COLUMBIA | ENGINEERING
The Fu Foundation School of Engineering and Applied Science

Gang Group: Integrated Nanomaterials Systems through Bio-Programming

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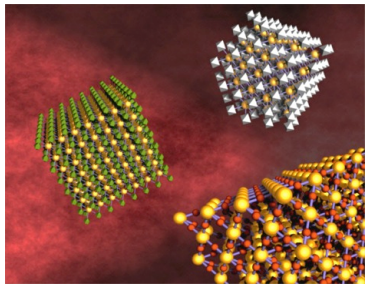
Designed Nanomaterials via Programmable Self-Assembly

Objectives

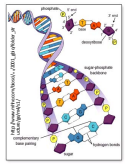
The ability to organize nano-components into the desired organizations is one of the limitations for creating nanomaterials with targeted functions. Our efforts are focused on establishing a broadly applicable DNA-based platform to address this challenge. We explore new concepts for creating targeted static and dynamic nano-architectures from nanoparticles and biomolecules. We are also applying self-assembly methods to create novel materials with optical, chemical, sensing and mechanical functions.



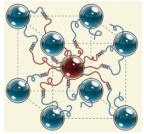
Y. Zhang et al., Nature Nanotechnology, 8 (11), 865 (2013)

Motivations and Approach

Particle cores are inorganic, carry function.

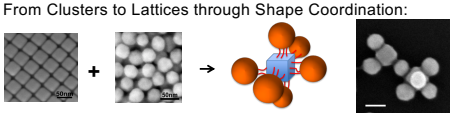


Shells from DNA dictate interactions.

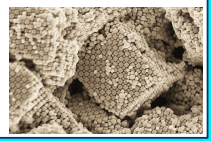


D. Nykypanchuk et al, Nature, 451, 549 (2008); H. Xiong et al, JACS (2008)

From Clusters to Lattices through Shape Coordination:

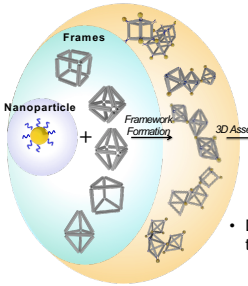


- Nano-cubes can direct spheres into formation of clusters with 6-fold coordination.

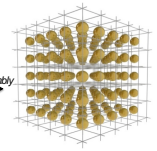


F. Lu, et al, Nature Comm., 6, 6912 (2015)

Prescribed 3D Structures

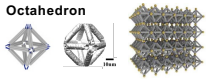


NP-DNA Framework

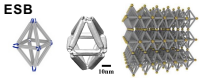


- DNA origami frames are used to coordinate nanoparticles.

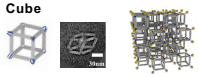
Octahedron



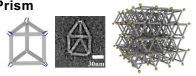
ESB



Cube



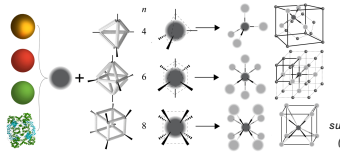
Prism



Y. Tian et al. Nature Materials 15, 654 (2016)
W. Liu et al. Science, 351, 582 (2016)

Platform for Nanoscale Organization

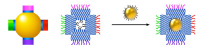
3D Assembly via Valence-prescribed Material Pixels:
Establishing a broadly applicable self-assembly platform



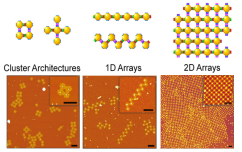
submitted (2018)

Self-Assembly using Polychromatic or "Colored" Bonds:

2D:



- Using multiple types of prescribed bonds to achieve assembly of target nanoscale architectures

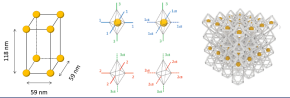


W. Liu et al , Nature Chemistry, 8, 867 (2016)

3D:

Use of octahedra origami:

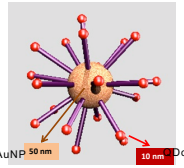
Target Unit Cell:



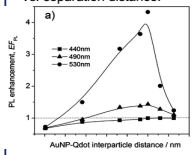
New functions through self-assembled nanomaterials

Optical Nanodevices

Gold Nanoparticle-Quantum Dot Clusters:

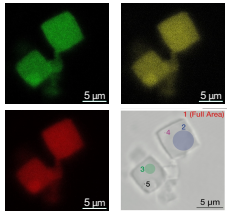


Photoluminescence enhancement *vs.* separation distance:

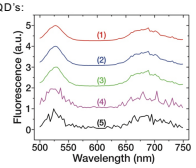


Sun et al., ACS Nano (2015)
Zhang et al ACS Nano (2019)

Assembly of 3D Arrays of Quantum Dots:



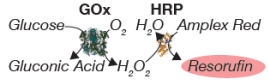
"Perfect Mixing" of fluorescence from QD's:



Y. Tian et al., Nature Materials, 2020

Designed Bio-nano systems

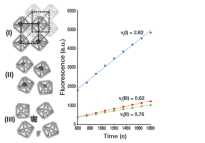
Enzyme Arrays for Catalytic Cascades:



(I) 3D Organization of Enzymes

(II) Enzyme-DNA Origami conjugates

(II) Free Origami and Enzymes

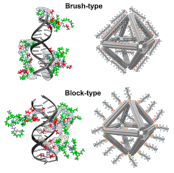


- Nanoscale arrays of enzymatic cascades enhance reactions

Y. Tian et al., Nature Materials, 2020

Peptoid coated DNA constructs anti-cancer drug delivery

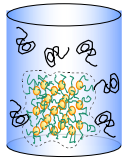
- Peptoid can protect DNA origami in physiological conditions. That allows using DNA constructs for anti-cancer drug delivery, in-vivo imaging and cell targeting.

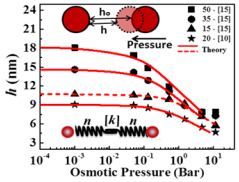


Wang et al., PNAS, 2020

Mechanical Responses

Designed ordered "gel":

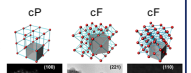




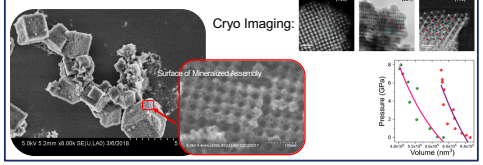
S. Srivastava et al, Soft Matter (2013)

Designed 3D nanomaterials by bio-templating

Unit Cell:

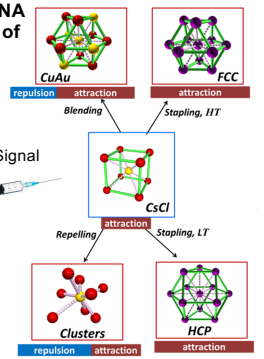


Cryo Imaging:



Switchable Materials

Dynamic Control of DNA Shells for 3D Lattices of Nanoparticles



- DNA signals can be used to reprogram the shells of spherical gold nanoparticles and thus their interactions, allowing for the selective transformation of the self-assembled structure.

Y. Zhang, et al. 14, 840, Nature Materials (2015)

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