, Athens, GA 30602
mj85616@uga.edu

Yiping Zhao
Department of Physics and Astronomy, University of Georgia, Athens, GA 30602

We report the discovery of deep ultraviolet (DUV) plasmonic waveguiding in Pd nanowires, leading to unexpected photoresist exposure beyond the illuminated regions. As shown in Figure 1A, an array of 120 Pd nanowires (45 μm in length, 20 nm in width, and spaced 200 nm apart, highlighted by the red dashed box) was fabricated via electron beam lithography on a Si wafer using a 50 nm PMMA resist at varying beam dosages. After Pd metallization and PMMA removal, a 1.5μm NR91500 negative photoresist was used to pattern connection electrodes via a 375 nm light source in a Heidelberg MLA 150. Due to misalignment, the $250 \times 250\ \mu m^2$ electrode pattern (purple boxes) on the left side of the nanowire array did not overlap with the wires, while the right-side pattern covered one-quarter of the array length. After exposure and removal of the photoresist, we observed that the photoresist layer atop and surrounding the nanowires had also been removed. Notably, between the left electrode and the array's left end, a 7.3 μm-wide photoresist strip remained (yellow box and zoom-in image), revealing the Pd nanowire array clearly in SEM imaging. This phenomenon appears linked to the electron beam dosage during nanowire fabrication. As shown in Figures 1A–1C, increasing the dosage from 250 to 500 $\mu C/cm^2$ reduced the width of the remaining photoresist (yellow box) from 7.3 μm to 3.8 μm, with the pattern breaking into two lifted tips at 500 $\mu C/cm^2$ (Figure 1C). The elevated tips suggest enhanced exposure near the Si surface, possibly due to structural and morphological changes in the Pd nanowires at higher electron beam dosage. This effect can be attributed to the plasmonic waveguiding properties of Pd nanowires for DUV light (Figure 2). During exposure, the right end of the illuminated nanowires channels DUV light toward the left, emitting guided light into the surrounding area and inducing photoresist exposure beyond the directly illuminated regions. The extent of this influence strongly depends on the electron beam dosage used in nanowire fabrication, with higher dosages expanding the affected region. Our findings reveal a novel plasmonic interaction in Pd nanostructures with significant implications for nanoscale lithography and optical manipulation at deep-UV wavelengths. The discovery of Pd nanowire plasmonic waveguiding in DUV exposure opens new possibilities for advanced lithography, where precise process control and optimization will be essential.

[1]This work was partially conducted at the Georgia Tech Institute for Electronics and Nanotechnology and the Joint School of Nanoscience and Nanotechnology, both part of the NSF-supported NNCI (Grant ECCS-2025462).

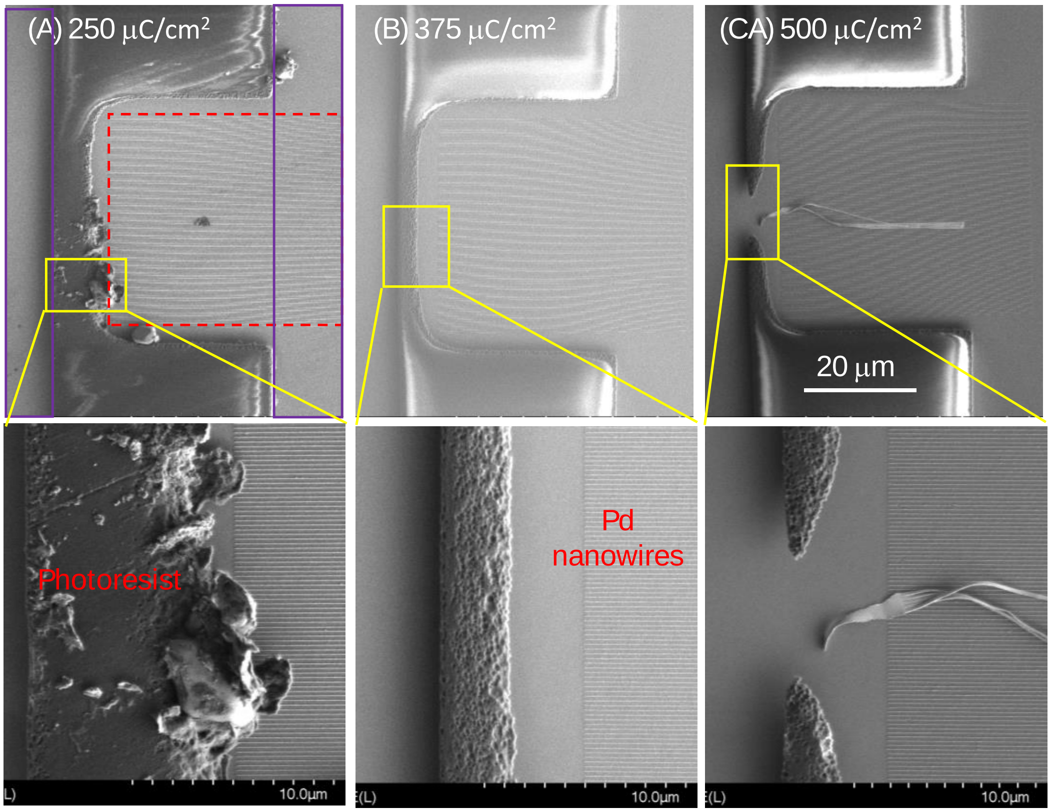

Figure 1: The SEM images show the remaining photoresist between the Pd nanowire array and the left electrode pattern for different electron beam dosages used in Pd nanowire fabrication: (A) 250, (B) 375, and (C) 500 μC/cm². In (A), the red dashed box highlights the nanowire region, the purple boxes indicate the electrode pattern and DUV exposure regions, and the yellow box marks the zoom-in SEM regions. The second row presents the corresponding zoomed-in SEM images of the yellow-boxed areas.

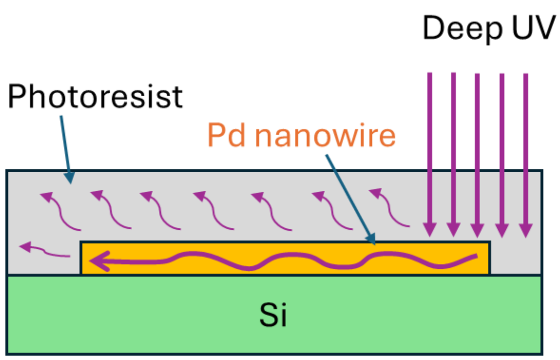

Figure 2: The DUV plasmonic waveguiding effect responsible for the unexpected photoresist exposure on top of the Pd nanowire arrays.