Department of Manufacturing Engineering and Engineering Management

Seminar Series

Magnetic Tweezers: Actuation, Measurement, and Control at Nanometer Scale

by

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Venue: Y4701, 4/F, Academic Building

Abstract

Cells are the smallest and functional units of all living organisms. Discovered more than 300 years ago, cells have been a very challenging yet interesting subject for researchers and till now we are still in the process of learning how cells work. It has been demanded to study cells at nanometer scale, i.e., the length scale of protein structures, as the functioning of cells and organisms are essentially controlled by individual biomolecules and their interactions, whereas the studies have been limited by the availability of high resolution technologies. Magnetic tweezers, which are capable of not only making observations in real time, but also applying forces to actively manipulate biological samples at nanometer scale, are developed and presented.

Magnetic tweezers use electromagnets and tip-shaped poles to generate a magnetic field gradient and exert magnetic force on microscopic magnetic particles. Due to the biocompatibility and target specificity of the magnetic force, micrometer/submicrometer magnetic probes can be employed to manipulate living cells in their physiological condition. Furthermore, the motion of and the force applied to the magnetic probe can be remotely controlled by varying the magnetic field. The developed magnetic tweezer consists of three components: the multi-axis magnetic

actuation, the three-dimensional particle tracking system based on computer vision, and the real-time visual feedback control system.

In particular, quadrupole magnetic tweezers are designed and implemented. An analytical magnetic force model, which characterizes the relationship between the applied currents to the coils and the resulting magnetic force to the probe, is formulated. Three-dimensional particle tracking system is built based on computer processing of real-time video images, and subnanometer resolution in all three axes is achieved. Feedback control further advances the magnetic tweezer from a force applier to a multi-functional manipulator. Combining the three components, the magnetic tweezer system is capable of not only trapping and tracking a magnetic probe in multiple axes, but also applying force to and sensing force from the probe.

The developed system is then applied to study the mechanical properties, the response anisotropy, as well as the adaptation to forces of normal and tumor human breast cells. This study has the potential to provide us a better understanding of the mechano-signatures of cells, which may eventually lead to the development of new strategies for cancer prevention and/or therapy.

BIOGRAPHY

Zhipeng Zhang received the B.S. degree from Tsinghua University, Beijing, China, in 2003, and the M.S. and Ph.D. degrees from The Ohio State University, Columbus, OH, USA, in 2005 and 2009, respectively, all in mechanical engineering. He is currently a post doctoral researcher at the Department of Mechanical Engineering at The Ohio State University.

His research has three areas of focus: 1) design, control, and instrumentation of electromechanical systems; 2) optical nano metrology and visual servo control; and 3) manipulation of active biological systems and cell mechanics

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All are welcome!