Geometrically programmed self-limited assembly of tubules using DNA-origami colloids

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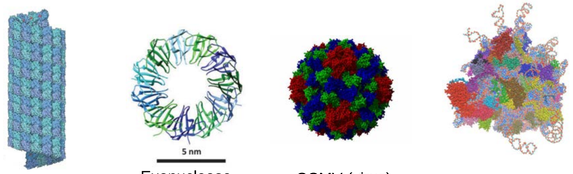
Introduction

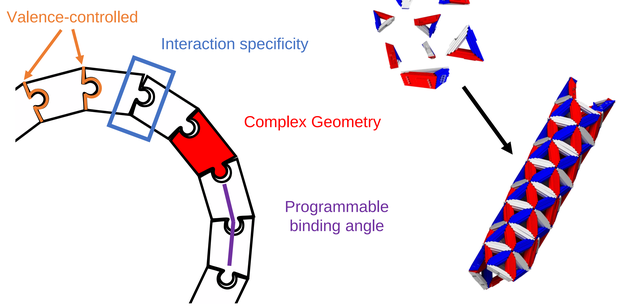
Biological systems have adapted to self-assemble many different objects with self-limiting dimensions, such as spherical viral capsid, filamentous microtubules, or planar lipid membranes. The goal of IRG1 is to engineer systems that will exhibit pathways to self-limited assemblies.



Microtubules Exonuclease CCMV (virus) Ribosome

One thrust to achieve this is varying the curvature of assembly subunits; this allows for different motifs of structure formation. Here, we are looking into the creating monomers for tubule formation.

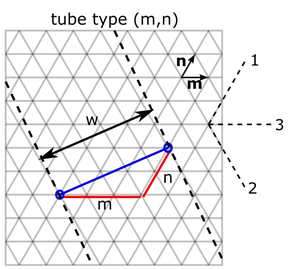
Goal: Can we make synthetic, self-limited assemblies?

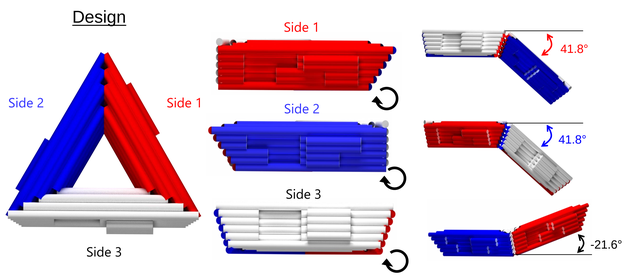


Designing building blocks for tubules

Design DNA origami monomers with:

- Valence limited interactions
- Specific, lock-and-key interactions
- Tunable binding angles



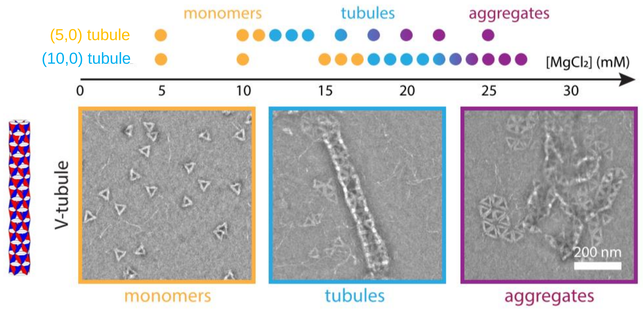


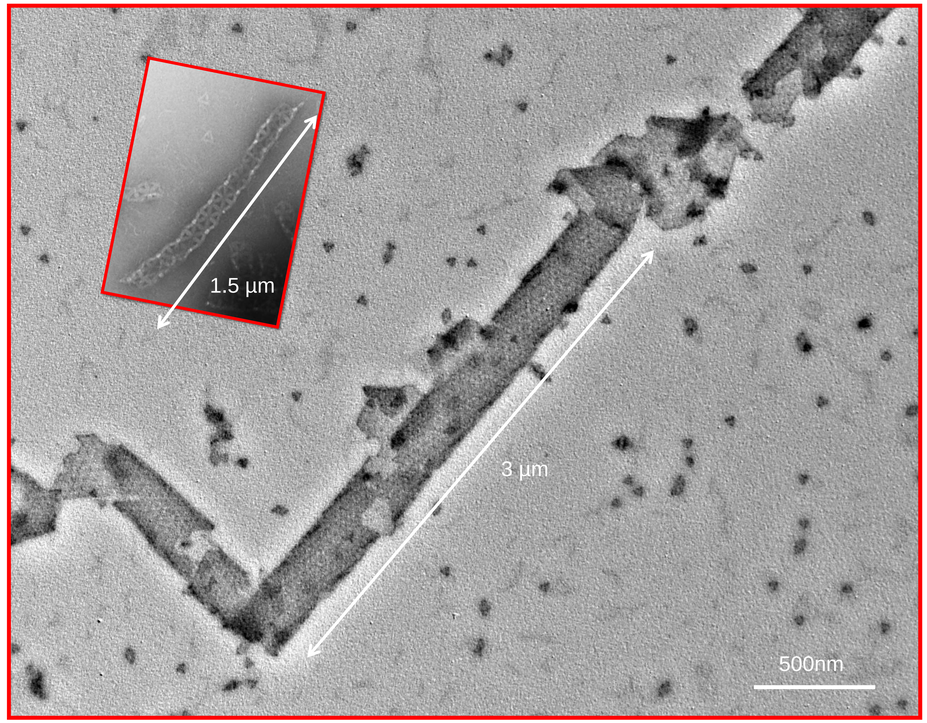
Realization of tubule assemblies

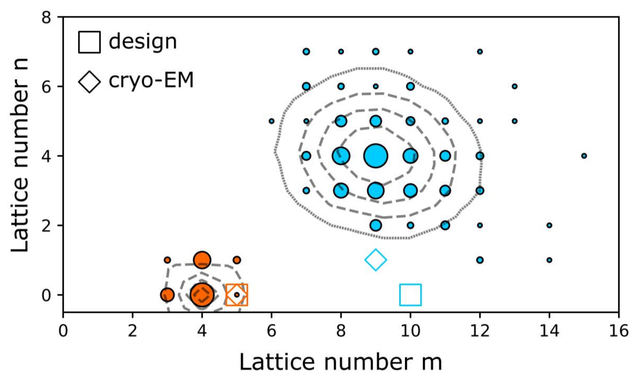
$MgCl_2$ concentration adjusts inter-particle binding strength.

There is a goldilocks zone where monomers assembly into tubules.

(10,0) tube can reach several microns in length **(1000s of monomers!)**

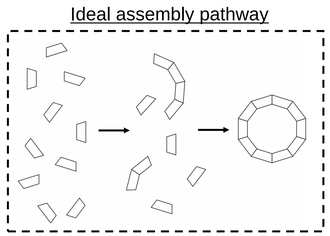






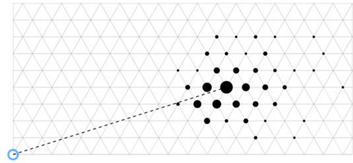
Despite designing monomers for a specific tubule type, we find a distribution of different assembly states.

Distribution of states inherent in self-limited assemblies

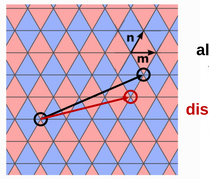


Fluctuations of binding angles leads to a distribution of final assembly states.

$$(\text{number of states}) \sim \frac{(\text{circumference})^2}{(\text{bending rigidity})}$$

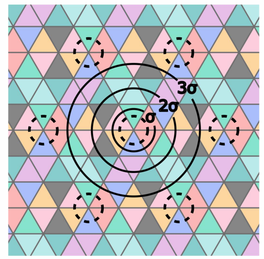


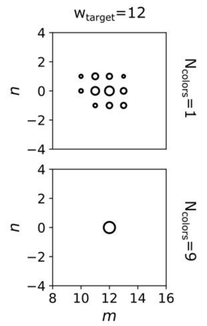
Improving specificity with multiple monomer species

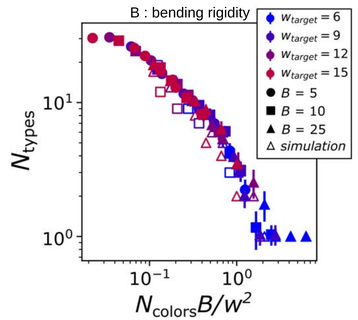


By adding more types of triangles, not all vertices are the same, limiting what states a tubule can form .

When the distance between similar vertices matches the length scale of fluctuations, we expect nearly full specificity for assembly.



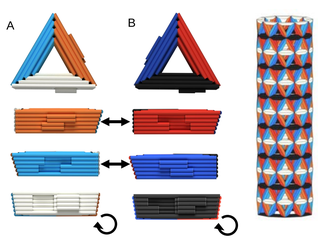


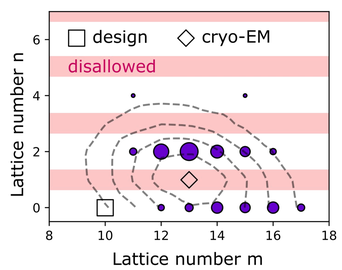


Experimental realization for two-species assembly

Using the two-species tiling above, we expect odd n states to be excluded.

In experiment, we see a reduction of states the way we expect!





Future Directions