Manufacturing TiO_2 Pillar Arrays and SiN Bullseye Cavities

CNF Project Number: 3008-22
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Primary Source(s) of Research Funding: UoR Startup

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Primary CNF Tools Used: JEOL 6300, Spin Coaters, PT770 RIE, Microscopes, Oxford 82, Oxford 100, Plasma-Therm Tikachi HDP-CVD, Yes EcoClean Asher, Filmetrics systems, Zeiss Ultra SEM

Abstract:

Our group is interested in quantum research on photonic integrated circuit platforms. Two topics we are currently exploring are on-chip lasing, and single-photon emission enhancement with circular Bragg gratings. There have been recent reports of on-chip lasing achieved through bound states in the continuum. The bound states are made possible with an array of dielectric pillars. To study and reproduce these results we manufactured the same arrays at the Cornell NanoScale Facility.

Summary of Research:

This was the first time the user worked at CNF to create a nanostructure so we were mainly concerned with learning how to use the JEOL 6300, and to try a range of dosages to find the best parameters to create the nano pillars. We believe we found a good recipe for the electron beam exposure, but the reactive ion etching timing might need some tuning. Additionally, the quartz substrate we used was exceedingly thin — the vacuum chuck for the spin coater caused non-uniform coating to occur. Regardless, as seen from the images below we successfully created the pillar array.

Additionally, this was the first time the group was trying to manufacture bullseye cavities. Hence dosage tests and anisotropic reactive ion etch times are under study for this fabrication as well. RIE lag has caused an issue in etching smaller but important features in the bullseye cavities. It is still inconclusive as to if this problem will force us to use multiple exposures and etches to maintain the integrity of the smallest physical features.

Conclusions and Future Steps:

With the array of pillars manufactured, the next steps are to optically characterize. If the resonance is where we want it to be, then we proceed with coating the structure in CdZnS to further recreate the paper we are referencing.

For the bullseye cavities, more fabrications will be done to dial in on the best e-beam dosage and etch time. AFM images will be made to determine whether the central hole of the bullseye in future fabrications is up to spec with a single e-beam exposure and etch step, or if multiple exposure and etch steps need to be made to successfully create this bullseye cavity.

References:

[1] Room-Temperature Lasing in Colloidal Nanoplatelets via Mie-Resonant Bound States in the Continuum, Mengfei Wu, Son Tung Ha, Sushant Shendre, Emek G. Durmusoglu, Weon-Kyu Koh, Diego R. Abujetas, José A. Sánchez-Gil, Ramón Paniagua-Domínguez, Hilmi Volkan Demir, and Arseniy I. Kuznetsov; Nano Letters 2020 20 (8), 6005-6011, DOI: 10.1021/acs.nanolett.0c01975.

[2] Enhanced Emission from WSe_2 Monolayers Coupled to Circular Bragg Gratings, Ngoc My Hanh Duong, Zai-Quan Xu, Mehran Kianinia, Rongbin Su, Zhuojun Liu, Sejeong Kim, Carlo Bradac, Toan Trong Tran, Yi Wan, Lain-Jong Li, Alexander Solntsev, Jin Liu, and Igor Aharonovich; ACS Photonics 2018, 3950-3955, DOI: 10.1021/acsphotonics.8b00865.

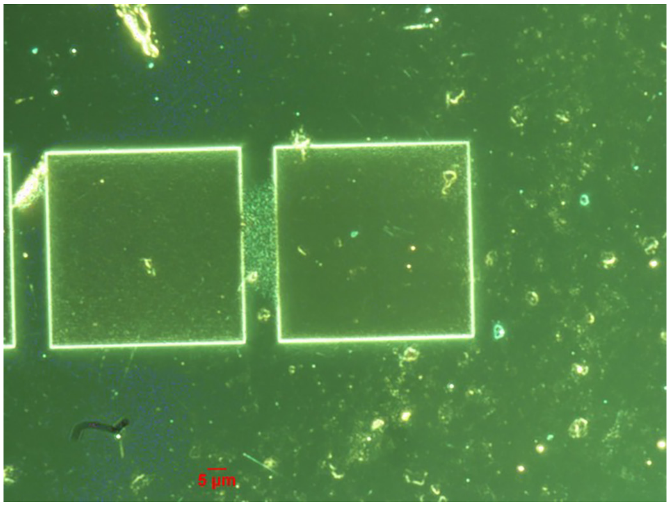

Figure 1: A microscope image of two pillar arrays made at CNF with the JEOL 6300.

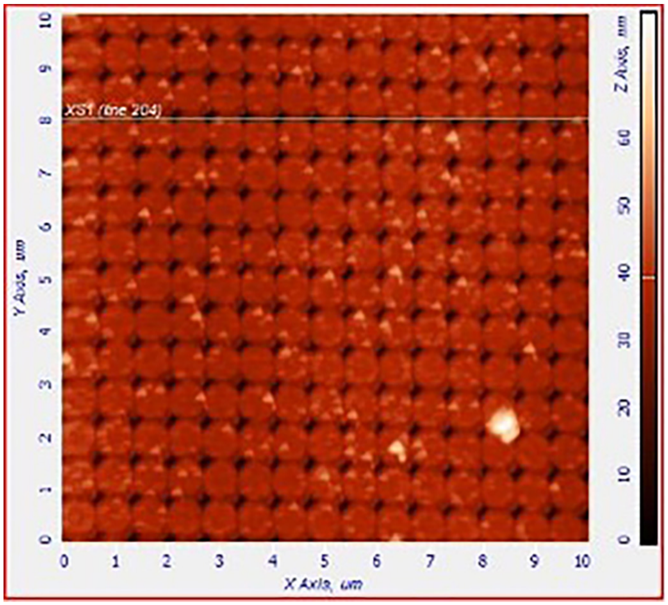

Figure 2: An Atomic Force Microscopy image of the array of pillars.

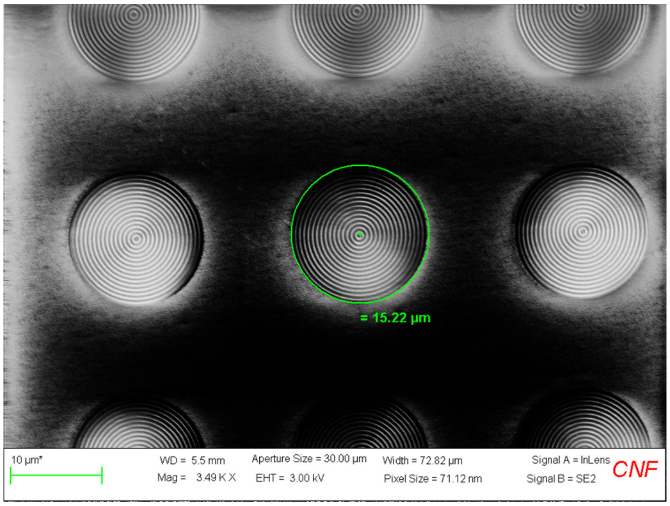

Figure 3: Array of bullseye cavities taken in Zeiss SEM Ultra.

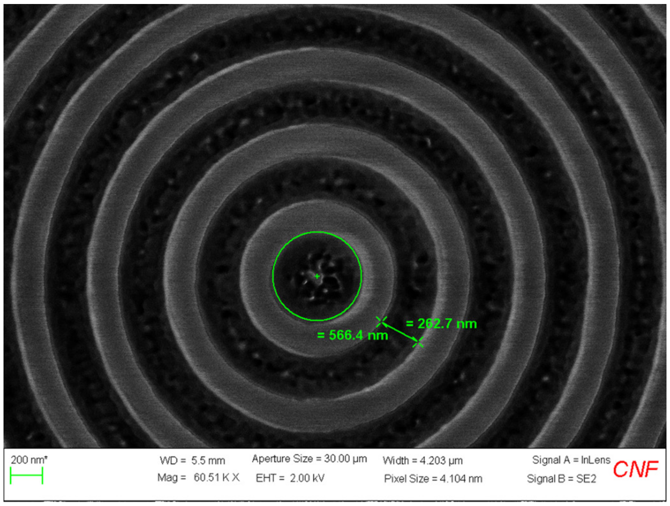

Figure 4: Center of bullseye cavity taken in Zeiss SEM Ultra.