# Fabrication of Gold Bowtie Nano-antenna by E-beam Lithography on $Si_3N_4$ Membrane for SERS

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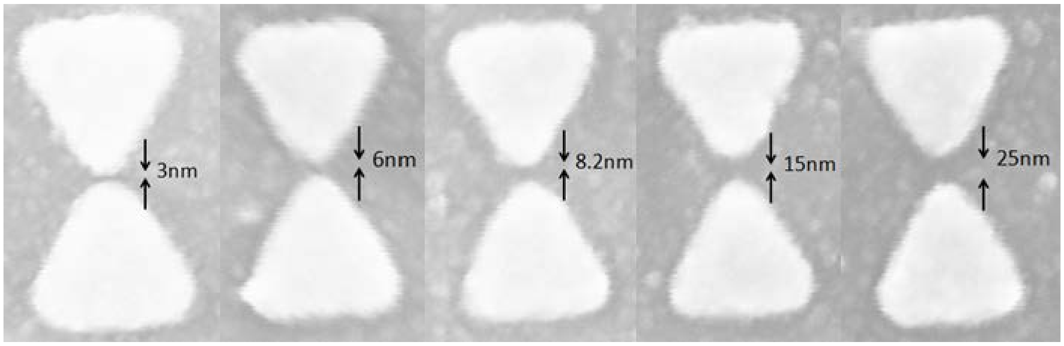
Surface enhanced Raman scattering (SERS) is a sensitive chemical sensing technique capable of single molecule detection, and is mainly due to the localized surface plasmon resonance (LSPR) of noble metal nano-particles onto which the target molecules adsorb. Strong LSPR thus strong SERS enhancement usually occurs at the “hot spots”, such as the sharp tips of the nano-particles, or the tiny gaps between adjacent nano-particles. Recently bowtie (two triangular nanostructures facing each other) array with nano-gap is considered as a more tunable and reproducible structure for SERS than randomly aggregated nano-particles[1, 2]. Both experiments and theoretical simulation showed that large enhancement factor occurs for small gap with several nanometers. Due to proximity effect in electron beam lithography (EBL), it is challenging to fabricate such a small gap. Though proximity effect can be significantly reduced by optimizing exposure dose distribution using numerical simulation of electron trajectory and energy loss in the resist and substrate[3], it can be nearly completely eliminated only by removing the thick substrate and coating the resist on a thin membrane[4, 5], which will be the focus of the current work.

In the experiment, 170 nm PMMA was spin-coated on 100 nm $Si_3N_4$ membrane and baked. Cr layer of 10 nm was coated on PMMA as a conducting layer for EBL. After exposure and development, 1 nm Cr and 25 nm Au were deposited by e-beam evaporation, followed by lift-off to achieve the gold bowtie array structures. As shown in Figure 1, the narrowest gap we obtained is 3 nm, though for this size the gap is not uniform with many gaps connected. Larger gaps are more uniform and reproducible.

For SERS characterization, the sample was soaked in the ethanol solution of 1 mM trans-1,2-bis(4-pyridyl)ethylene (BPE) for overnight. Figure 2 shows the Raman spectrum with excitation laser wavelength of 785 nm. As expected, the Raman scattering peak intensity depends strongly on the gap size, implying a strong hotspot effect in the bowtie structure. Figure 3 shows numerical simulation using FDTD method of the near field distribution at 785 nm wavelength for the bowtie structure with 8 nm gap. As seen, the field is strongly localized at the gap of the bowtie structure.

[1] A. M. Michaels, J. Jiang, L.Brus, J. Phys. Chem. B, 104, 11965 (2000).
[2] N. A. Hatab, C. H. Hsueh, A. L. Gaddis, S. T. Retterer, J. H. Li, G. Eres, Z. Zhang, B. Gu, Nano Lett., 10, 4952 (2010).
[3] M. Manheller, S. Trellenkamp, R. Waser, S. Karth, Nanotechnol., 23, 125302 (2012).
[4] M. D. Fischbein, M. Drndić, Appl. Phys. Lett., 88, 063116 (2006).
[5] H. Duan, A. I. Fernández-Domínguez, M. Bosman, S. A. Maier, J. K. W. Yang, Nano Lett., 12, 1683 (2012).



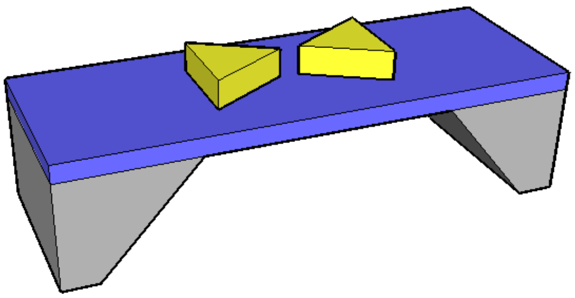



Figure 1: Schematic and SEM image of gold bowtie nano-structure with varied gaps from 3 nm to 25 nm.

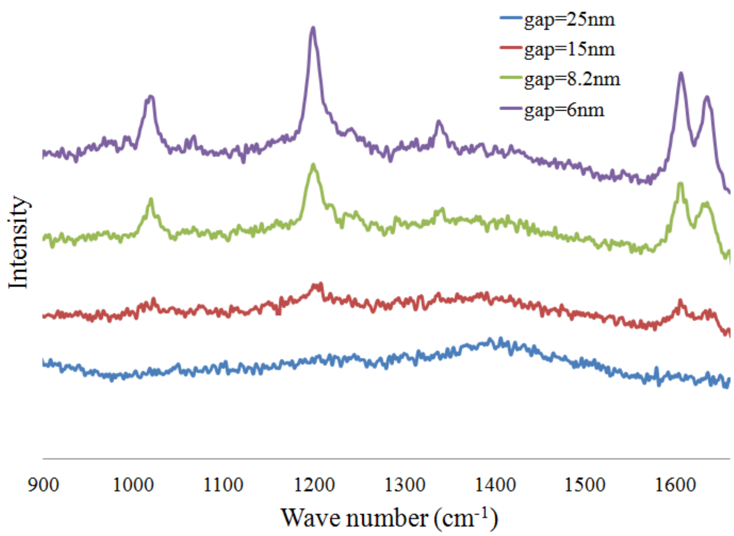



Figure 2: Raman spectrum of gold bowtie array with gap of 6 nm, 8.2 nm, 15 nm and 25 nm.

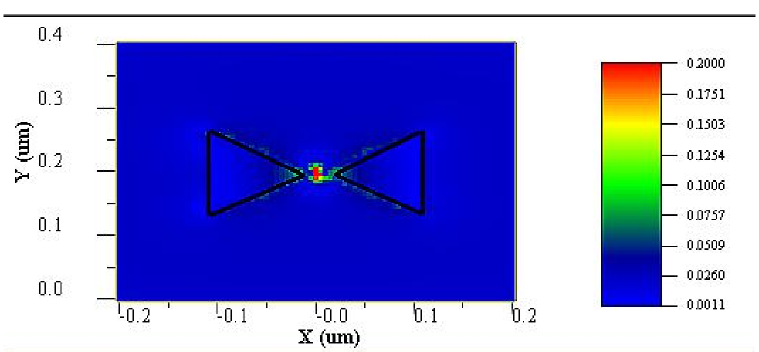



Figure 3: Simulated electric field distribution of a gold bowtie structure with 8 nm gap generated by the laser with wavelength of 785 nm.