Dynamical Formation of Plasmonic Nanopore and its Optical Characteristics For Ultrafast Genome Sequencing

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Recently there have been tremendous interests about the nanopore technology due to urgent demands of the ultrafast DNA sequencing device with less than 24 hour diagnosing time and less than $1000 demands by NIH, USA. DNA translocation through a natural hemolysin nanopore with electrical signal detection scheme has been successfully carried out by Dr. Bayley and et al [1, 2]. The solid-state nanopore array using SiN and graphene has also been tried to provide the DNA footprints by others. However, the optical detection technique such as SERS can better characterize the DNA. In this report, the dynamical sequence of the nanopore formation *with video-imaging* and the optical characteristics of the nanofabricated plasmonic nanopore will be presented. Initially, the oxide aperture was fabricated followed by metal deposition. The metal aperture slit ranging from ~ 10^0 nm width to 10^2 nm is obtained. Figure 1 shows the differences of the surface morphology of the FESEM from those of 200 keV TEM due to the nonuniform cylindrical wall. The 5keV FESEM imaging and 200 keV TEM images present the nonuniform structure of the nanopores. In order to get the uniform cyldrical wall of the nanopore, the 30 keV Focused Ga ion beam (FIB) drilling is introduced and the Au diameter of ~50 nm was obtained. In order to better control the size reduction of nanopore less than 10 nm, the electron beam annealing technique is introduced. The pore diameter of ~5 nm or less is obtained using 20 keV electron beam exposure. The probe diameter of the Hitachi S 4800 Type II FESEM is ~ 1 nm and has a maximum current of ~ 2 nA. The temperature rise due to electron beam exposure is linearly dependent upon the electron energy and the current, and inversely proportional to thermal conductivity of the materials [3]. The widening and the reduction of the nanopores depending upon the electron fluences were also observed and *videorecorded* during 300 keV electron beam exposure. The successive size reduction of the nanopore was also observed for 200 keV using JEOL 2010 TEM [Figure 2]. These can be attributed to melting and evaporation of the Au membrane dependent upon the temperature from electron beam bombardment on the Au membrane. In addition, the optical characteristics of the fabricated Au nanopore were measured using Nikon TE inverted microscope with tungsten halogen lamp and Princeton instrument/Acton (Pixie:400, spectroscopic-format CCD). The increasing optical transmittance with decreasing the nanopore size is shown in Figure 3. The extraordinary transmission can be attributed to the optical vortexed photonic flow into the decreasing the size of the Au nanoaperture[4, 5]. The nanofabricated device can be utilized as single molecule nanobio sensor and genome sequencing.

References

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Figures:

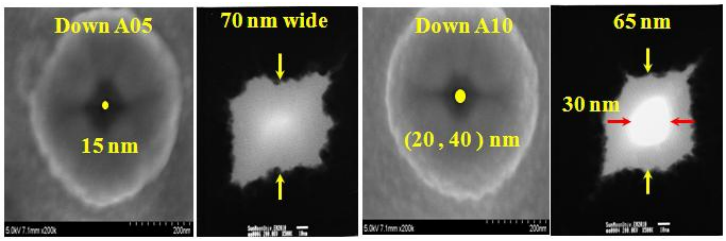

Figure 1. Nanopore images of the samples. The images of the 5 keV SEM for the samples AO5 and A10 does present different images from the images of 200 keV TEM images. This phenomena can be attributed to the nonuniform cylindrical structure of the nanopore, and the different sampling depth for different electron energy of FESEM, and due to the different imaging technique of TEM from that of the SEM.

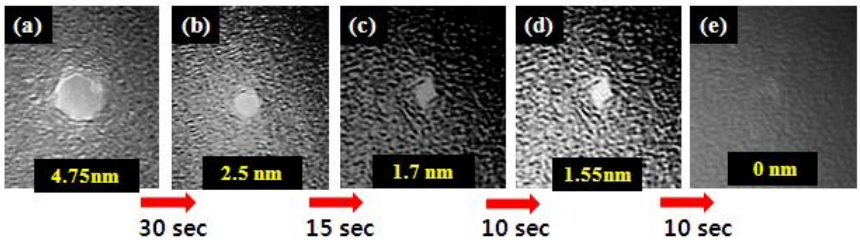

Figure 2. Dynamic sequence of nanopore closing using electron beam exposure with 200 keV TEM(Jeol 2010).

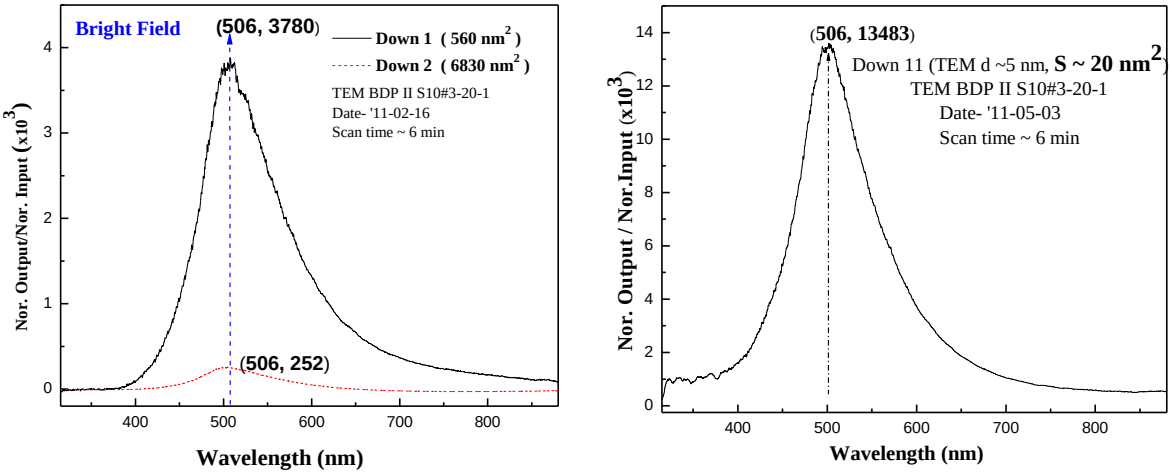

Figure 3. Optical transmittance spectra through the Au nano-channel on the pyramid. With decreasing the size from 6830, 580, and 20 nm^2, the peak transmittance has been increased to 252, 3780, and 13483, respectively. The peak position was also shifted.from input peak 678 nm to output peak 550 nm due to surface plasmon resonance.