Topics in Nano-Biophotonics: Fabrication of Plasmonic Metasurfaces that Attract and Spectroscopically Interrogate Cancer Cells

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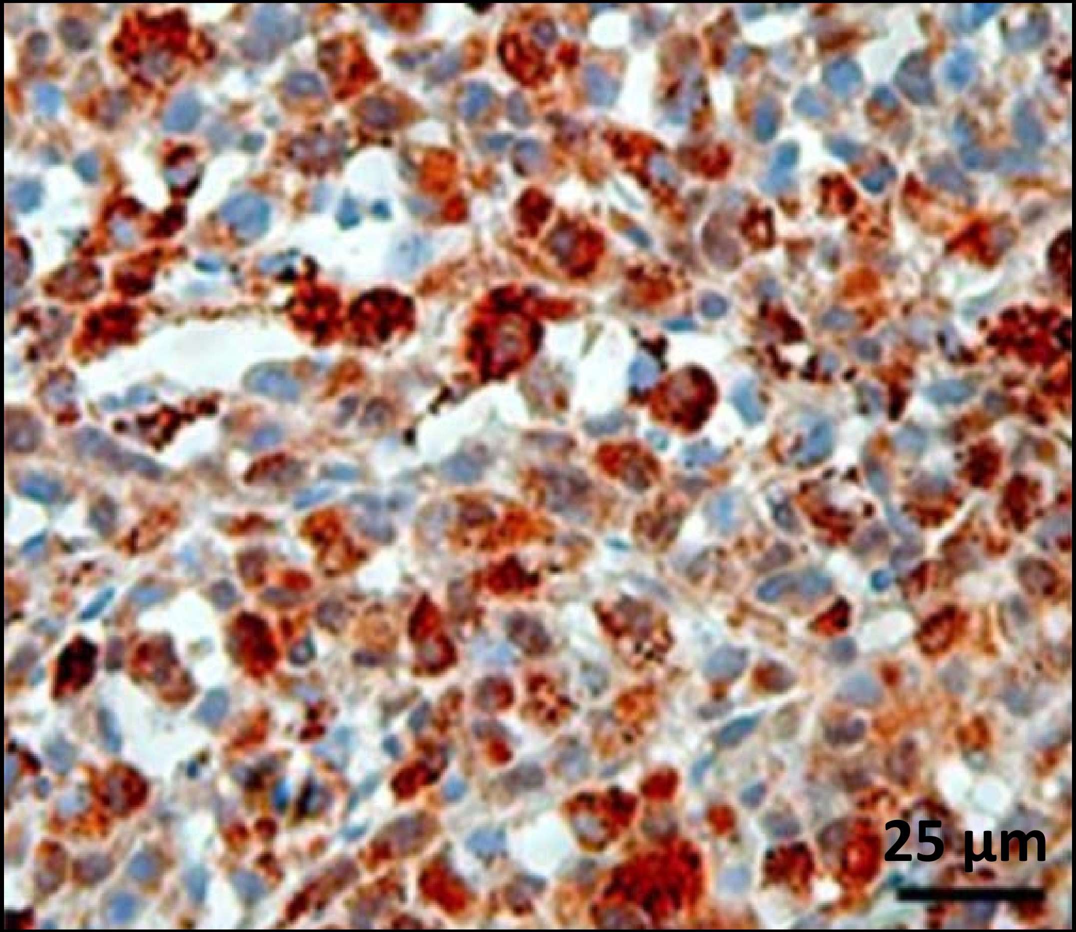
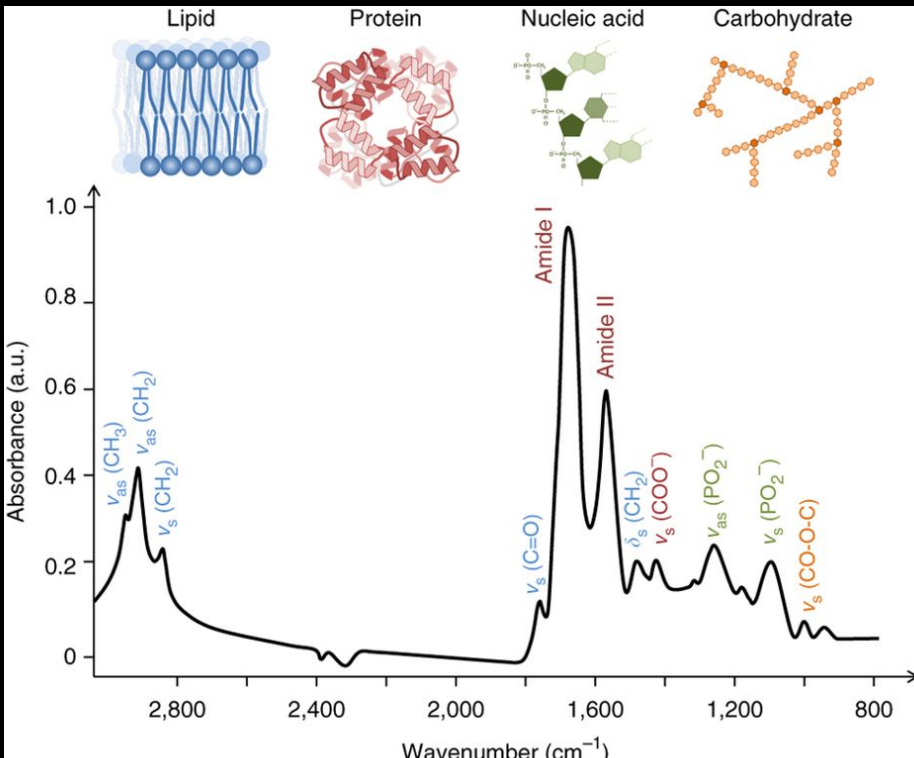
Motivation

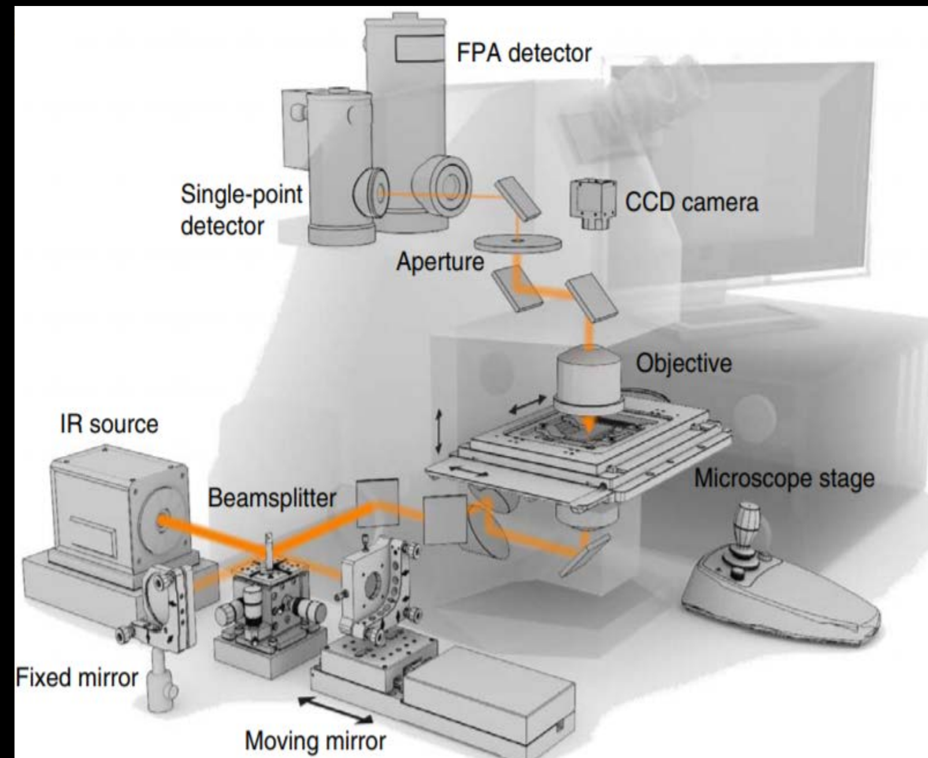


Hypoxia staining using PHD2 immunohistochemistry of prostate cancer tumor sections; scale bar is 25 microns. Al-Mahrouki, A. A., Iradji, S., Tran, W. T., & Czarnota, G. J. (2014). Cellular characterization of ultrasound-stimulated microbubble radiation enhancement in a prostate cancer xenograft model. Disease Models & Mechanisms,7(3), 363-372.

Biomolecular Sensing by IR Spectroscopy



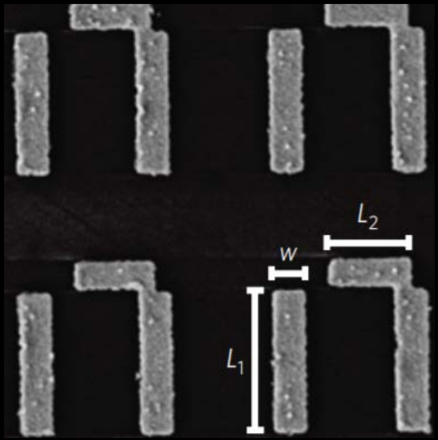
Transmission spectrum of human breast cancer cell



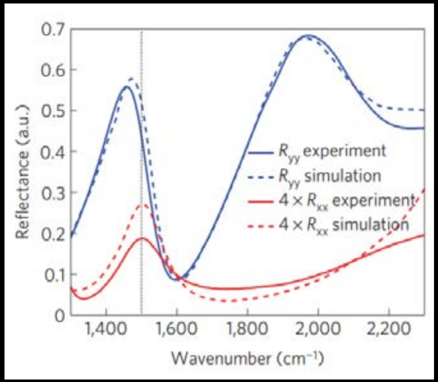
Schematic of FTIR setup

Baker, M. J. et al. (2014). Using Fourier transform IR spectroscopy to analyze biological materials. *Nature Protocols,9*, 1771-1791.

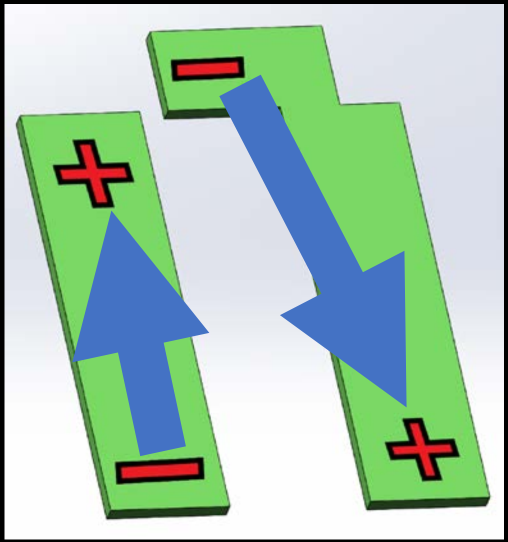
Metasurface



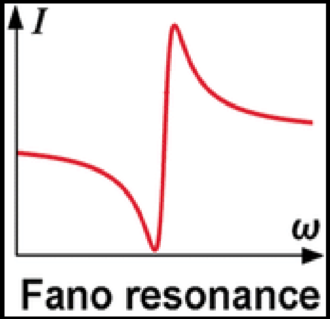
SEM image of Fano Resonant Asymmetric Metamaterial (L_1 = 1.8 µm, L_2 = 0.9 µm, w = 0.36 µm). Fano-resonant asymmetric metamaterials for ultrasensitive spectroscopy and identification of molecular monolayers. *Nature Materials,11*(1), 69-75.



Polarized reflectivity spectra: blue is Fano asymmetric non-Lorentzian lineshape for vertical polarizations. Wu, C. et al. Fano-resonant asymmetric metamaterials for ultrasensitive spectroscopy and identification of molecular monolayers. *Nature Materials,11*(1), 69-75.



Excited subradiant mode in pi structure with dipole moments shown to illustrate the importance of symmetry breaking.



Fano asymmetric lineshape. Liu, Zhiguang & Li, Jiafang & Liu, Zhe & Li, Wuxia & Li, J.J. & Gu, Changzhi & Li, Zhi-Yuan. (2017). Fano resonance Rabi splitting of surface plasmons. Scientific Reports. 7.

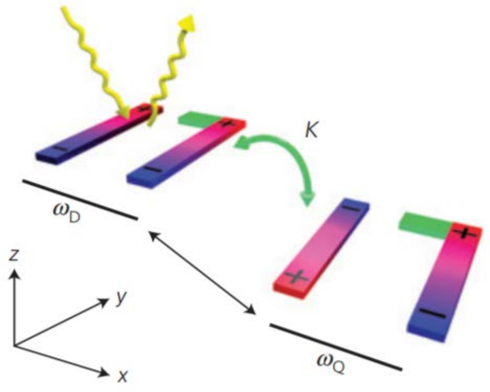
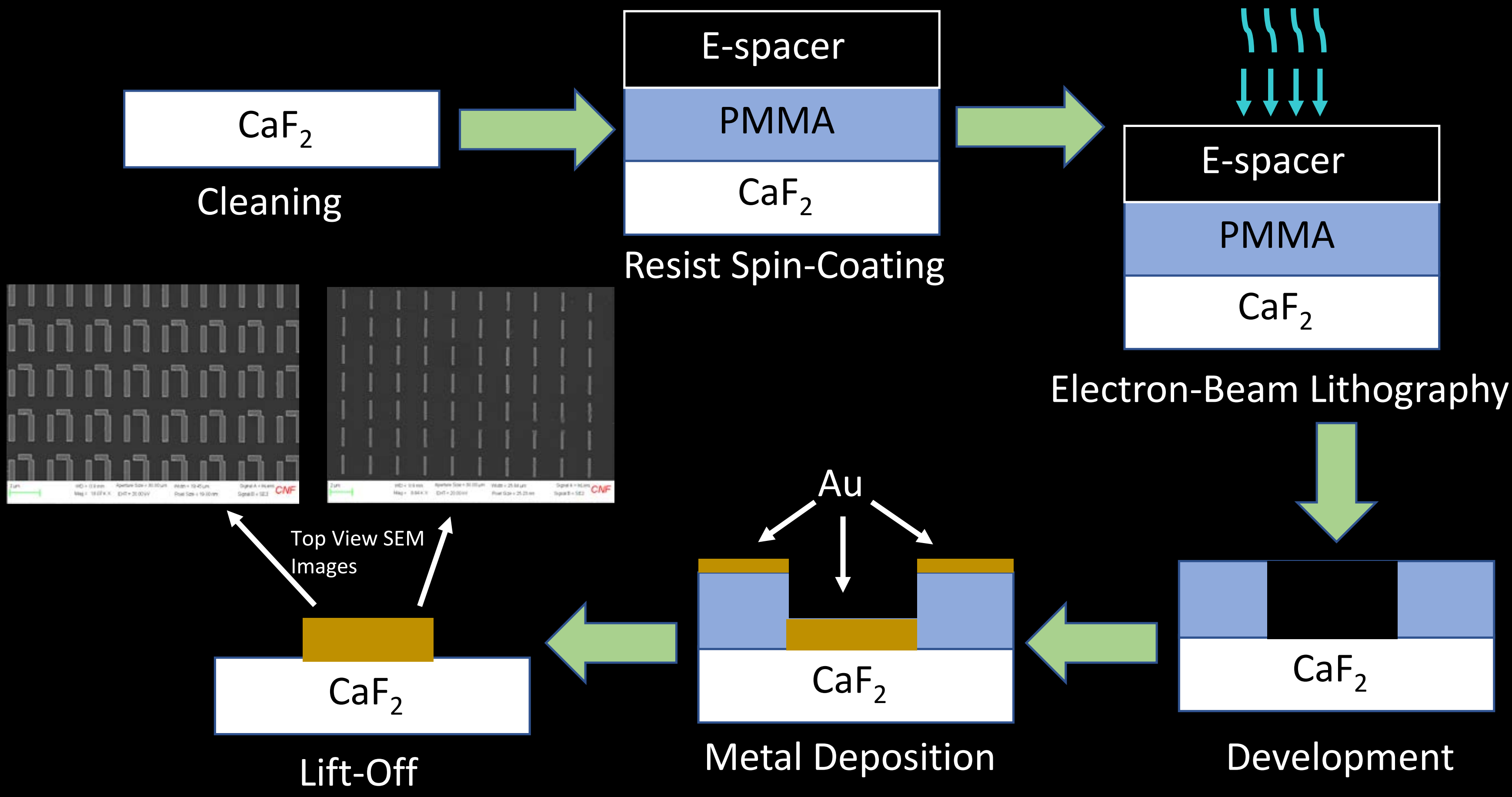
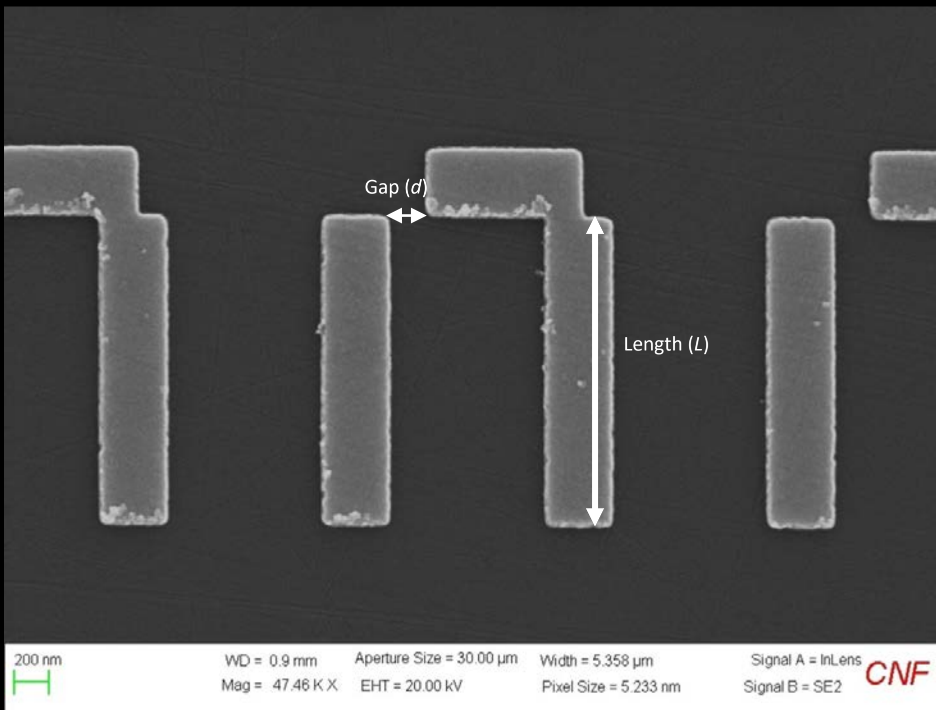


Diagram of Fano-resonant asymmetric metamaterial (FRAMM or pi structure) showcasing superradiant (ωD) and subradiant (ωQ) modes being coupled to IR light. Wu, C. et al. Fano-resonant asymmetric metamaterials for ultrasensitive spectroscopy and identification of molecular monolayers. *Nature Materials,11*(1), 69-75.

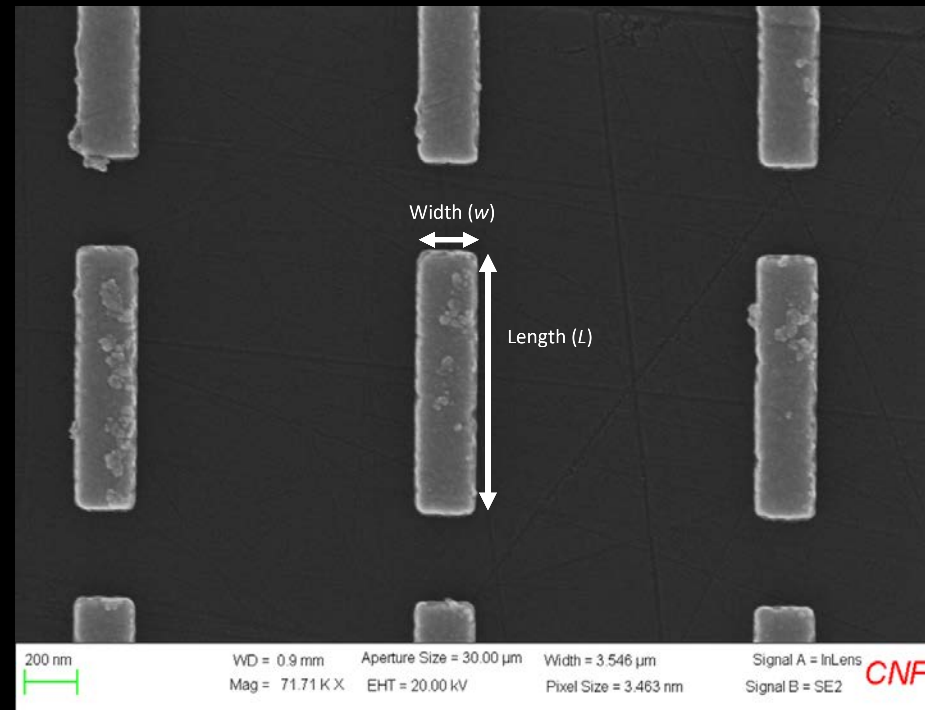
FRAMM and Nanoantennae Fabrication



FRAMM & Nanoantennae SEM Images

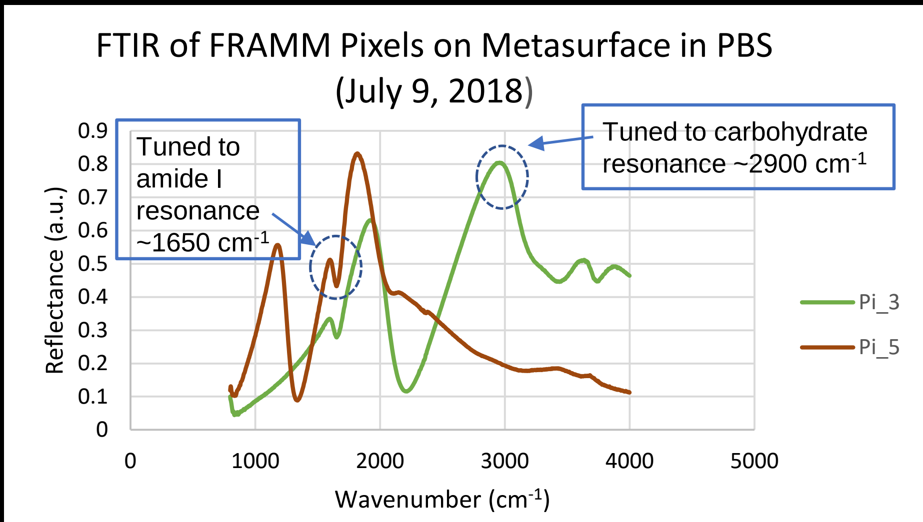


Pi structure with *d = 225.1 nm* and *L = 1.727 µm*.



Nanoantennae with *w = 238.3 nm* and *L = 962.4 µm*.

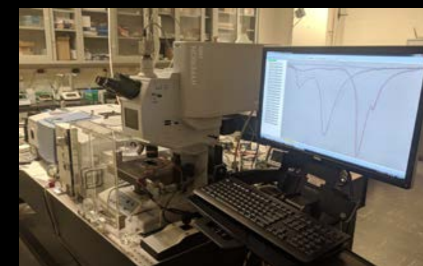
FRAMM and Nanoantennae Data



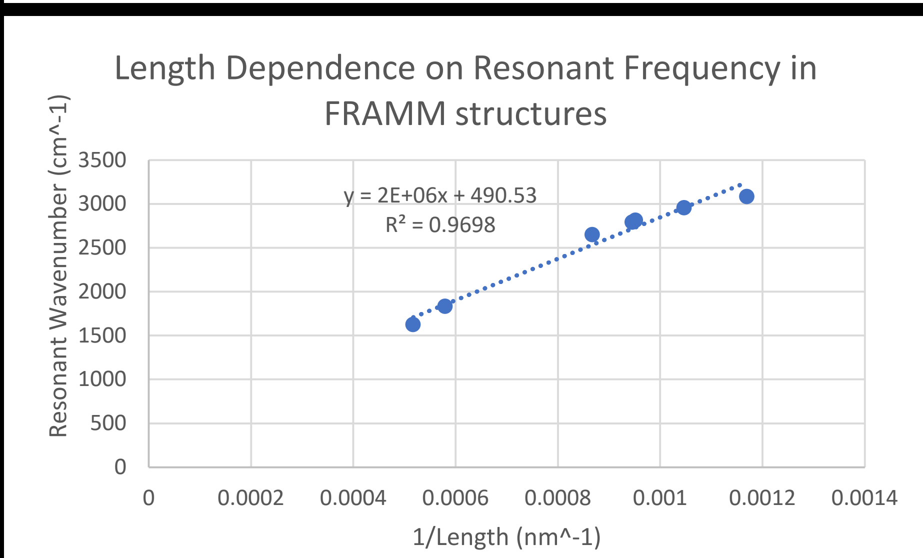
Structure	Gap, d (nm)	Length, L (nm)
Pi_1	120.1	1153
Pi_2	73.08	1058
Pi_3	66.19	955.5
Pi_4	43.49	855.3
Pi_5	225.1	1727
Pi_6	118.9	1051
Pi_7	263.6	1935

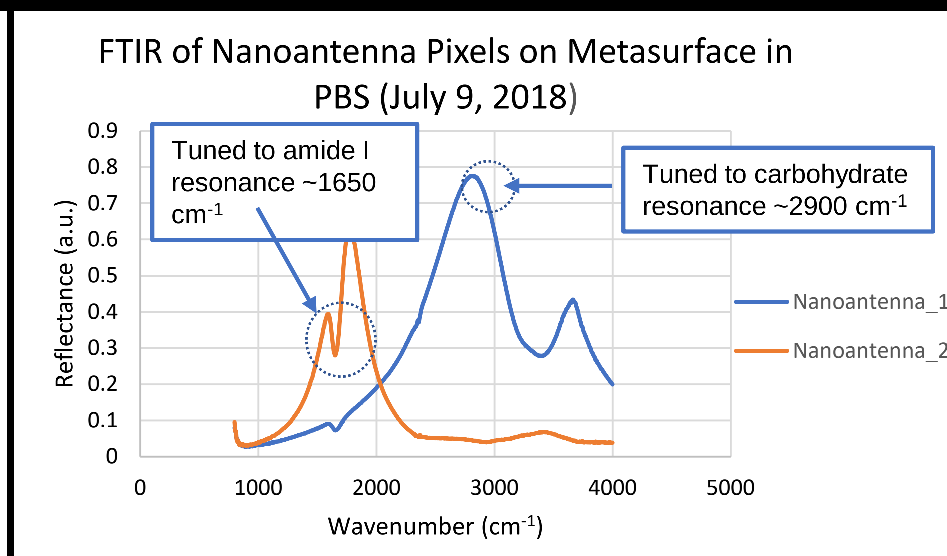
Structure	Width, w(nm)	Length, L(nm)
Nanoant_1	238.3	962.4
Nanoant_2	234.8	1693

PDMS Microfluidic Chamber

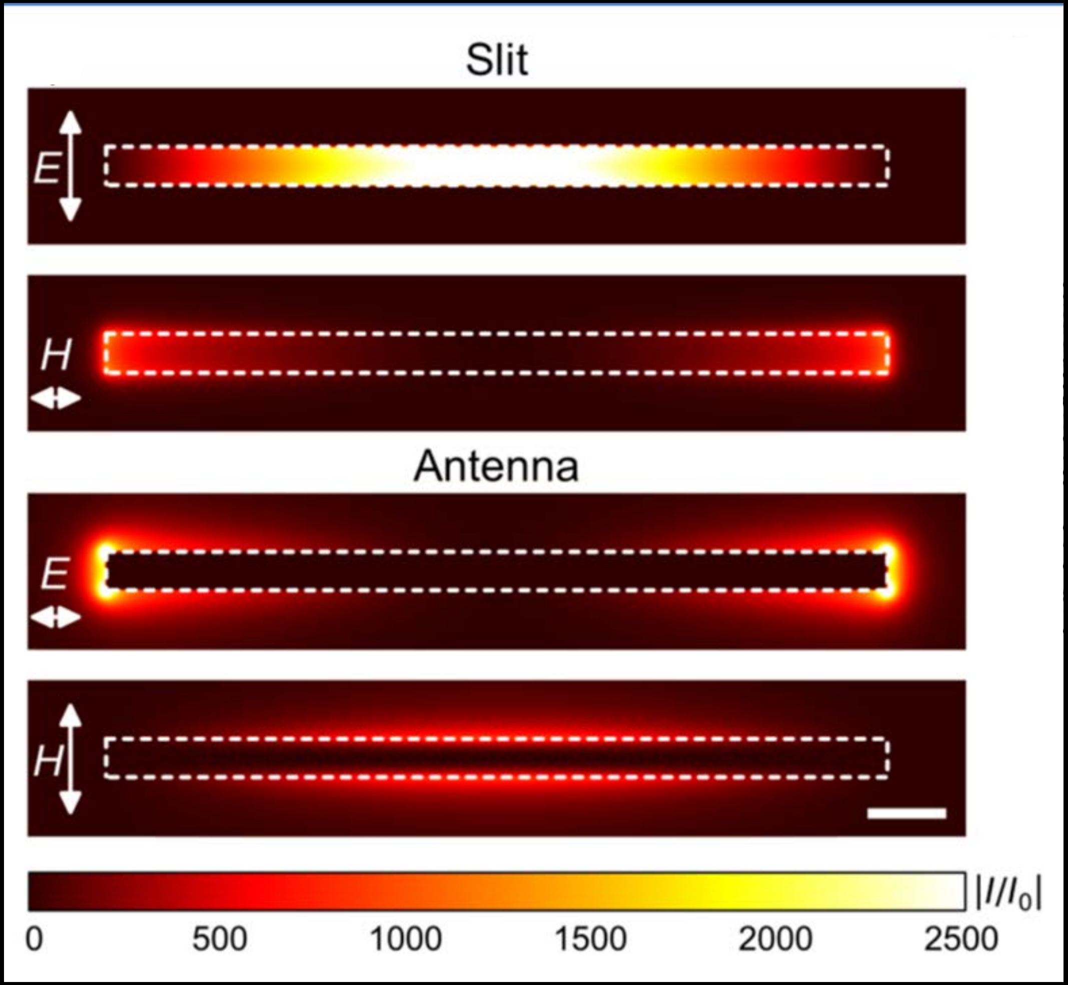


FTIR Setup



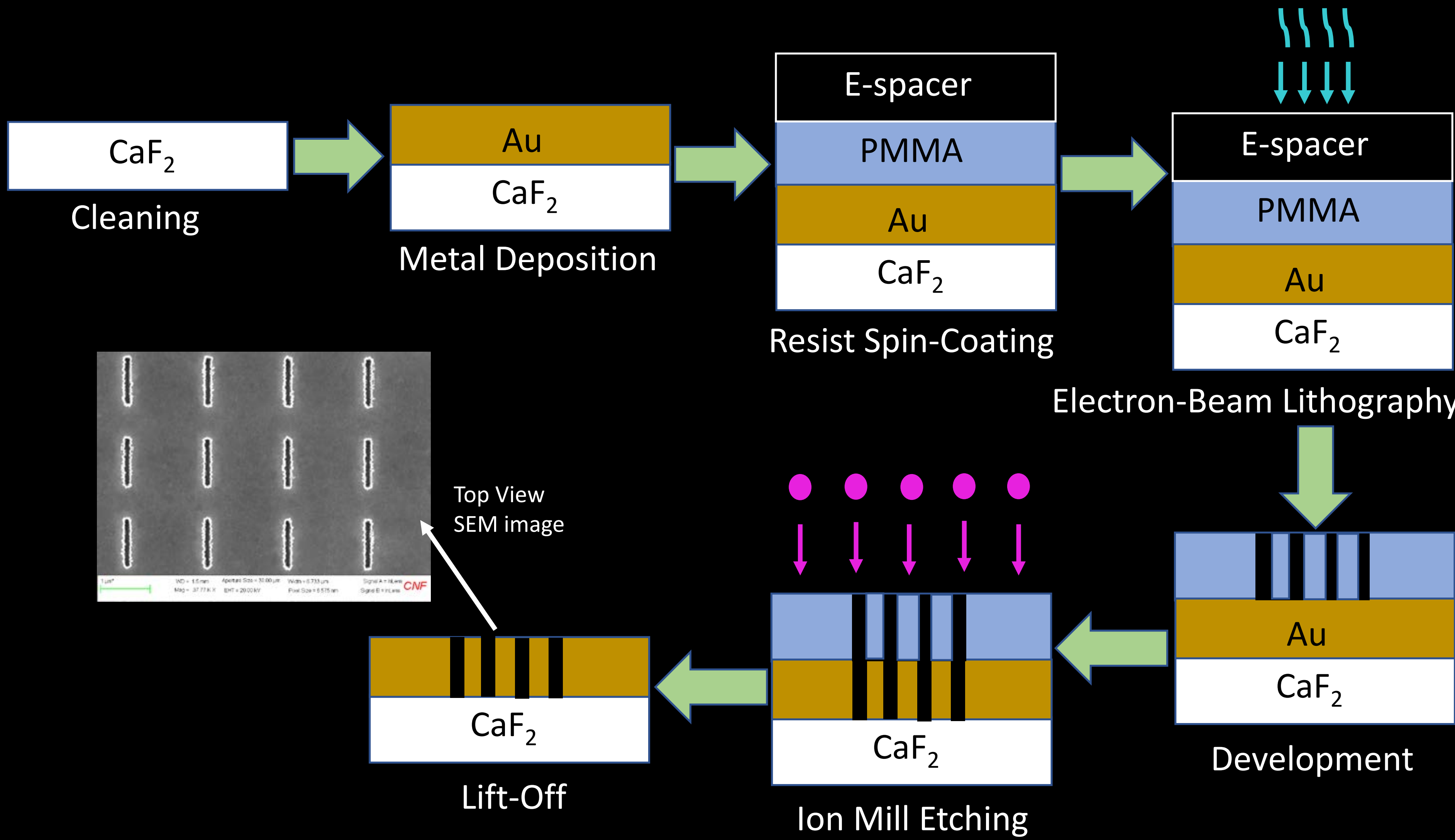


Nanoslit Theory

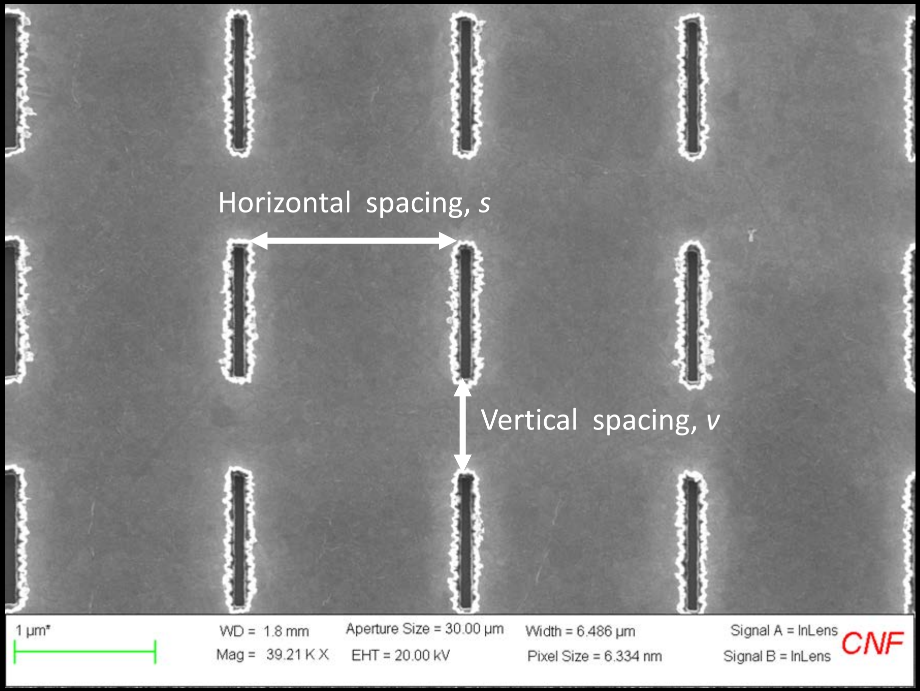


Near field intensity distribution of nanoslit and nanoantenna. Plasmonic Enhancement of Infrared Vibrational Signals: Nanoslits versus Nanorods. Christian Huck, Jochen Vogt, Michael Sendner, Daniel Hengstler, Frank Neubrech, and Annemarie Pucci. ACS Photonics 2015 *2* (10), 1489-1497. DOI: 10.1021/acsphotonics.5b00390

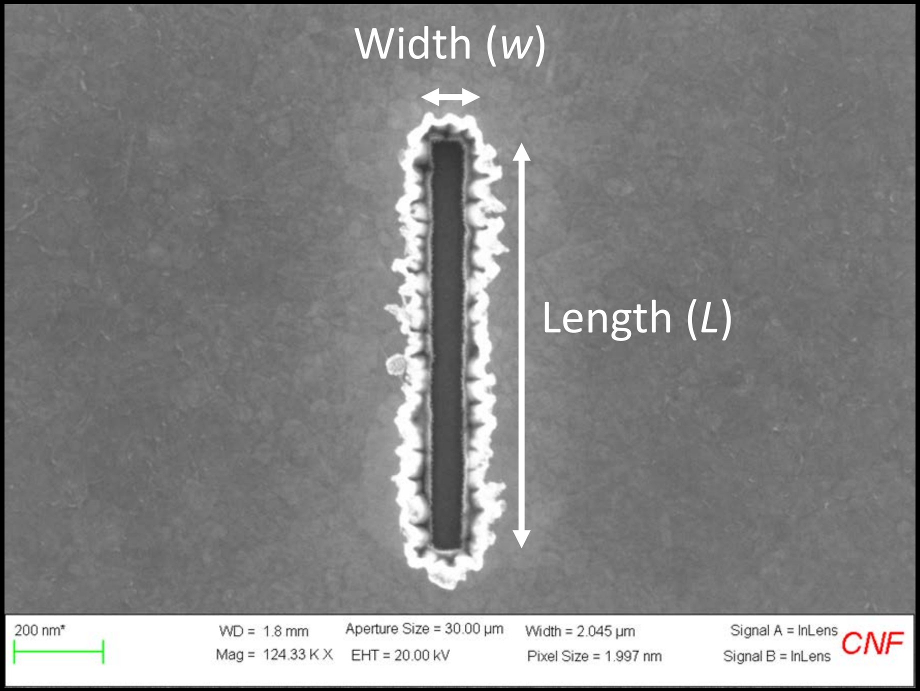
Nanoslit Fabrication



Nanoslit SEM Images

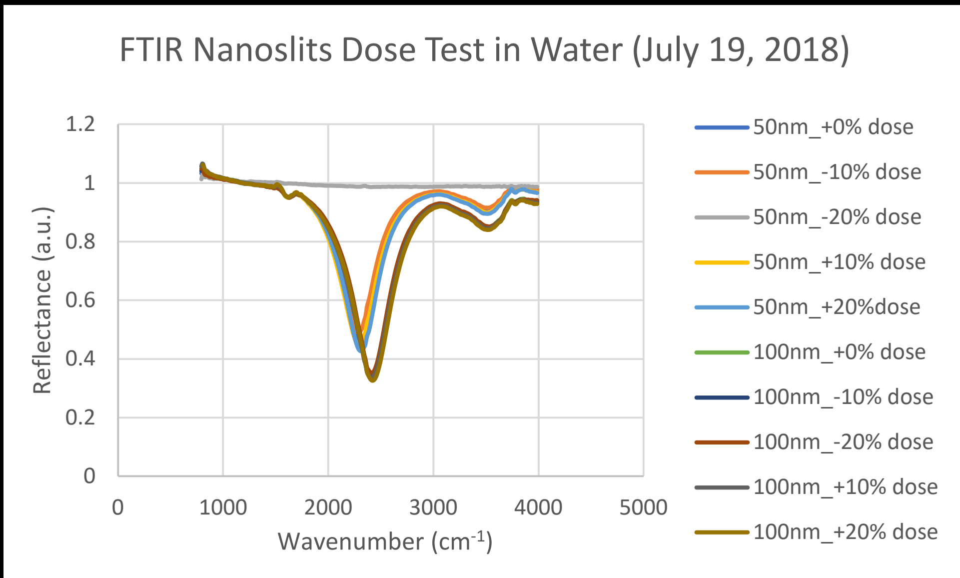


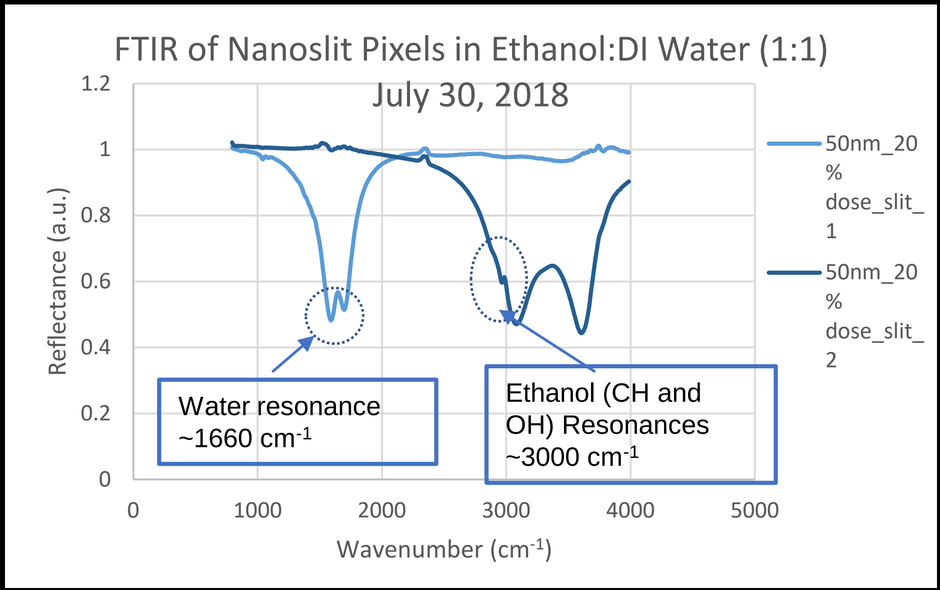
Nanoslit array with *s = 1.488 µm* and *v* = 634.6 *nm*.

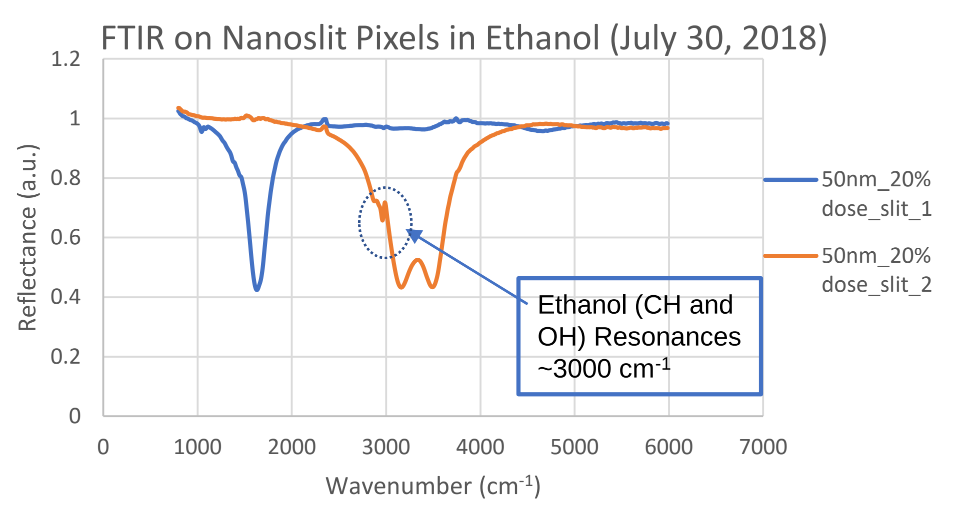


Nanoslit with *w = 102.3 nm* and *L = 956.5 nm*.

Nanoslit Data

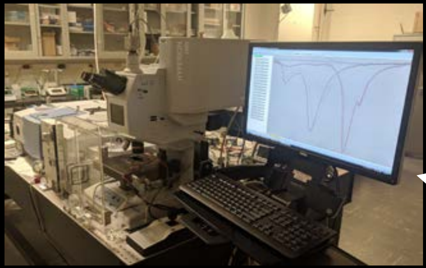






PDMS Microfluidic Chamber

Structure	Width, w (nm)	Length, L(nm)
slit_1	50	700
slit_2	50	1500



FTIR Setup

Conclusions & Acknowledgements

- **CONCLUSIONS:**
  - **Successfully fabricated FRAMM, nanoantennae, and nanoslits structures**
  - **Tuned resonances to desired frequencies**
  - **Shows promise for biosensing by plasmonic metasurface-enhanced IR spectroscopy**

- **ACKNOWLEDGEMENTS:**
  - **National Science Foundation**
  - **National Nanotechnology Coordinated Infrastructure**
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  - **Dr. Steven Huang, Dr. Maxim Shcherbakov**
  - **CNF REU Program Coordinator & Staff**
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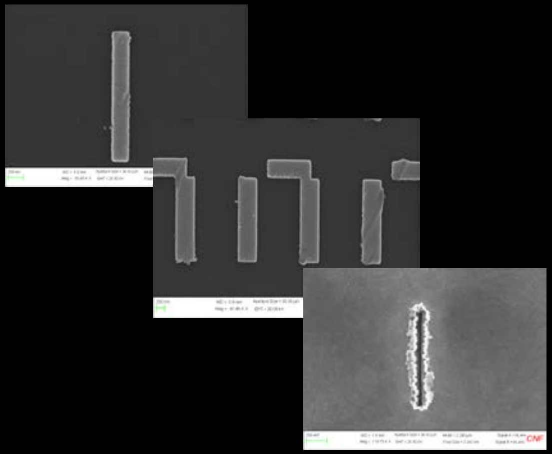

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