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Assembling and Transporting Nanocomposite Materials using Kinesin and Microtubules

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Living materials are fundamentally different from synthetic materials with respect to both intrinsic nature and formation. While synthetic materials are generally static, living systems utilize energy to assemble, reconfigure, and dismantle materials in a dynamic, highly non-equilibrium fashion, and are capable of adapting to changing environmental conditions or stimuli. The overall goal of our work is to exploit key strategies used by living systems to develop new types of nanocomposite materials in which the assembly, configuration, and disassembly can be programmed or self-regulated in microfluidic environments. Kinesin motor proteins and microtubule filaments (MTs) have been selected as a model system for directing the transport of molecular cargo, and assembly of nanocomposite materials at synthetic interfaces.

Initial work has focused on characterizing and engineering the properties of kinesin and MTs for robust performance in microfluidic systems. The coding sequence of a thermostable kinesin from *Thermomyces lanuginosus* has been isolated, cloned, and over-expressed in *E. coli*. Characterization of the temperature-dependent kinetics of this kinesin demonstrated a significant increase in the rate of ATP hydrolysis and MT transport at elevated temperatures (Fig. 1). As a whole, the unique properties of this kinesin suggest that it is well suited for its application in artificial systems.

Several strategies have been developed for assembling and organizing metal and semiconductor nanoparticles using MT filaments as nanoscale scaffolds (Fig. 2). A variety of nanocomposite structures may be formed using these strategies. Subsequent work has demonstrated the ability to transport composite MTs at synthetic interfaces using surface-tethered kinesin. The binding efficiency and transport velocity, however, are distinctly dependent on the nanoparticle composition and distribution on MT filaments.

Most recently, work has focused on directing the transport and transfer of cargo in microfluidic platforms using the kinesin/MT system. A combination of micromachined surfaces and self-assembled monolayers were used to demonstrate selective absorption of kinesin, and effective guiding of MTs. Further, we have characterized the transfer of attached cargo between MTs being transported by surface-tethered kinesin (Fig. 3).

In summary, we have established a number of key enabling technologies for using kinesin/MTs as a means for assembling and transporting nanocomposite materials. The long-term goal of this work is to demonstrate the ability to control the structure and functionality of nanocomposite materials through the dynamic processes associated with active transport by MTs and kinesin.

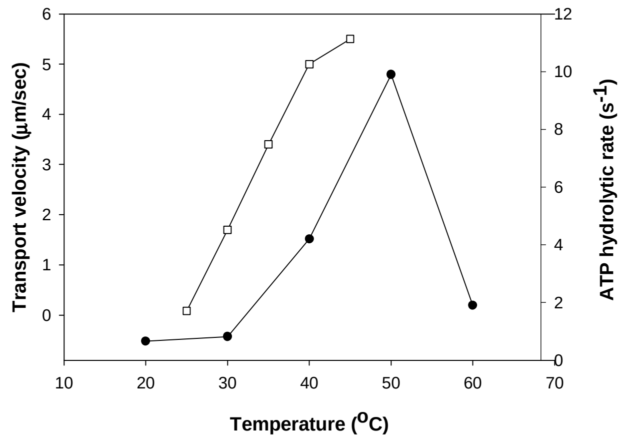

Fig. 1. Temperature dependent effects on the transport velocity (-□-) and ATP hydrolytic rate (-●-) for *Thermomyces kinesin.*

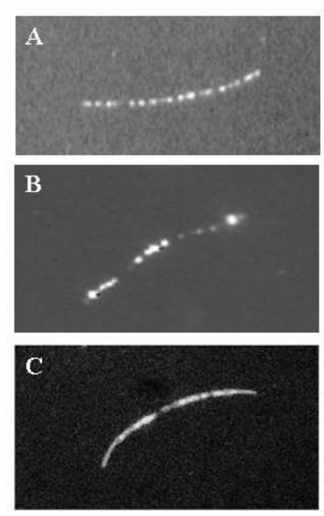

Fig 2. Fluorescence photomicrographs of (A) gold nanoparticles and (B, C) CdSe nanocrystal quantum dots organized on MT scaffolds.

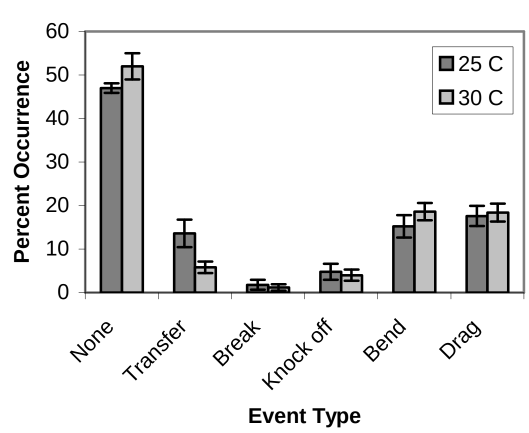

Fig 3. Proportions of the different events at 25°C and 30°C observed during cargo transfer studies.