University of Victoria | Graduate Studies

Notice of the Final Oral Examination for the Degree of Doctor of Philosophy

of

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"Double Nanohole Optical Tweezer for Single Molecule and Nanoparticle Analysis"

Department of Electrical and Computer Engineering

Tuesday, January 12, 2016
9:30 A.M.
Engineering Office Wing
Room 230

Supervisory Committee:
Dr. Reuven Gordon, Department of Electrical and Computer Engineering, University of Victoria (Supervisor)
Dr. Tao Lu, Department of Electrical and Computer Engineering, UVic (Member)
Dr. Marting Byung-Guk Jun, Department of Mechanical Engineering, UVic (Outside Member)

External Examiner:
Dr. Peter Pauzauskie, Material Science and Engineering, University of Washington

Chair of Oral Examination:
Dr. Daniela Constantinescu, Department of Mechanical Engineering, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies

Abstract

This dissertation presents novel techniques applied to double nanohole (DNH) optical tweezer with the idea of characterizing and developing capabilities of nanoaperture trap, for single molecule and nanoparticle analysis. In addition, an alternative approach for fabrication of double nanoholes using template stripping is presented. The strength of the DNH tweezer was characterized quantitatively in terms of trap stiffness using two techniques: autocorrelation of Brownian-induced intensity fluctuations and trapping transient. These experimental techniques have, for the first time, been applied to an aperture based trap used for trapping Rayleigh particles in the range of few nanometres. These techniques can be used for calibration and comparison of the aperture based traps among themselves and with other nano-optical tweezers. A statistical technique based on the parameters, time-to-trap and the transient jump due to optical trapping was used for sensing the concentration, size and refractive index of the nanoparticles. The time-to-trap showed a linear dependence with particle size and a -2/3 power dependence with particle concentration, which is in agreement with the diffusion theory based on simple microfluidic considerations. The transient jump in the trapping signal at the trapping instant scales empirically as the Clausius–Mossotti factor for different refractive index particles. The ability of the DNH tweezer to hold small Rayleigh particles with high efficiency and also the increased sensitivity of the transmission signal to the trapped particle during detection makes it favourable for studying the dynamics and interactions of biomolecules. In this direction, the unzipping of the hairpin DNA and its interaction with the tumour suppressor p53 transcription protein, which suppresses the unzipping, were detected using double nanohole optical tweezer. The energy associated with the suppression of unzipping was found to be close to the binding energy of p53-DNA complex. The mutant p53 inability to supress the unzipping of the DNA was also confirmed, showing the ability of the DNH tweezer to distinguish between the mutant p53 and the wild-type. An extraordinary acoustic Raman (EAR) technique was used to study the vibrational modes of ssDNA molecule. The resonant vibrational modes were found to be in the sub 100 GHz range and could be tuned based on the base sequence and length of the DNA strand. The vibrational modes were verified using 1-D lattice vibration theory. Finally, an alternative approach of template stripping for fast and cheaper fabrication of DNH is presented. The template strip process can be used reliably for mass production of gold slide containing DNH's and also results in cost reduction by 70 % for a single gold slide. Also, we have successfully used this approach to transfer DNH structure to the tip of the cleaved fiber, which would make the DNH tweezer module more compact and scalable. This would open up opportunities for many other applications for single molecule and nanoparticle analysis such as transfer of molecules in-situ to other biomolecular solution for studying their interactions and many others.