Implementation of Nanopillar Metasurfaces for the Sensitive Detection of Antibiotic Signatures

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Advancing metasurfaces and metamaterial technology has allowed for exponential growth in the application of the techniques for a variety of mediums. This field has seen great interest in use as biosensors due to their high customizability, sensitivity, and often nondestructive sensing strategies.[1] Through precise control of the dimensions of subwavelength features, a variety of novel effects can be observed based on particle interactions due to alterations in the surrounding refractive index, or from plasmon resonance in the presence of photons to the surface of nanoscale structures.[2,3] Fabrication of the unique silicon nanopillars described herein allows for production of the intricate geometries capable of producing a desirable reflectance spectrum for the sensitive and specific detection of bound analytes. The 1 cm^2 samples are covered with periodic nanopillars, which currently consists of either 150 nm, 180 nm, or 200 nm nanopillars at a customizable edge-to-edge distance varying from 155 nm to 240 nm. The height of the nanopillar is controlled at 110 nm or 210 nm by adjusting etching parameters. This array results from a facile fabrication workflow that only requires DUV lithography, with a negative photoresist/BARC layer, and a rapid metal etch process with an accompanying strip step resulting in the desired features. To pursue sensing of target analytes in the form of antibiotics, the surface of the silicon nanopillars and planar surface are functionalized by a self-assembling monolayer consisting of an 11-aminoundecyltriethoxysilane monomer. The molecule preferentially binds to the native oxide layer on the silicon, resulting in a terminal amino group. This chemical structure binds to carboxylic compound groups that on β-lactam antibiotics like penicillin or cephalexin.[4] The antibiotic component acts as a linker in this system, allowing for specialized BSA-coated gold nanoparticles (BSANS) to be bound to the silicon features. The coupling of the gold to silicon allows for plasmon resonance effects to be detected by the reflectance spectra of the device. Extensions of this work would enable the identification of β-lactam-resistant bacteria through degradation of the antibiotic, preventing capture of nanoparticles on the nanopillars.

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[1] J. Hong, M. Su, and K. Zhao et al., Biosensors **13**, 327 (2023).
[2] T. Zhou, W. Ji, H. Fan et al., Biosensors **13**, 681 (2023).
[3] J. Hu, F. Safir, K. Chang et al., Nature Communications **14**, (2023).
[4] Q. Li, T. Zhang, and L. Bian, Journal of Chromatography B **1014**, 90 (2016).

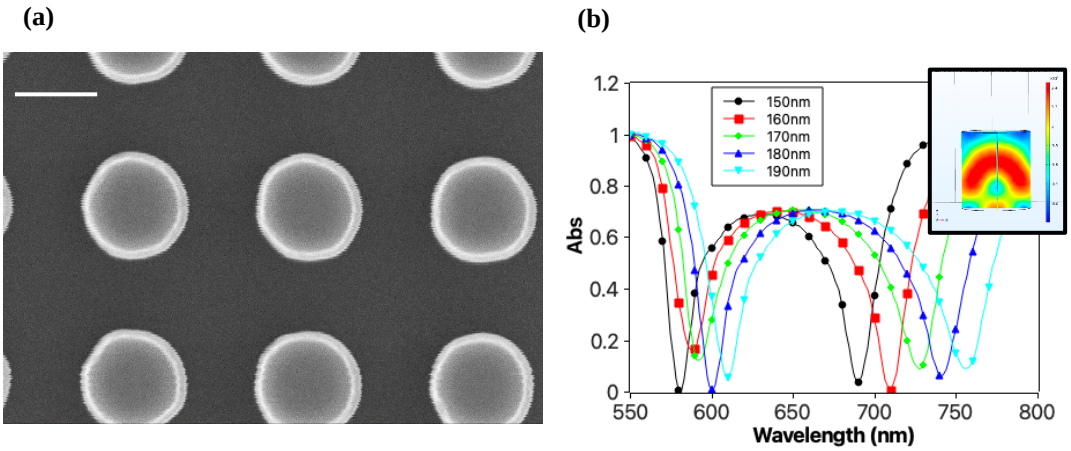

Figure 1: (a) Top-down SEM image of the nanopillar array. (scale bar: 200nm) (b) Simulated reflectance spectrum demonstrating double valley signature at changing nanopillar heights. Inset shows electron heat map of a singular nanopillar coupled to surrounding nanopillars.

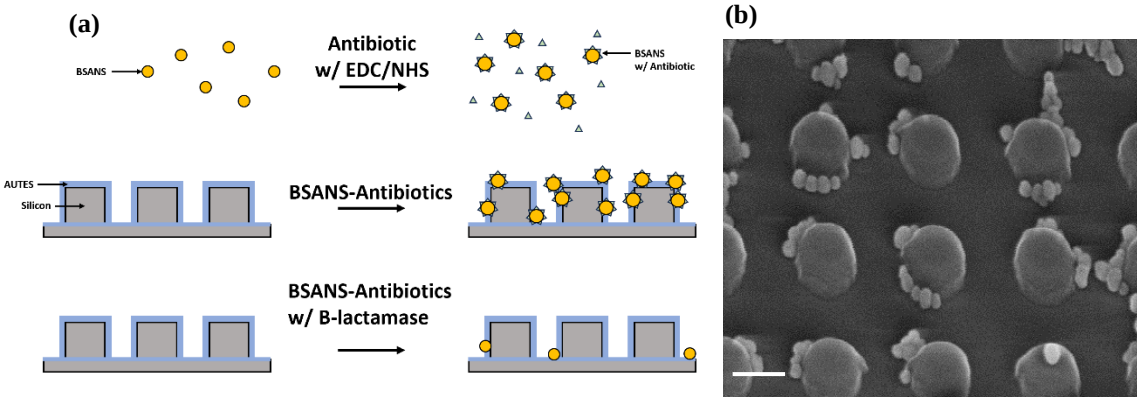

Figure 2: (a) Schematic representation of antibiotic linking system for capture of gold nanoparticles on device surface. (b) SEM image of BSANS bound to monomers on nanopillar surface. (scale bar: 200nm)