Fabrication of Nanojunction with Sub-10 nm Nanogap for Surface Enhanced Raman Scattering by Tensile Stress Mechanically Breaking

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How to obtain an ultrasensitive, uniform, stable surface enhanced Raman spectroscopy (SERS) response is always a bottleneck for practical application of SERS. It has been widely recognized that the SERS phenomenon is mainly based on the laser excitation inducing localized electromagnetic field enhancement (the area with high electrical field was called 'hotspots') on the surface of roughed or patterned noble metals. Therefore, researchers who were focused on the optimization of the SERS substrates paid much attention to nanogaps, which are ideal nanostructure to produce high 'hotspots'. However, fabrication of sub-10 nm features meets the limits of top-down nanofabrication. Photolithography is limited by the diffraction of light with only advanced deep UV reaching sub-100 nm features. Electron beam lithography can typically produce features only on the order of tens of nanometers. To overcome these limitations, various methods have been developed, such as glancing angle deposition, focused ion beam milling, electromigrated break junctions and mechanically break junctions[1].

This work has developed a technique that advances the mechanically break method in order to produce nanojunctions with the width of the nanogap well controlled below 10 nm. A summary of the fabrication procedure is as follows. A single electron-beam lithography (EBL) step was used to define the pattern of the nanojunction array on a (100) silicon substrate with a 200 nm low-pressure chemical vapor deposition silicon nitride. Then the pattern was transferred into the silicon nitride film, creating an array of 100 nm wide by 250 nm long junction connecting two pads. After the other part of silicon nitride film being etched out, the junction mechanically broken and formed a nanogap with sub-10 nm in width due to the tensile stress, as shown in Figure 1a and Figure 1b. Metallization was carried out by magnetron sputtering of a 10 nm Ag directly to the nanojunction. Figure 1c shows a tilt-view scanning electron microscope image of a metalized nanogap, which indicates a nanogap of sub-10 nm. A water soluble protein cytochrome c was chose to for this study. Figure 1(d) is the Raman spectrum of cytochrome c. The distinguished Raman signal from ultra-low concentration of protein molecules elucidate that the preponderance of the nanojunction in plasmonic based detection.

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[1] J.H. Tian, B. Liu, X.L. Li, Z.L. Yang, B. Ren, S.T. Wu, N.J. Tao, and Z.Q. Tian, J. Am. Chem. Soc. 128, 14748 (2006).

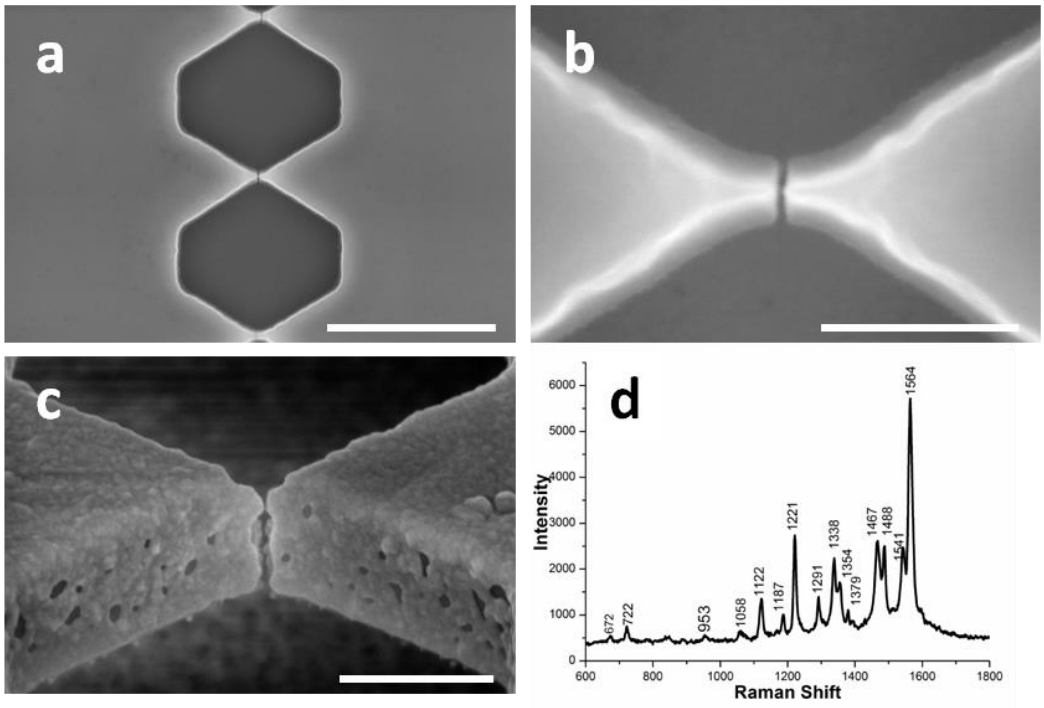

Figure 1: (a)-(c) are scanning electron microscope images of nanojunction array, single nanogap and tilt-view of a metalized nanogap at an angle of 52°. Scale bars are 1 μm, 200 nm and 300 nm, respectively. (d) The Raman spectrum of cytochrome c.