Programmable Self-Assembly of Bio-Abionic Hybrid Materials

NSF Nanobiology

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DNA nanostructures and nanomachines

What make the approach work well?

Complex interactions (both intra-molecular and inter-molecular) are programmable, because of the simple and robust molecular coding language of DNA (basepairing).
Examples of complex DNA nanostructures

Science 2012
50nm

Science 2014
100nm

Nature Comm 2019
50nm

Nature Comm 2021

Nature 2017
100nm

Nature Chem 2014
200nm

JACS 2014
20nm
Examples of DNA nanomachines

- Wang, et al., JACS 2021
- Song, et al., Science 2017
- Bazrafshan, et al., Angew. Chem. 2020
Combining “designer DNA nanostructures” with “assembly of other molecules/materials” provides more enabling platforms.
Programmable assembly of nanoparticles and nanorods
Position-controlled spatial organization of proteins

Zhan, et al., Chemical Reviews 2023
Controlled polymer assembly or growth

A. Polymers assembled on the U-shaped pattern

B. Energy transfer through photonic wire

C. Dopamine+H₂O₂

D. Multiple wavelength photopolymerization on DNA origami tubes

E. Monomer derivatives

F. High MW chain

Zhan, et al., Chemical Reviews 2023
Selective mineralization/metallization

A. Thiolated DNA origami template

B. DNA origami

C. Inert pcDNA

Zhan, et al., Chemical Reviews 2023
DNA-directed assembly and fabrication of nanomaterials/biomaterials

**Scaffolding**
- Wang, et al., JACS 2016
- Lan, et al., JACS 2015
- Urban, et al., JACS 2016

**Mineralization**
- Wang, et al., Nature Communications 2021

**In-situ assembly/growth**
- Zhou, et al., JACS 2020
- Yang, et al., Angewandte Chemie 2021

**Lithography**
- Jin, et al., Nature Communications 2013
Some challenges to improving this technology

- Electrode
- Carbon nanotube
- Single molecule analyte

High-density sensor nanoarray

Sun, et al., Science 2020
Some challenges to improving this technology

(1) High precision, low defect, cost-effective assembly.
(2) Multicomponent assembly.
(3) Integration of DNA-based nanodevices into top-down manufactured devices.
(4) Removal, stabilization, and modifications of DNA-based nanodevices.

High-density sensor nanoarray
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