Fast and Efficient DNA Molecular Machines: A Bipedal Walker

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Abstract

Biological molecular machines can perform hundreds of serial operations with remarkably high yields and operational rates. Inspired by such machines, researchers have utilized DNA nanotechnology to develop DNA-based machines that demonstrate enzymatic activity, structural manipulations, maneuvering of substrate molecules and molecular computing. However, low operational yields and slow machine responds hinder machines development and application.

In an effort to develop fast and efficient DNA molecular machines we have developed a bipedal motor that strides on a DNA origami. The motor operates by responding to ‘fuel’ and ‘antifuel’ DNA strands that are provided by computer controlled microfluidics device, and the motor operation and progress are monitored by single-molecule fluorescence spectroscopy.

With this setup we demonstrated the performance of 32 walking steps (64 consecutive chemical reactions), which amount to 370 nanometers traveled by the walker. In this motor version, high concentrations of fuel strands, which are required for fast motor respond, resulted in low operational yields. To solve this problem, we have developed a new bipedal walking mechanism that allows using high concentrations of fuels without reducing operational yield, and demonstrated 10-fold increase in motor speed. This is significantly more operations and faster motor responds than were previously reported for DNA based externally controlled molecular machines.

Furthermore, detailed analysis of the motor performance and reaction kinetics, made possible by the microfluidics and single-molecule fluorescence, yielded detailed understanding of the motor operational mechanisms and accurate modeling of the walker processivity, and facilitate rational improvements of the motor design and operational mechanism.

References


Figures

Figure 1. Bipedal DNA walker strides on DNA origami track