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Author(s)	Mst. Rubaya, Rashid
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学 位 論 文 の 要 約

博士の専攻分野の名称　博士（理学）　　　　氏名　Mst Rubaya Rashid

学 位 論 文 題 名

Force Measurement of Kinesin Propelled Microtubules in Swarming Using an Electromagnetic Tweezer
（電磁ピンセットを用いたキネシンにより推進する微小管の群れにおける力測定）

Swarming is the collective behavior of multiple self-propelled entities like insects, birds, fish, and microorganisms, emerging through local interactions rather than a leader. Swarming has several advantages that a single entity cannot achieve, such as parallelism, robustness, and flexibility. Inspired by natural swarms, researchers in the field of biotechnology and materials science aim to replicate them in artificially exploiting their advantages in different nanotechnological applications.

Recently, DNA-based controllable swarming of MT driven by multiple kinesins has been demonstrated to exhibit translational and rotational motions. The swarming of MTs holds great potential as their motion can be harnessed to perform work for nanotechnological applications, in molecular machines and robotics. To ensure real-life applications, it's essential to quantify the work harnessed from MT swarms. The force-velocity relationship for single and multiple kinesins (1 to 10) under increasing loads is well-studied. In this work, I quantified the force associated with kinesin-driven MT swarming.

For single molecular force study in biological systems, an optical tweezer is a commonly used tool that provides the forces in the piconewton range. The force of the MT swarm propelled by multiple kinesins is expected to be higher than single kinesins. Recently, it has become popular to use magnetic beads as cargo to apply controlled forces using electromagnetic tweezers (EMTw), and forces ranging from 0 to hundreds of pN can be easily handled. An EMTw system has been custom-built in this work to apply controlled force (emf). Dynabeads attached to MT swarms by DNA interaction and emf was applied to determine the force of the swarm.

By changing the direction of a bead loaded onto a swarm ring with circular motion, the electromagnetic tweezer (EMTw) system applied varying force amplitudes based on the angles between the emf and the bead's motion and velocity was manipulated. Using a force calibration curve, I determined the swarm's force. The density of kinesin was also estimated to compare force from different swarms. The forces from different swarm ring sizes showed a sub-additive force increase with more active kinesins. This force estimation will enhance the applications of MT swarms in nanotechnology and robotics.

The structural details of the packing and alignments of MTs in a swarm was also investigated using a high speed atomic force microscopy. It was found that, the multiple MTs self-organize laterally and form multiple layers with an increasing number of MTs in a swarm. These findings provide new insight into the structure of the ring-shaped MT swarms and the alignment of MTs in the swarms.