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Toehold Mediated Shape Transition of Nucleic Acid Nanoparticles

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Abstract : Development of functional materials undergoing structural transformations in response to an external stimulus such as environmental changes (pH, temperature, etc.), the presence of particular proteins, or short oligonucleotides are of great interest for a variety of applications ranging from medicine to electronics. The dynamic operations of most nucleic acid (NA) devices, including circuits, nano-machines, and biosensors, rely on networks of NA strand displacement processes in which an external or stimulus strand displaces a target strand from a DNA or RNA duplex. The rate of strand displacement can be greatly increased by the use of “toeholds,” single-stranded regions of the target complex to which the invading strand can bind to initiate the reaction, forming additional base pairs that provide a thermodynamic driving force for transformation. Herein, we developed a highly robust nanoparticle shape transition, sequentially transforming DNA polygons from one shape to another using the toehold-mediated DNA strand displacement technique. The shape transformation was confirmed by agarose gel electrophoresis and atomic force microscopy. Furthermore, we demonstrate that our approach is applicable for RNA shape transformation from triangle to square, which can be detected by fluorescence emission from malachite green binding RNA aptamer. Using gel-shift and fluorescence assays, we demonstrated efficient transformation occurs at isothermal conditions (37°C) that can be implemented within living cells as reporter molecules. This work is intended to provide a simple, cost-effective, and straightforward model for the development of biosensors and regulatory devices in nucleic acid nanotechnology.

Keywords : RNA nanotechnology, bionanotechnology, toehold mediated DNA switch, RNA split fluorogenic aptamers
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