DNA Origami: Prospects for Nanomanufacturing

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Since its invention in 2006,[1] DNA origami has proven to be an invaluable platform for exploring the potential of DNA nanotechnology. However, to move from research tool to manufacturing technology, a number of questions have to be answered. For example, what controls the speed and yield of an assembly process? Is it possible to integrate a broad range of heterogeneous nanostructures onto origami? What factors control the minimum spacing between them? What precision can be expected in their placement? Can high-purity products be generated? By investigating such questions we have sought to provide design rules for the fabrication of functional constructs using DNA origami as a nanoscale breadboard.

We will describe the heterogeneous integration of quantum dots (Qdots) and gold nanoparticles (AuNPs) onto origami and present data that enables us to determine the effect of the interaction of the Qdots with AuNPs on Qdot fluorescent lifetime as a function of Qdot emission wavelength, and the number, size, and spacing of the AuNPs. The data we obtain demonstrates that the placement precision of the various nanoparticles is approximately one nanometer. Combined with our earlier work[2] on the reaction rates for the assembly process and current work on the potential for high-yield product purification, this information provides a framework for developing a set of design rules for origami-based constructs. We will demonstrate that, while perhaps not suited to the production of electronics, DNA-base methods can be very powerful for the fabrication of nanoscale sensors and theranostic agents.

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[1] P. W. K. Rothemund, *Nature* **2006**, *440*, 297-302.
[2] S. H. Ko, G. M. Gallatin, J. A. Liddle, *Adv. Funct. Mater.* **2012**, *12*, 1015-1023

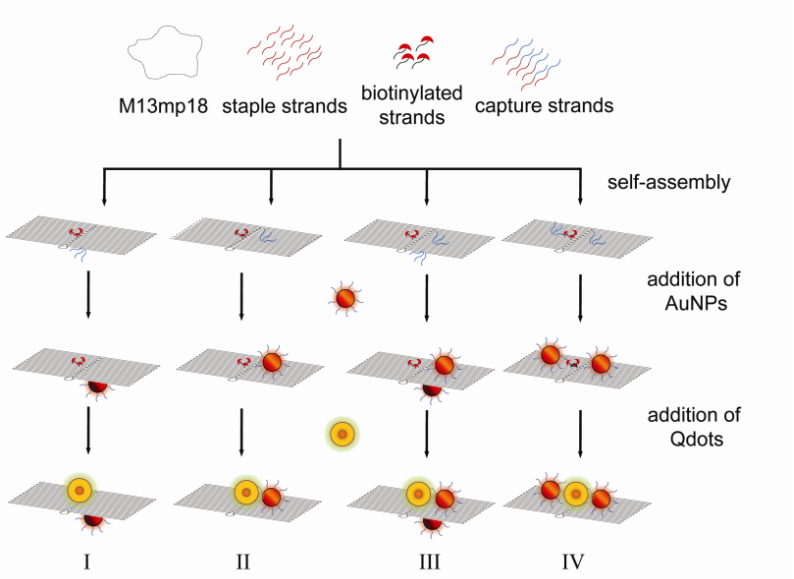

Fig. 1. Schematic representation of the fabrication process of Qdot-AuNP conjugates on DNA origami templates. Each group of three biotin-conjugated staple strands and triple sticky-end capture strands is located at predetermined binding sites to capture streptavidin conjugated Qdots and DNA-functionalized AuNPs, respectively. The estimated interparticle distances of Qdot and 15 nm diameter AuNPs are (15.0 ± 1.1) nm for the same side (I, III, and IV) and (17.6 ± 1.1) nm for the opposite side (II and III).

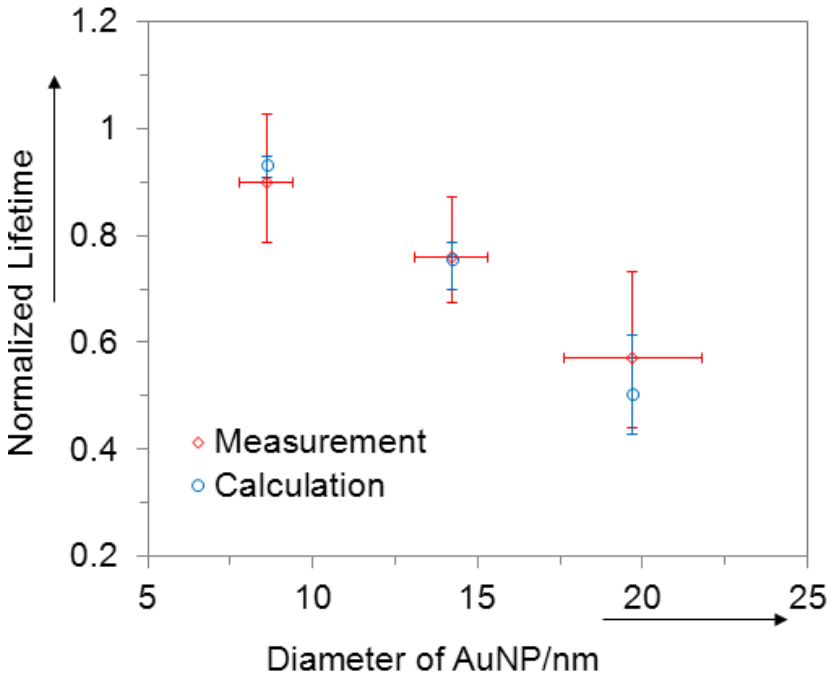

Fig. 2. Comparison of calculated and measured normalized lifetime of Qdot 585 with different size of AuNPs on the same side of DNA origami (design II). The horizontal error bars for the particle size are one standard deviation (σ), as determined from the TEM measurements of AuNP diameter, while the vertical error bars are one standard deviation in measured lifetime. The error bars for the calculation are determined by performing the calculation for the range (mean ± 1σ) of AuNP sizes observed. The calculation represents the weighted average of the lifetimes given tangential (T) or radial (R) orientations of the Qdot dipole with respect to the AuNP, i.e. (2T+R)/3.