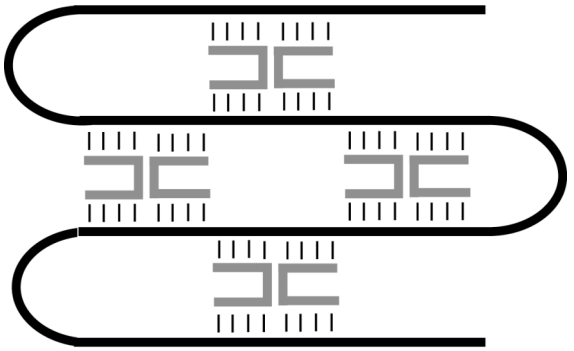
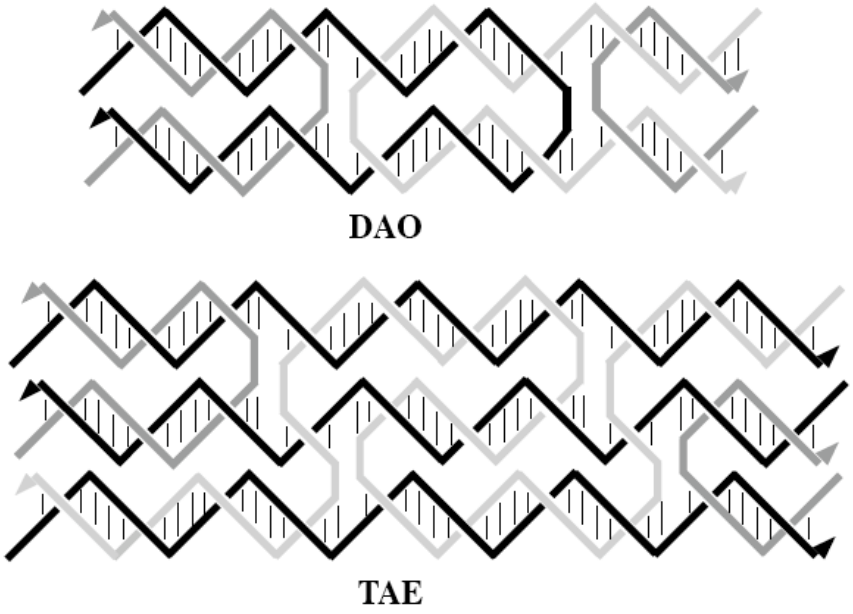
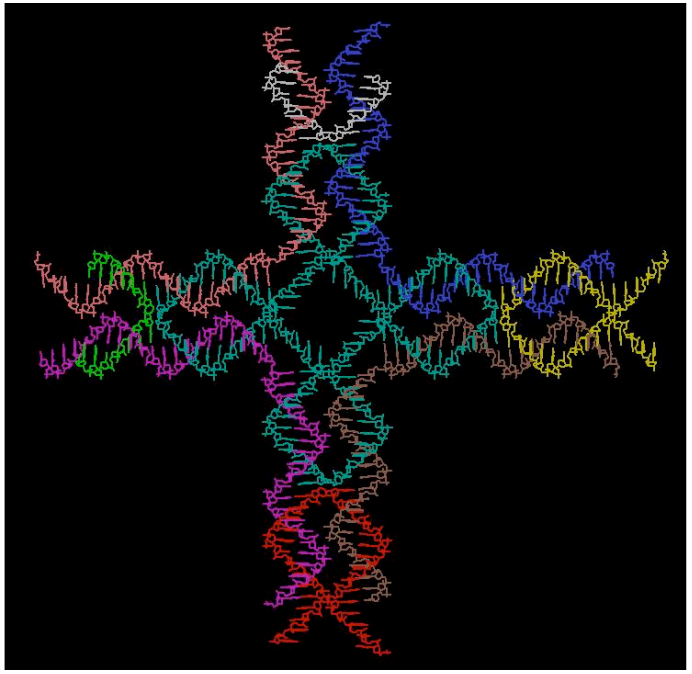
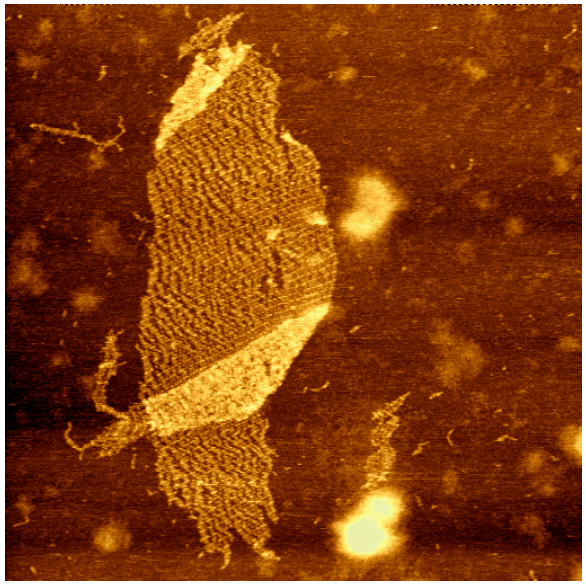
DNA tiles

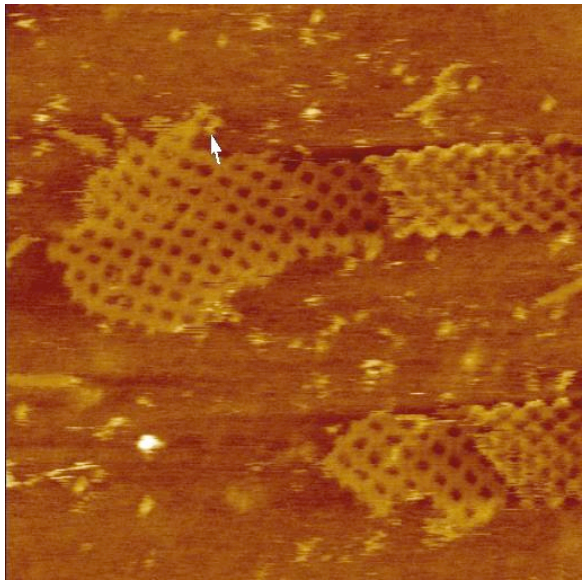






Self-Assembly Strategies





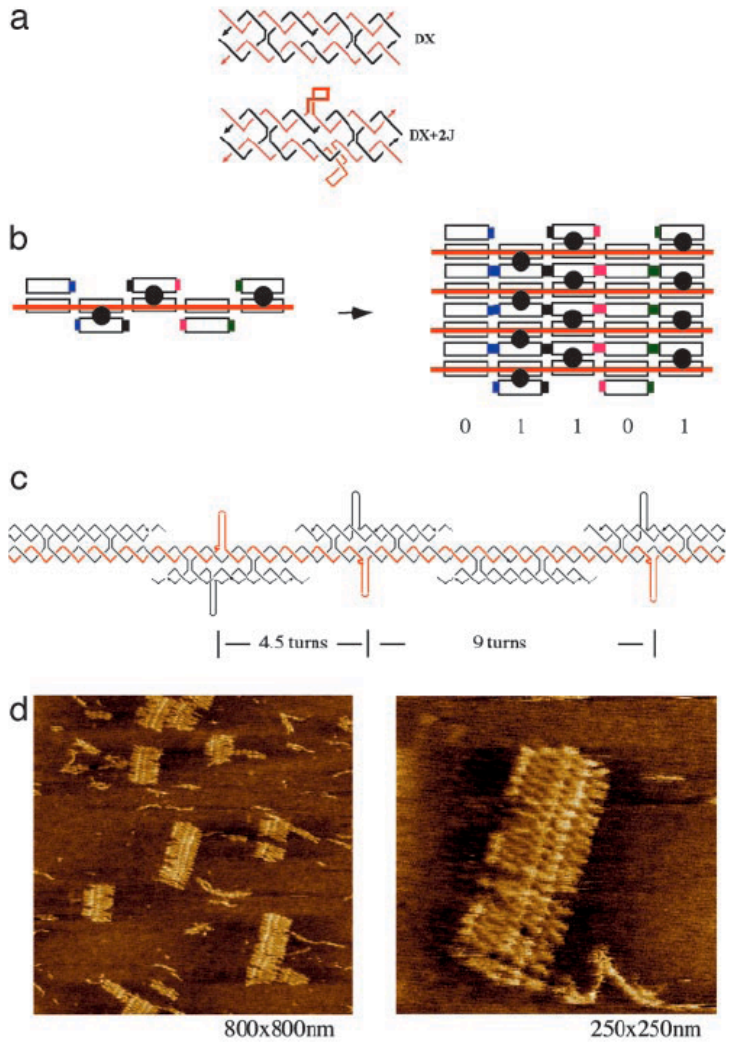
- Unmediated (single step).
- Nucleated (scaffold strand).
- Serial or Sequential (multi stage).
- Hierarchical (multi stage).
- Algorithmic.

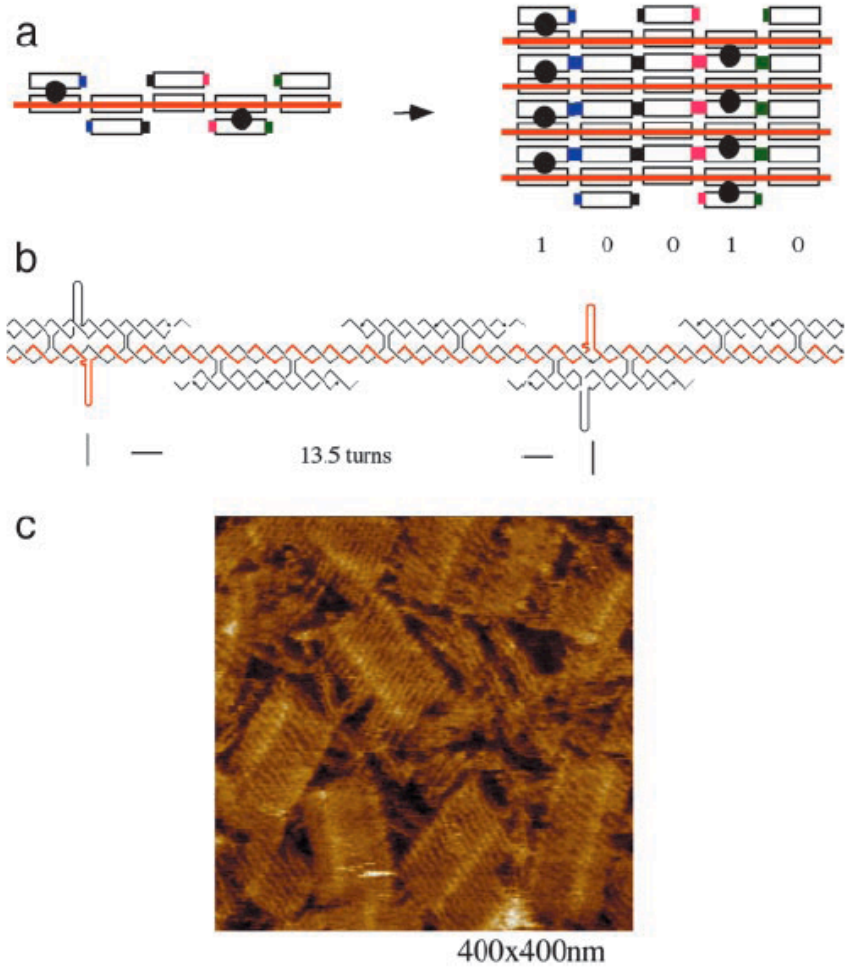
Directed nucleation assembly of DNA tile complexes for barcode-patterned lattices

Hao Yan, Thomas H. LaBean, Liping Feng, and John H. Reif*

Department of Computer Science, Duke University, Durham, NC 27708

PNAS | July 8, 2003 | vol. 100 | no. 14 | 8103–8108





PNAS | July 8, 2003 | vol. 100 | no. 14 | 8103–8108

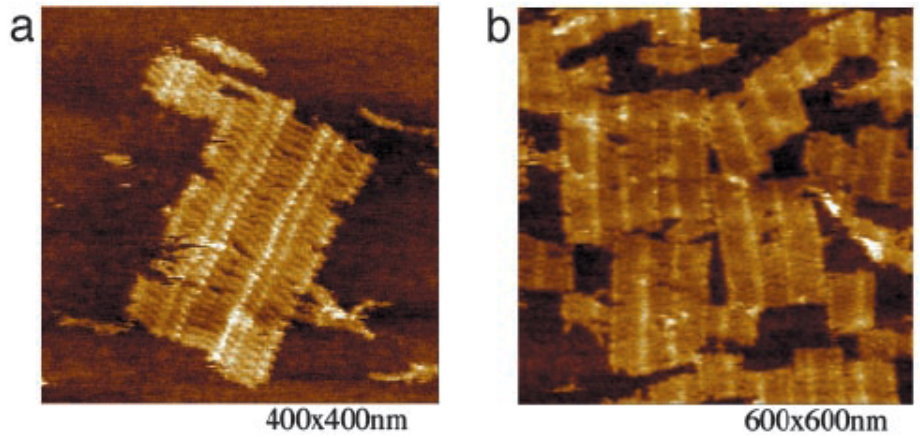
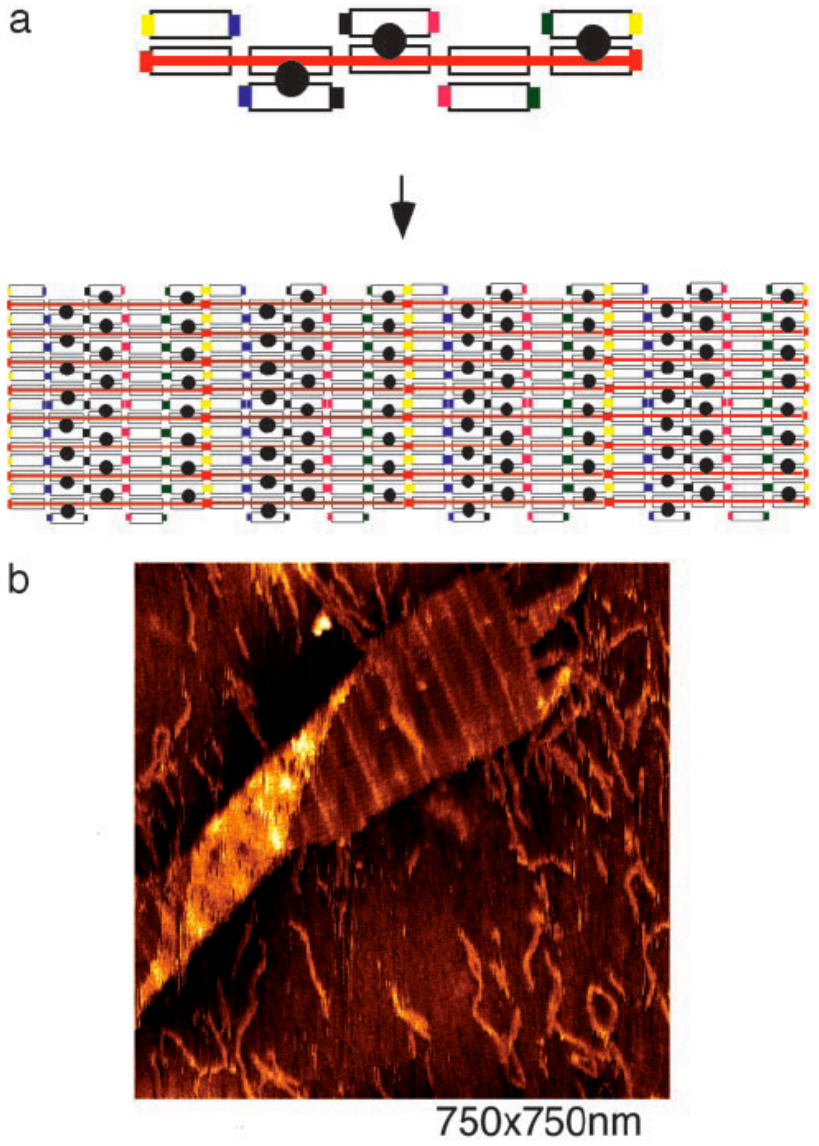


Fig. 3. AFM images showing blunt-end helix stacking of tile assemblies. The scale is indicated below each image. (*a*) AFM image showing the alignment of two pieces of the first barcode lattice (01101) oriented in opposite directions. (*b*) AFM image showing the alignment of fragments of the second barcode lattice (10010) to form larger pieces of lattice.



PNAS | July 8, 2003 | vol. 100 | no. 14 | 8103–8108

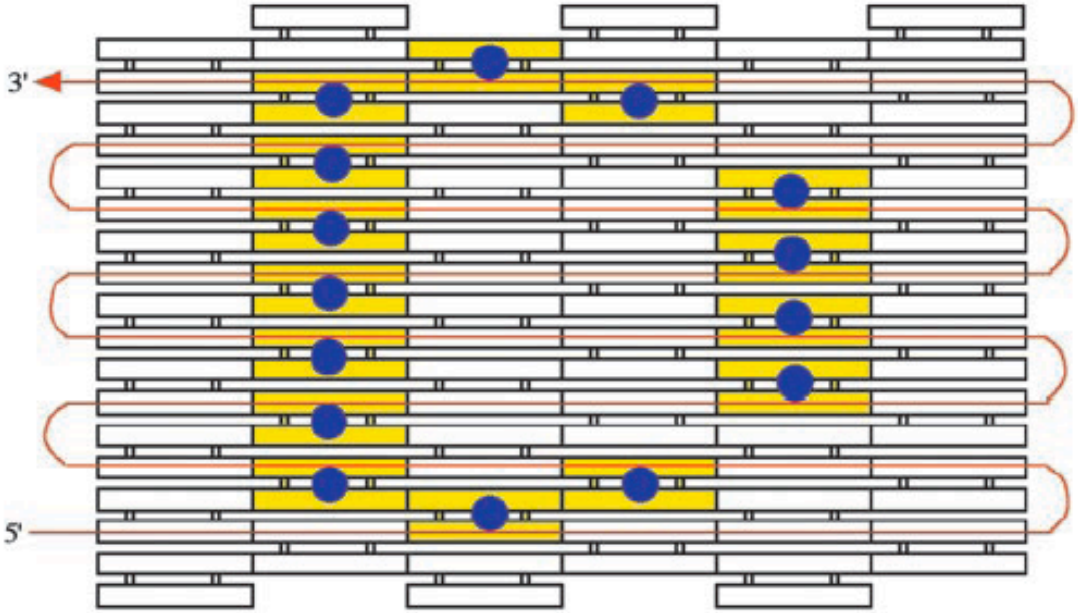
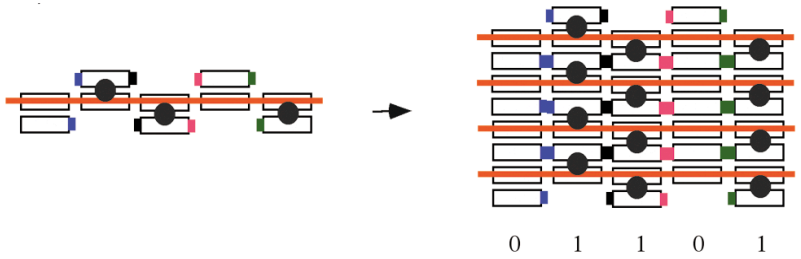
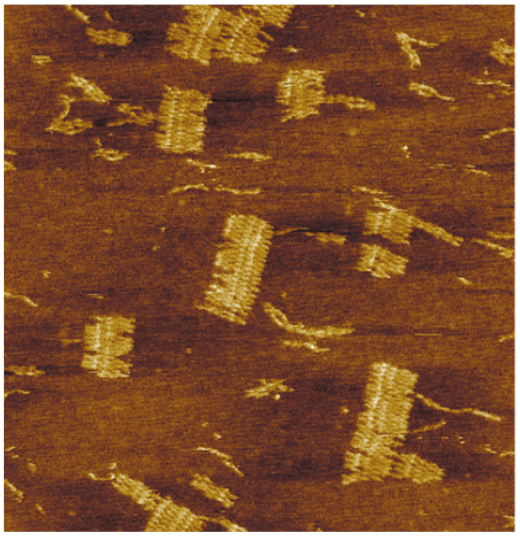


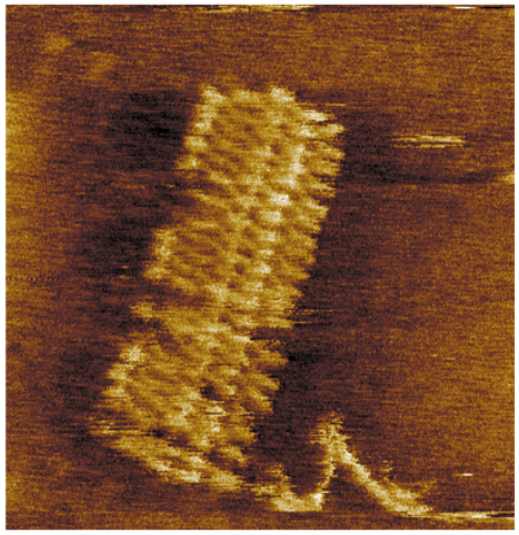
Fig. 5. Schematic drawing of a proposed 2D pattern using a directed nucleation assembly technique. In red is an input single-stranded DNA scaffold strand that encodes a 2D pattern (each odd row traversing from left to right, and each even row traversing right to left). Specific DNA tiles self-assemble around each segment of this input strand. The tiles then (or perhaps concurrently) self-assemble into a 2D tiling lattice with the predetermined pattern.



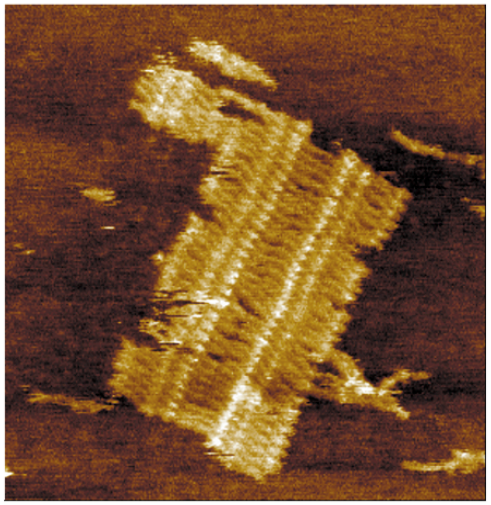
Barcode Lattice



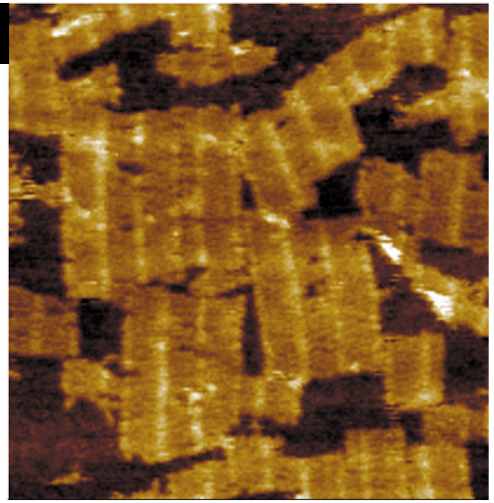
800x800nm



250x250nm



400x400nm



600x600nm

- Directed nucleation
- Propagation of 1D information into second dimension for AFM read-out
- Programmable display
- Note: Helix stacking

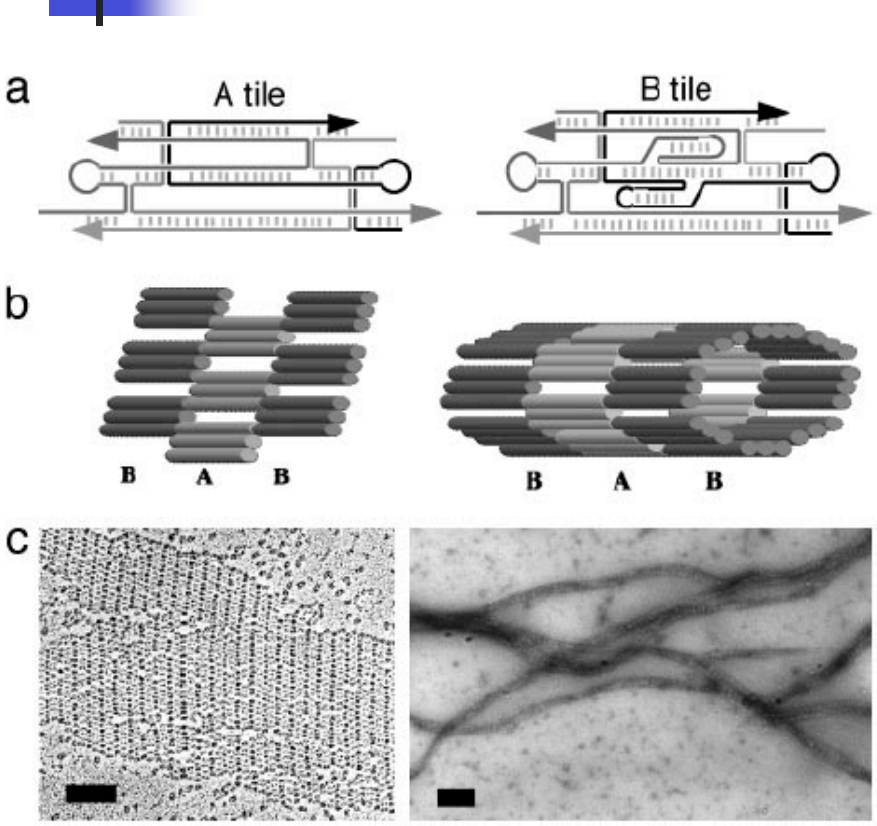
Yan, H., LaBean, T.H., Feng, L., & Reif, J.H. (2003) Directed nucleation assembly of DNA tile complexes for barcode-patterned lattices, *PNAS* 100, 8103-8108.

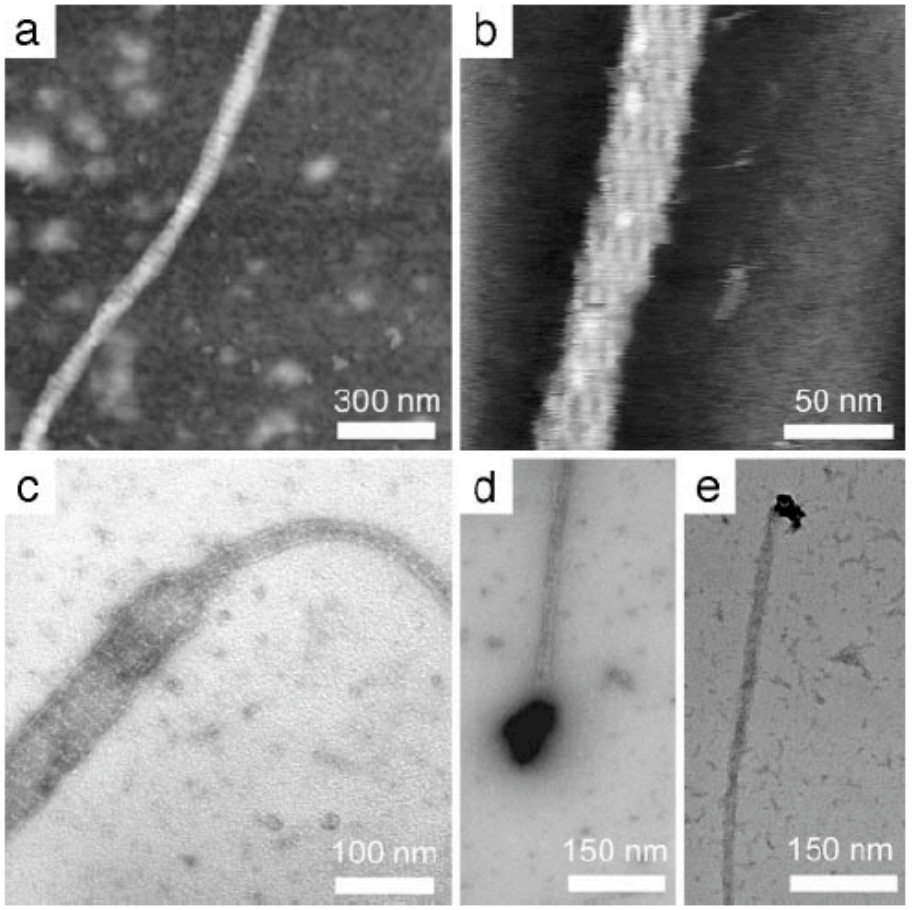
DNA nanotubes self-assembled from triple-crossover tiles as templates for conductive nanowires

Dage Liu*, Sung Ha Park*†, John H. Reif*, and Thomas H. LaBean*‡

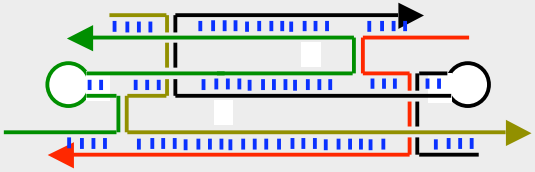
Departments of *Computer Science and †Physics, Duke University, Durham, NC 27708

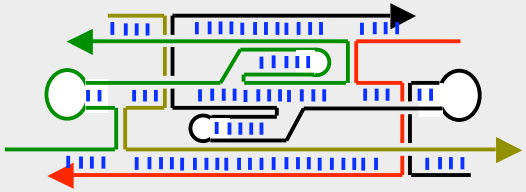
PNAS | January 20, 2004 | vol. 101 | no. 3 | 717–722

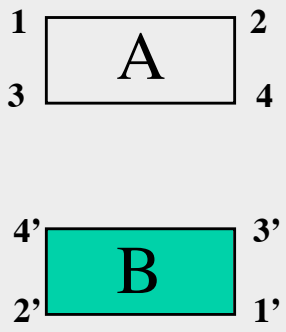


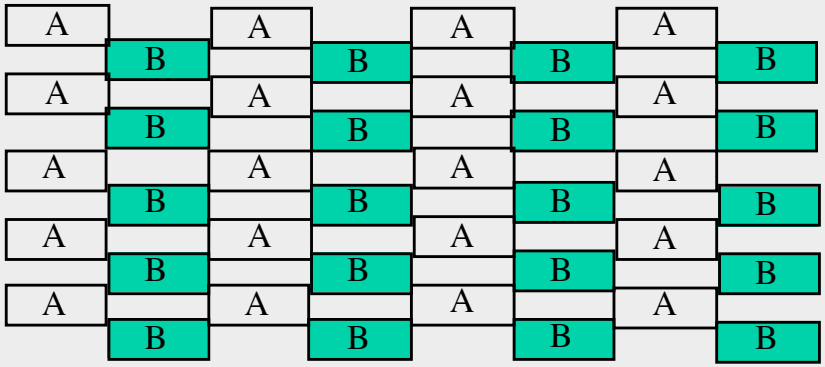


TAO AB* Lattice

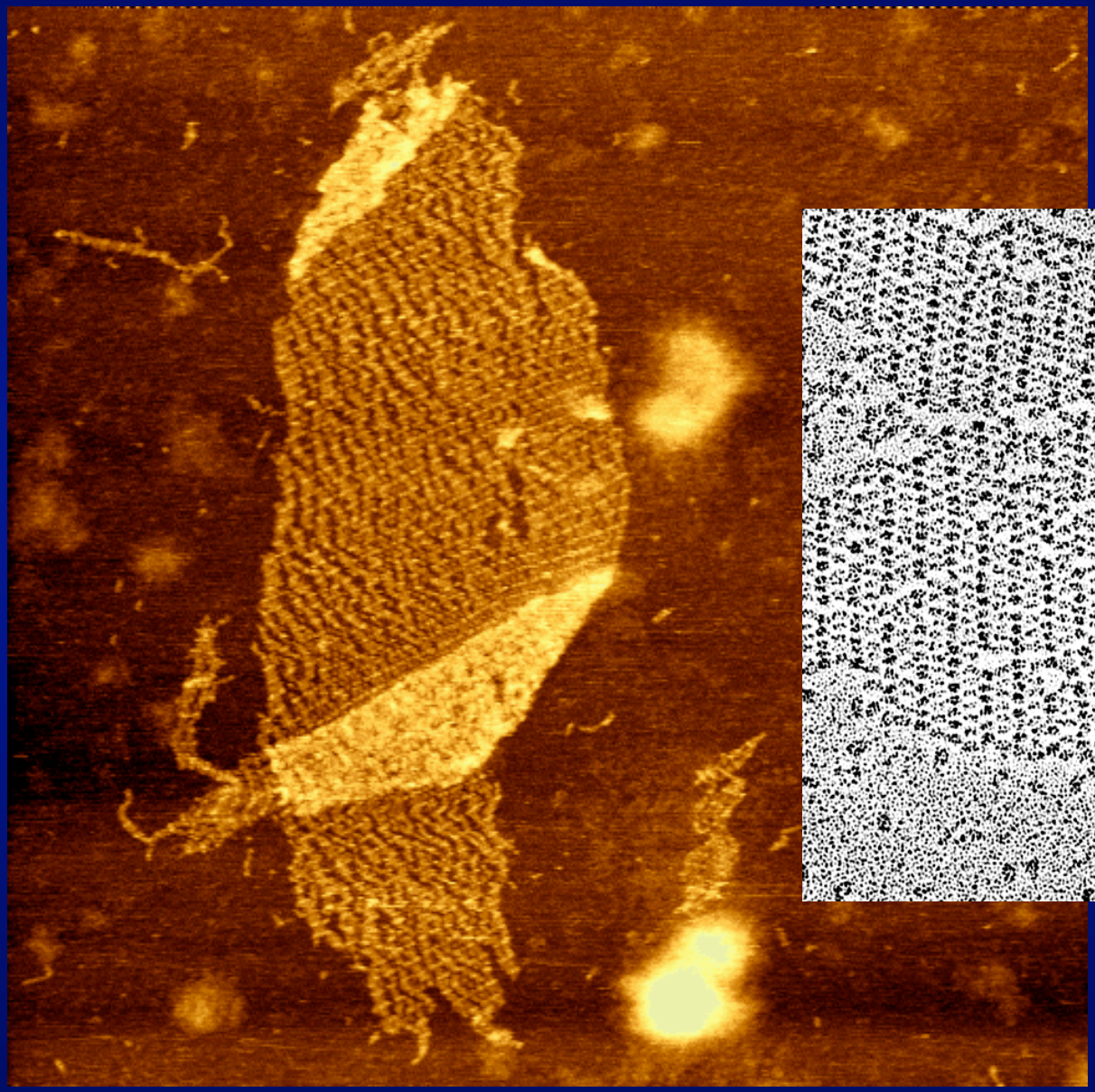


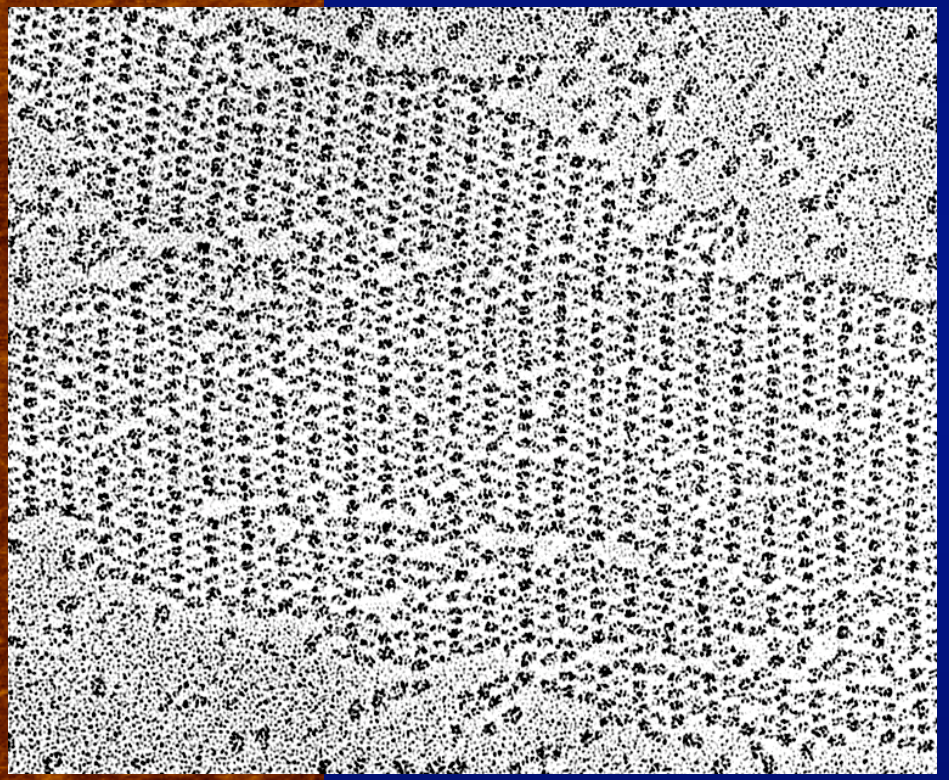




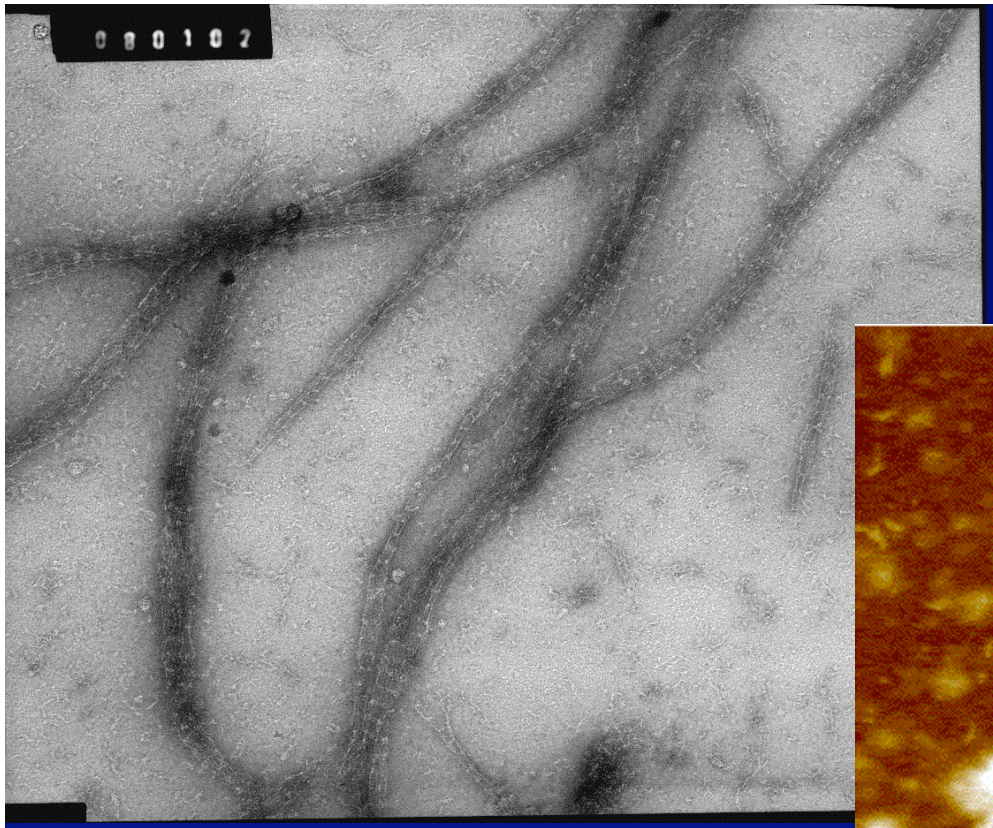


TAO AB* Lattice Visualized by AFM & TEM



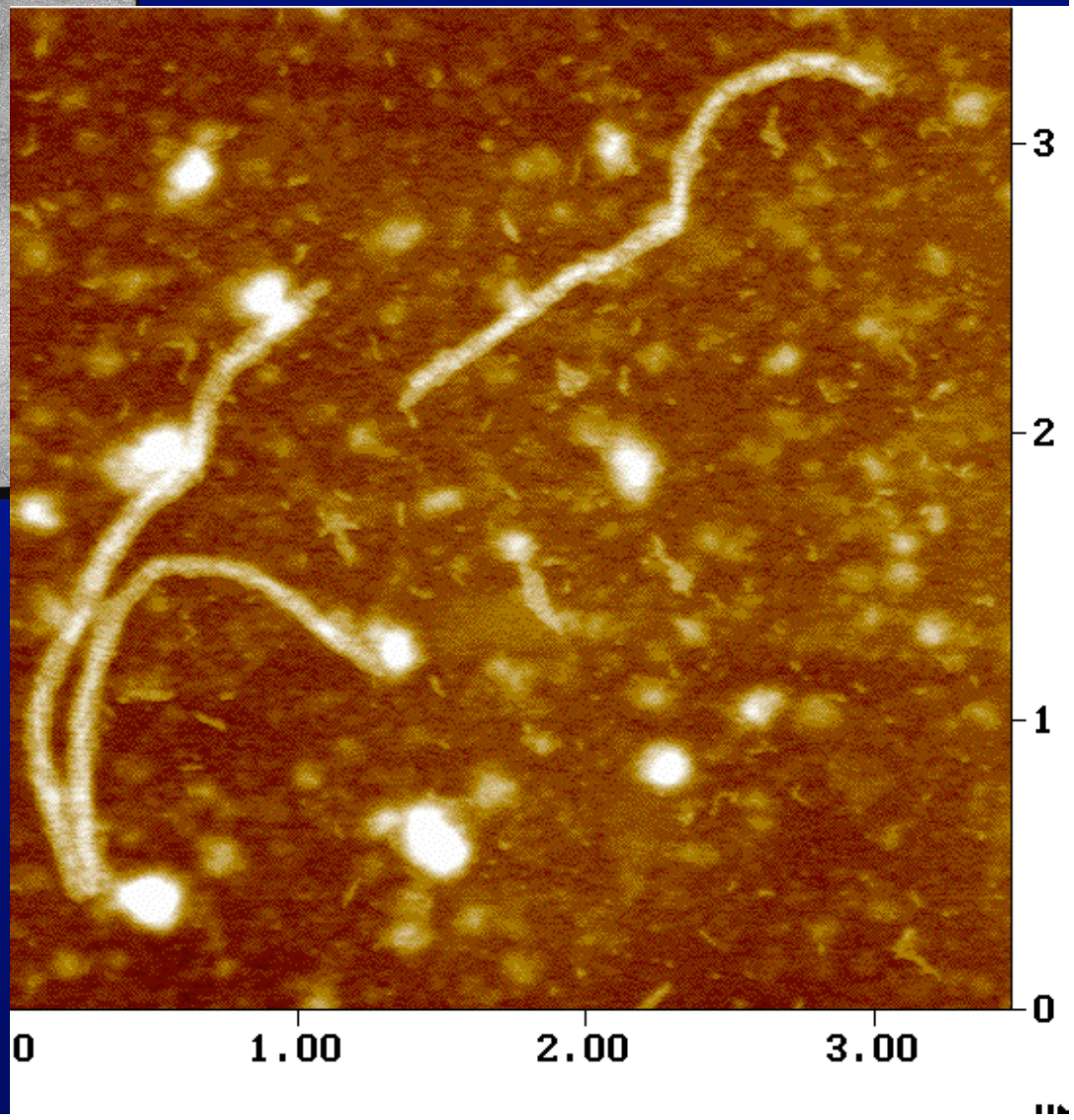


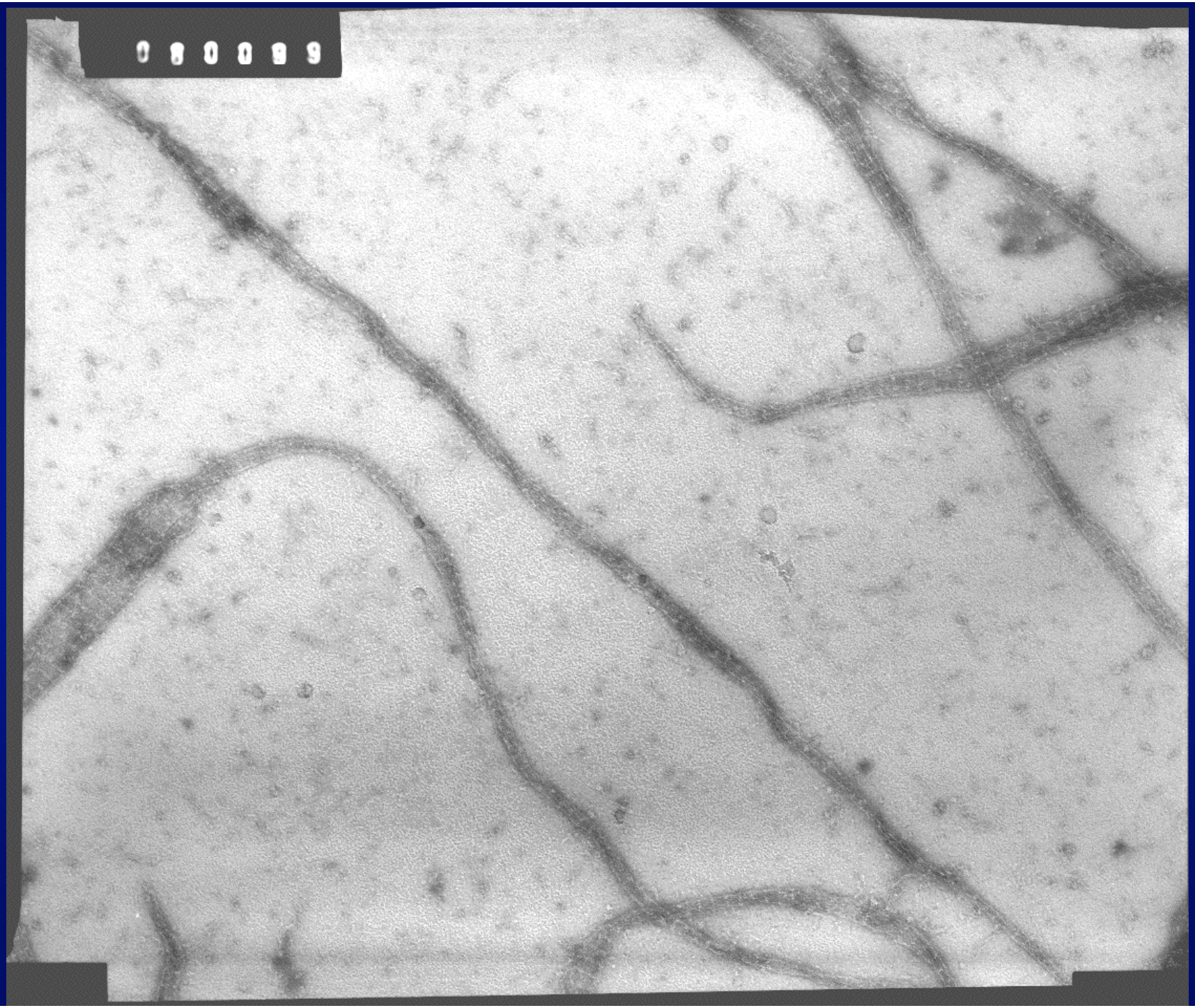
TX-tile DNA Nanotubes



TEM (negative stained)

AFM




080099

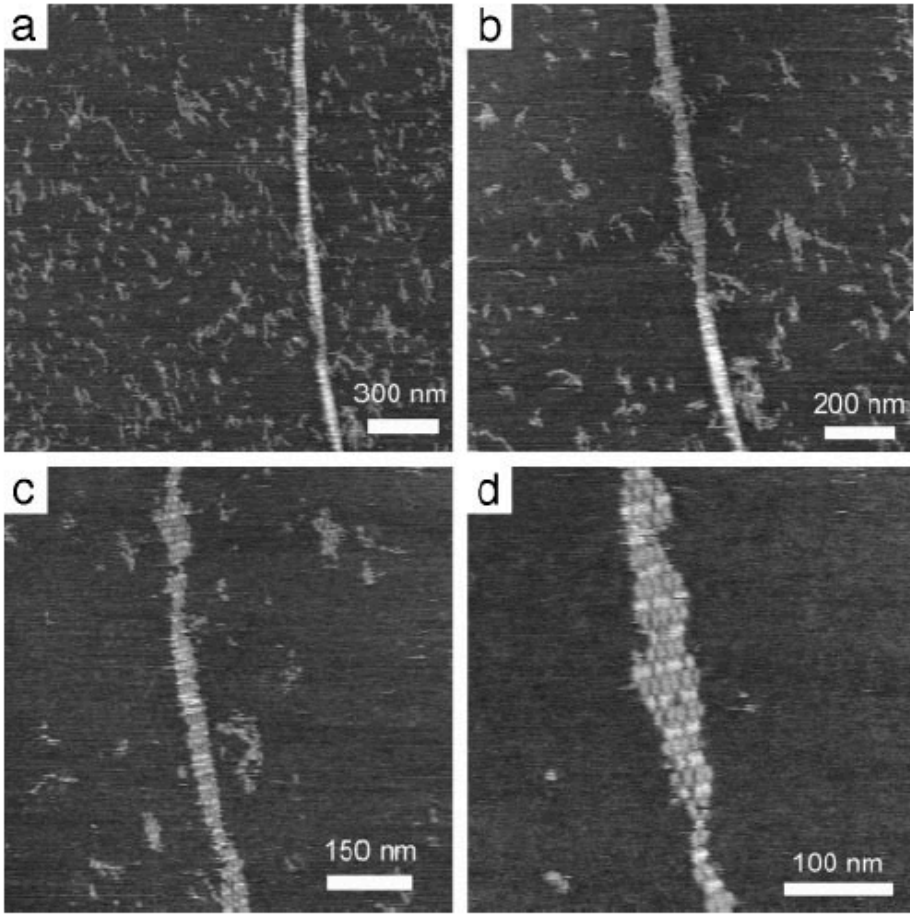


Fig. 3. A series of AFM images captured by repeatedly reimaging and zooming in on the same nanotube, which appears mostly tube-like in *a*, with increasing wear-and-tear through *b* and *c* until a section of unfolded tube becomes a single-layer flat lattice (*d*) displaying stripes composed of lighter (higher) B tiles and darker (shorter) A tiles.

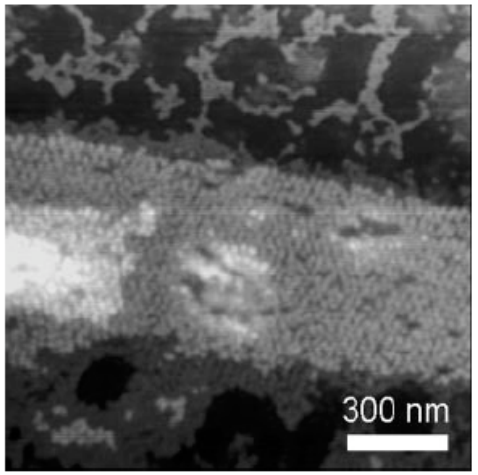
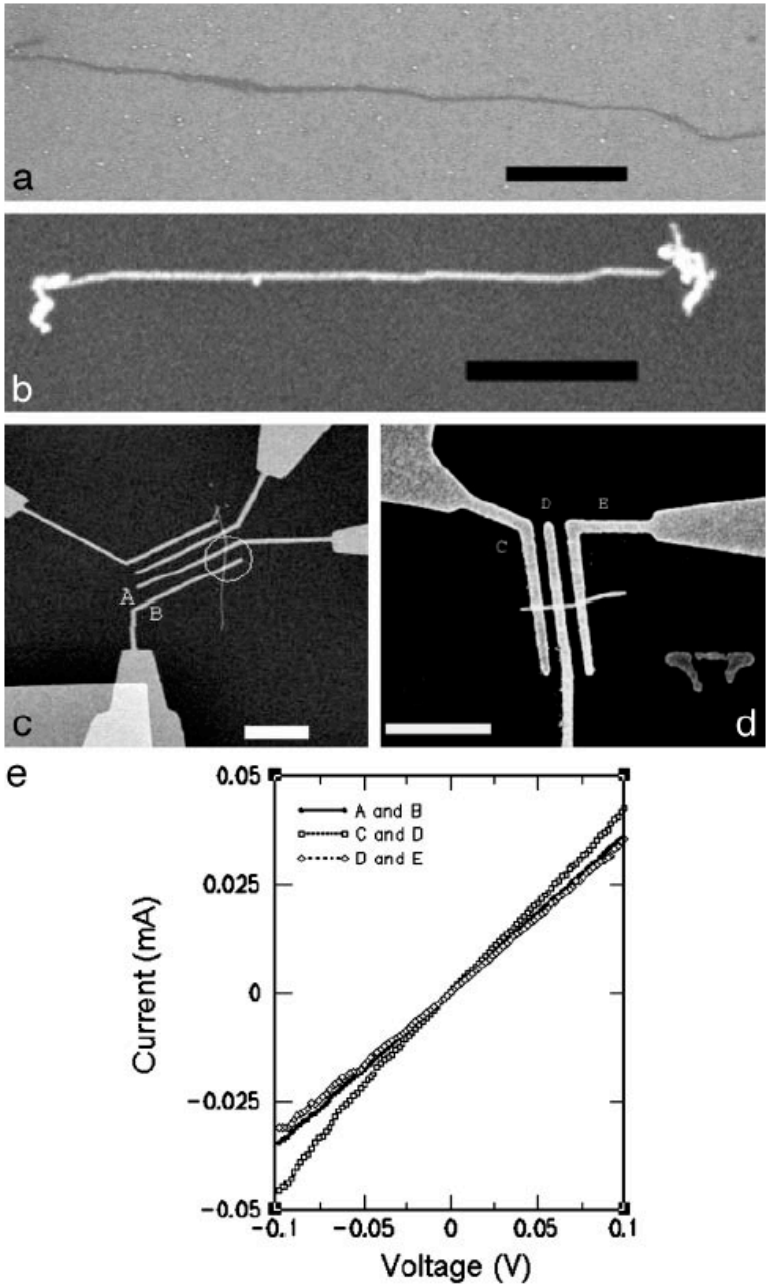


Fig. 4. AFM image of self-assembled superstructure formed by annealing the tube-forming thiolated oligonucleotides in the presence of thiol reducing agent (20 mM dithiothreitol). No nanotubes were observed.

Evidence for Tube Structure

- Vast length (10 mm) with uniform width (~30 nm) indicates cyclic cross section.
- Thiols unavailable for chemistry.
- Gold attraction for tube termini.
- Added amines chemically reactive on tube surfaces.
-

PNAS | January 20, 2004 | vol. 101 | no. 3 | 717–722

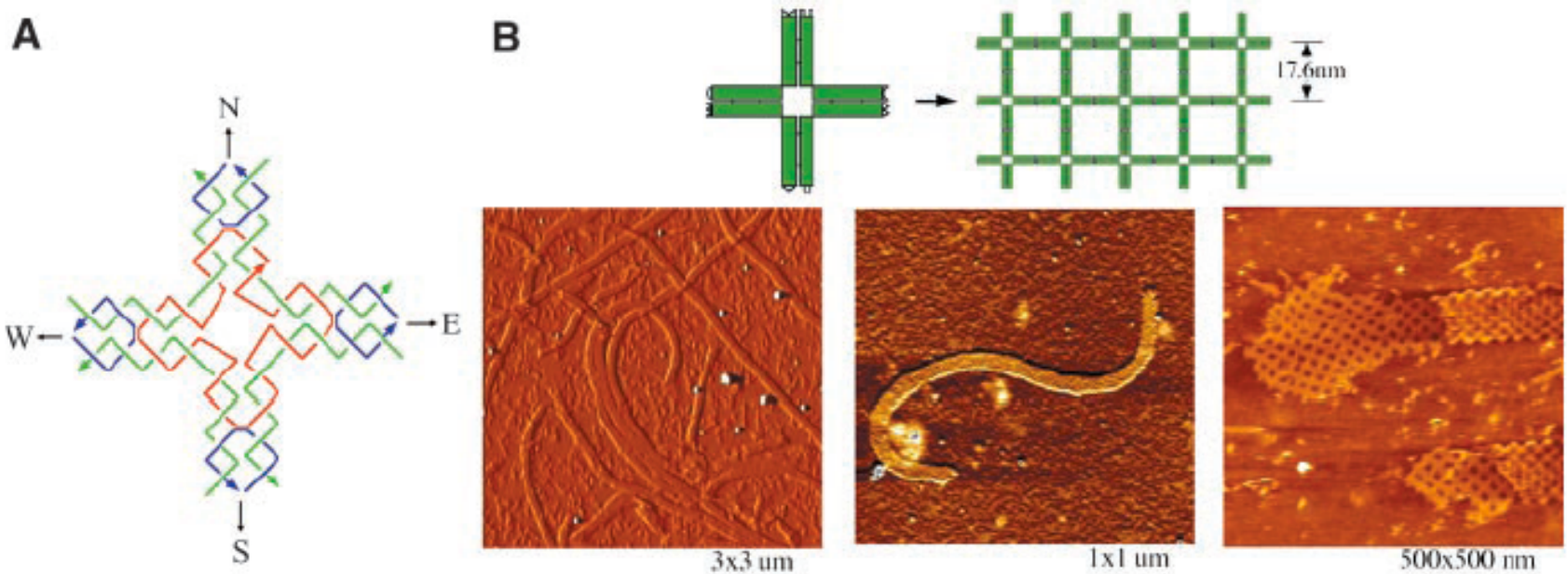


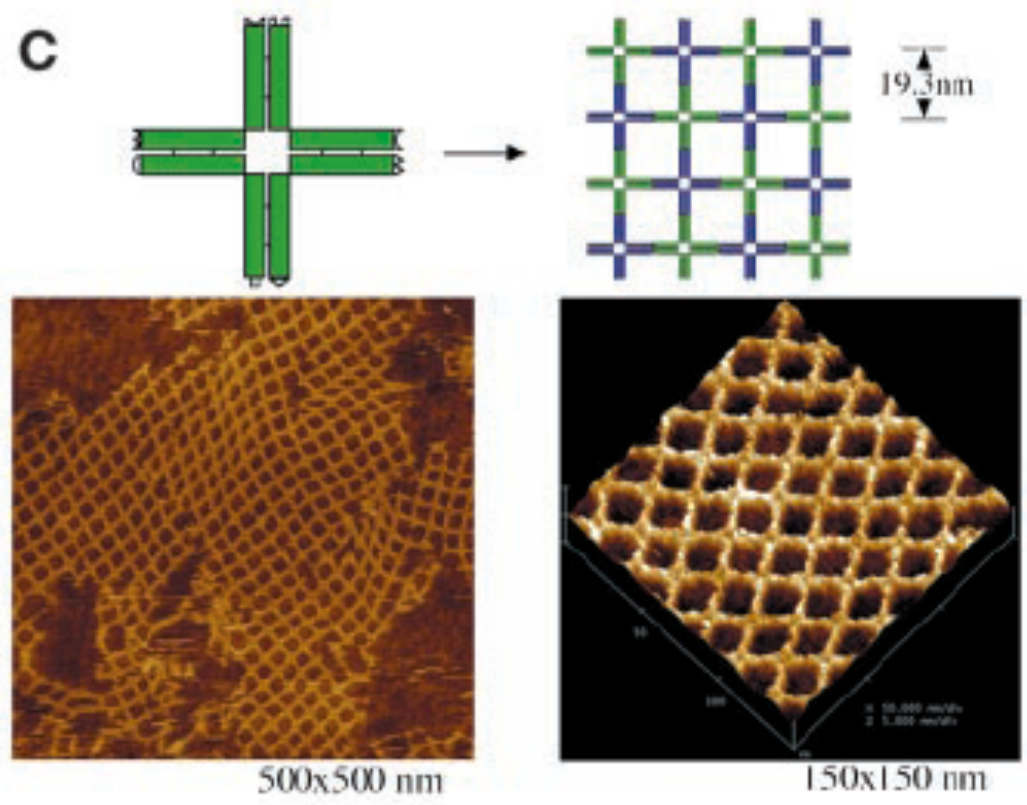
- Lattice morphology switched by chemical modification of tile interactions.
- Nanowire templates.

DNA-Templated Self-Assembly of Protein Arrays and Highly Conductive Nanowires

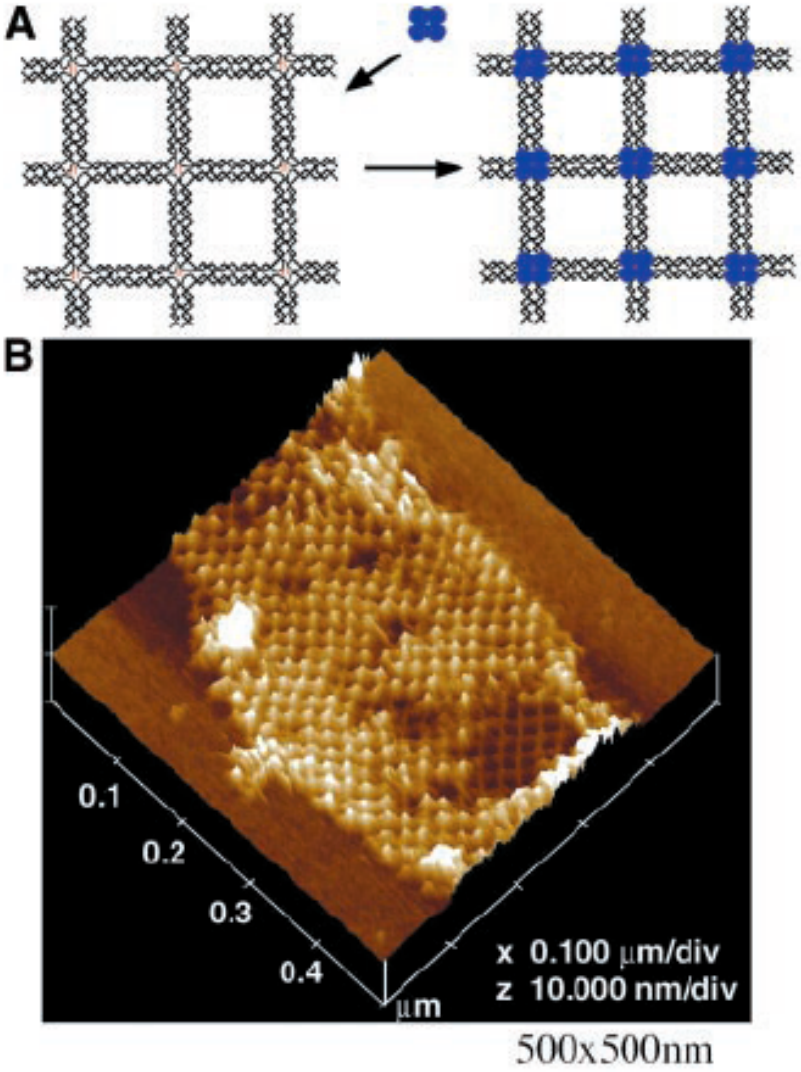
Hao Yan,[1*] Sung Ha Park,[1,2] Gleb Finkelstein,[2] John H. Reif,[1] Thomas H. LaBean[1*]

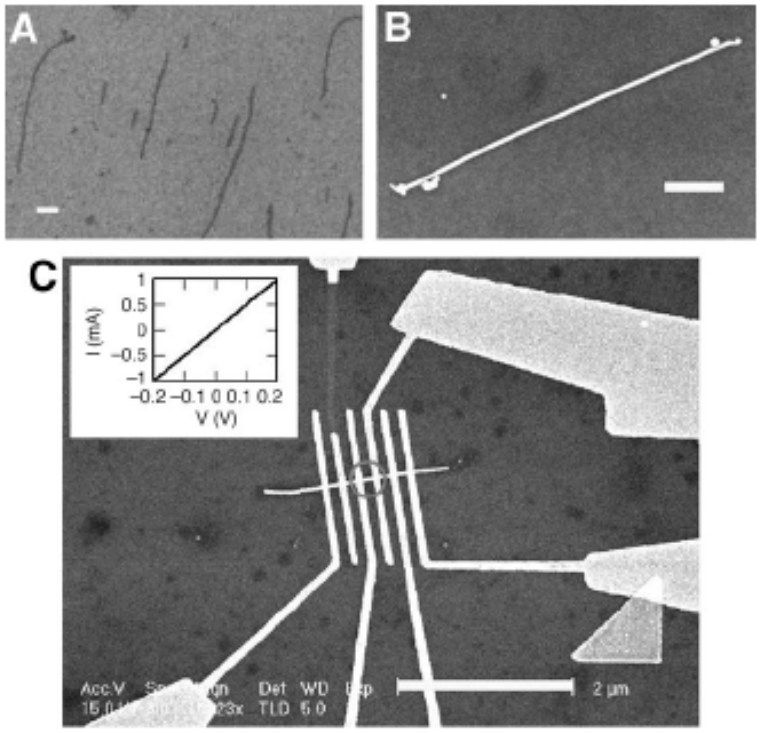
A DNA nanostructure consisting of four four-arm junctions oriented with a square aspect ratio was designed and constructed. Programmable self-assembly of 4 × 4 tiles resulted in two distinct lattice morphologies: uniform-width nanoribbons and two-dimensional nanogrids, which both display periodic square cavities. Periodic protein arrays were achieved by templated self-assembly of streptavidin onto the DNA nanogrids containing biotinylated oligonucleotides. On the basis of a two-step metallization procedure, the 4 × 4 nanoribbons acted as an excellent scaffold for the production of highly conductive, uniform-width, silver nanowires.



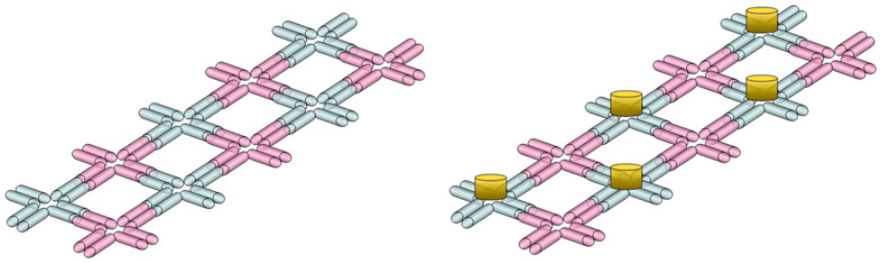


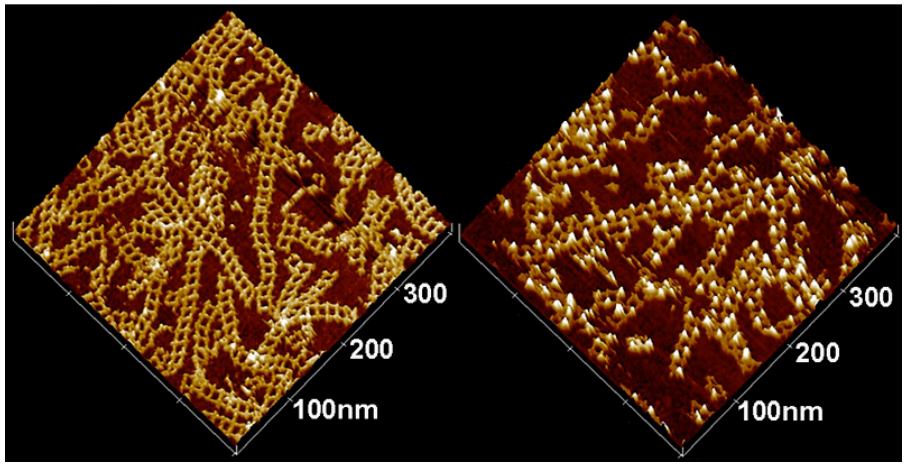
Lattice morphology switching via alternation of tile orientation relative to lattice plane.


A
B
0.1
0.2
0.3
0.4
µm
x 0.100 µm/div
z 10.000 nm/div
500x500nm


A
B
C
I (mA)
1
0.5
0
−0.5
−1
−0.2 −0.1 0 0.1 0.2
V (V)
2 µm

Programmable 2D Assemblies.





Programmable DNA Self-Assemblies for Nanoscale Organization of Ligands and Proteins

Sung Ha Park,† Peng Yin,† Yan Liu,‡ John H. Reif,† Thomas H. LaBean,*,† and Hao Yan*,‡

NANO LETTERS

2005
Vol. 5, No. 4
729–733

- Organization of biological, chemical, electronic, or photonic components.
- Ultimate high-density sensor arrays (single molecule detection).
- Integration with lithographic features.
- Supertiles for hierarchical assembly.

<u>Attachment strategies:</u>
Thiol/gold, protein/small molecule, Protein/protein, cDNA, aptamer, antibody, coupling chemistry.

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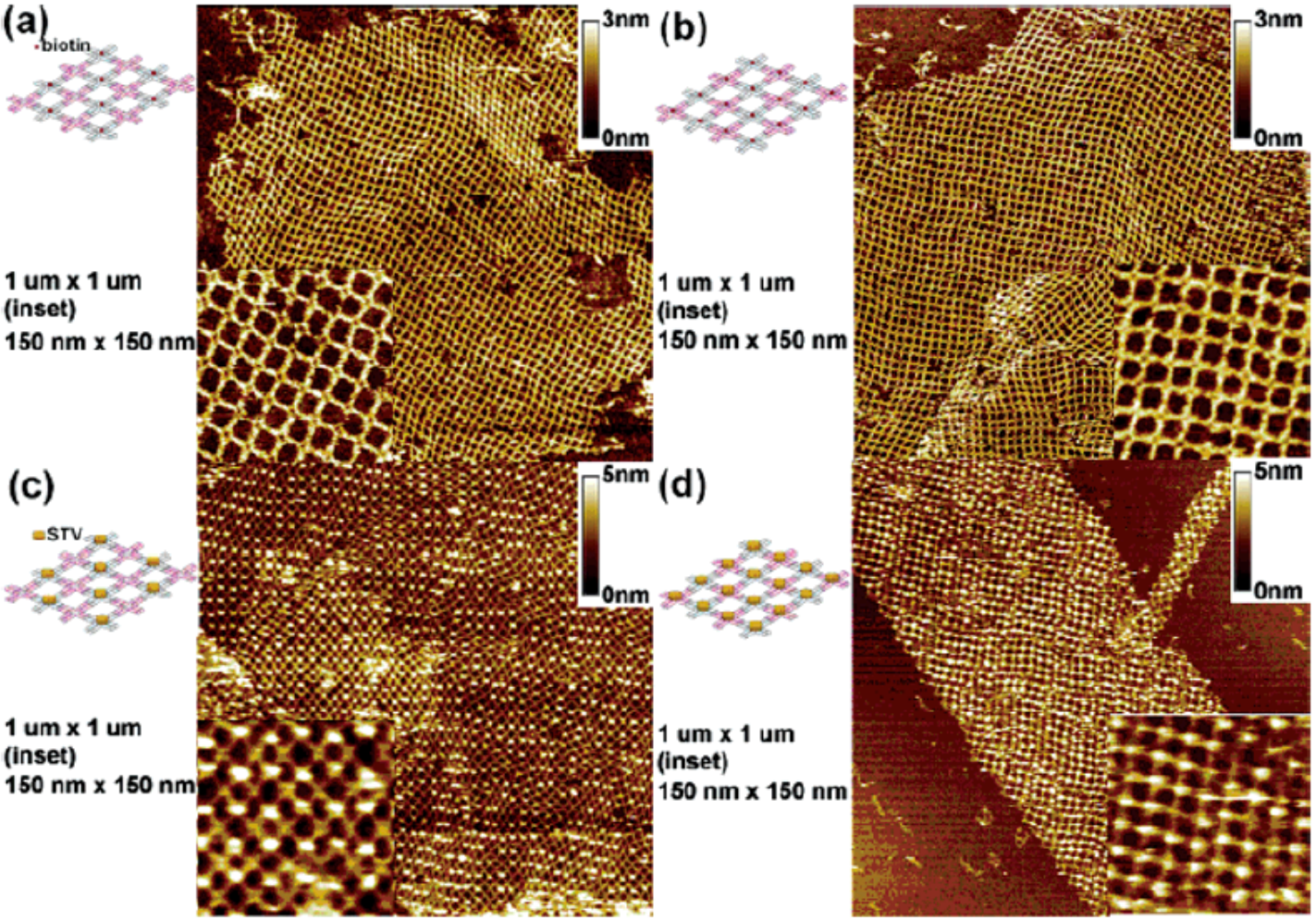
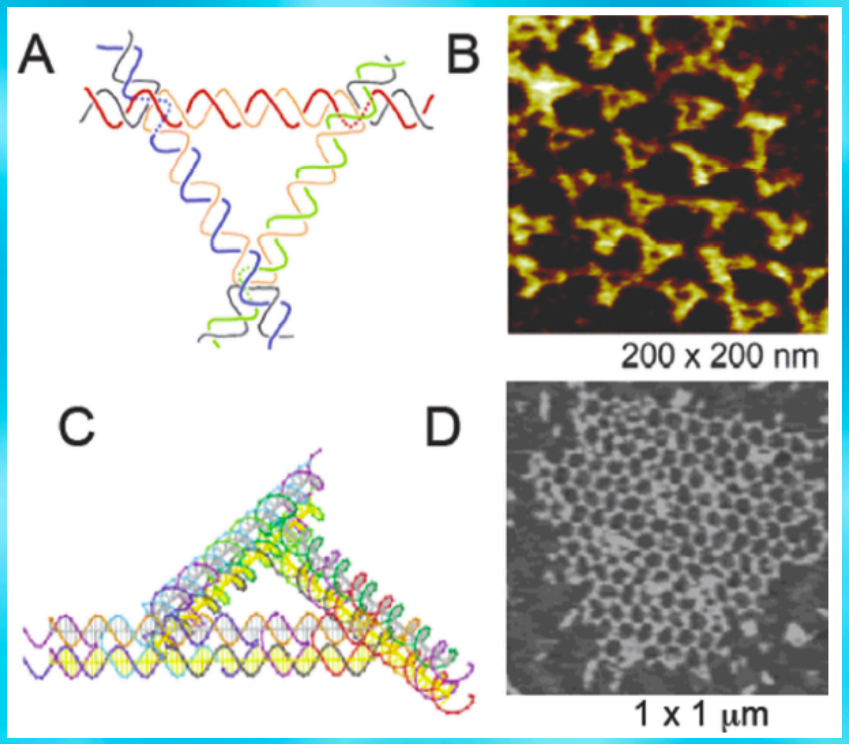
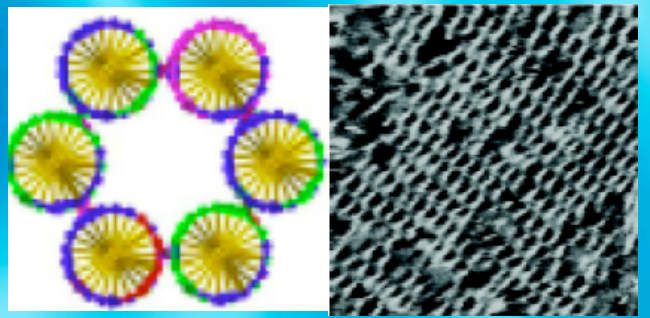
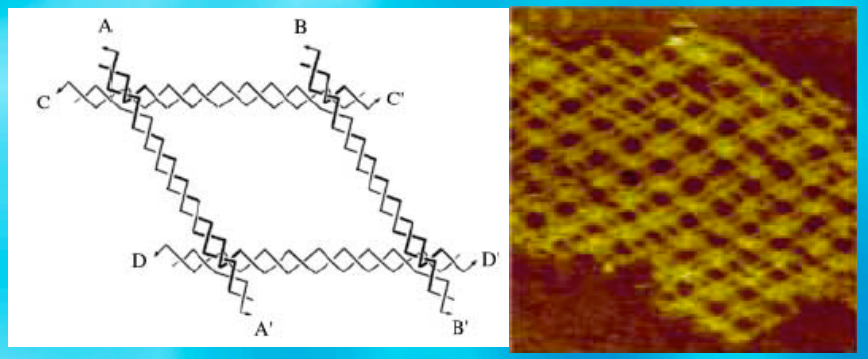
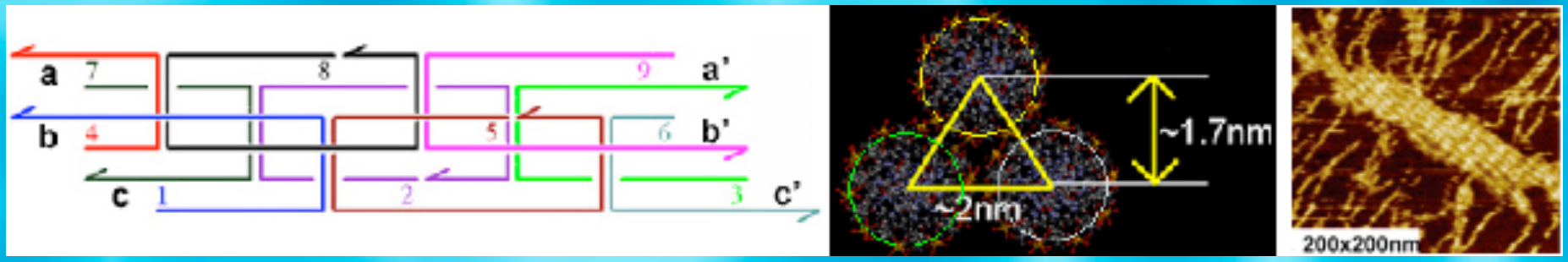


Other DNA Tilings

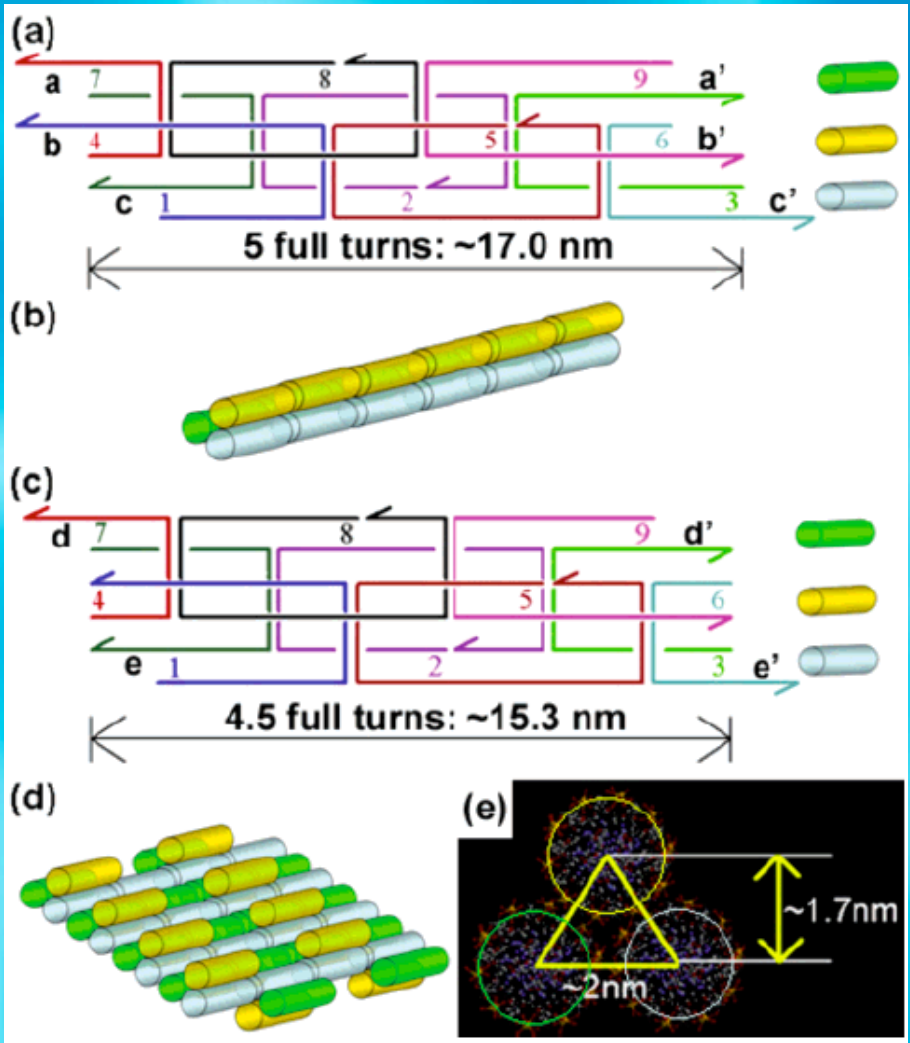


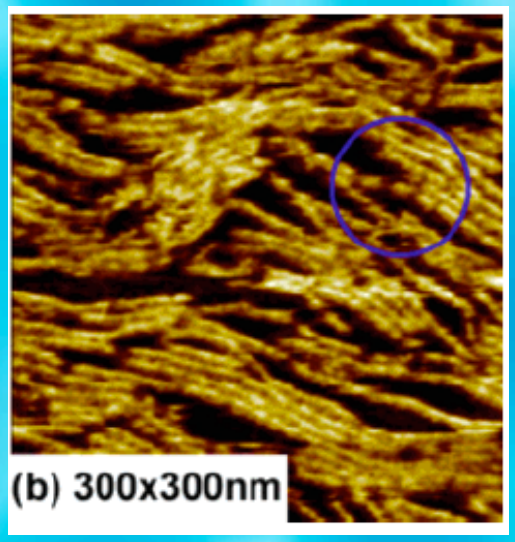


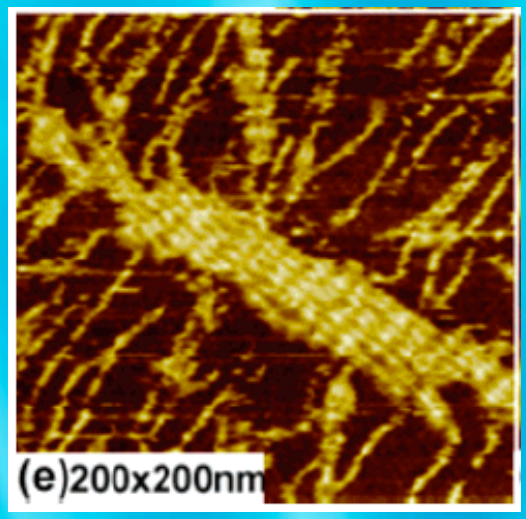




3HB Non-planar TX Tiles

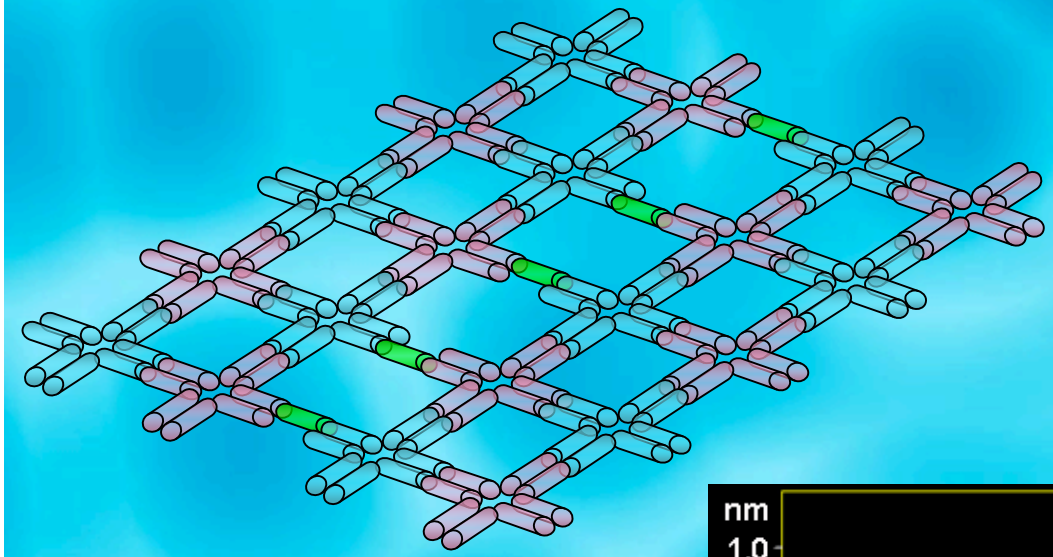


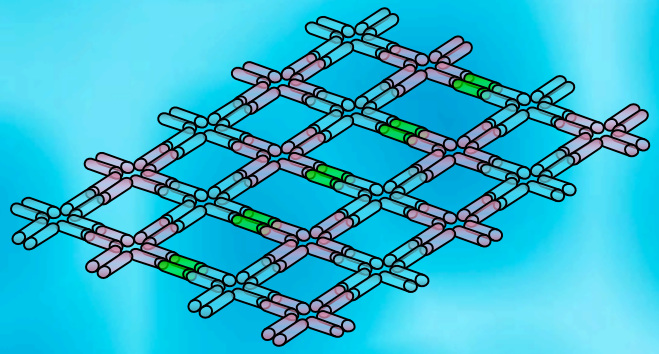


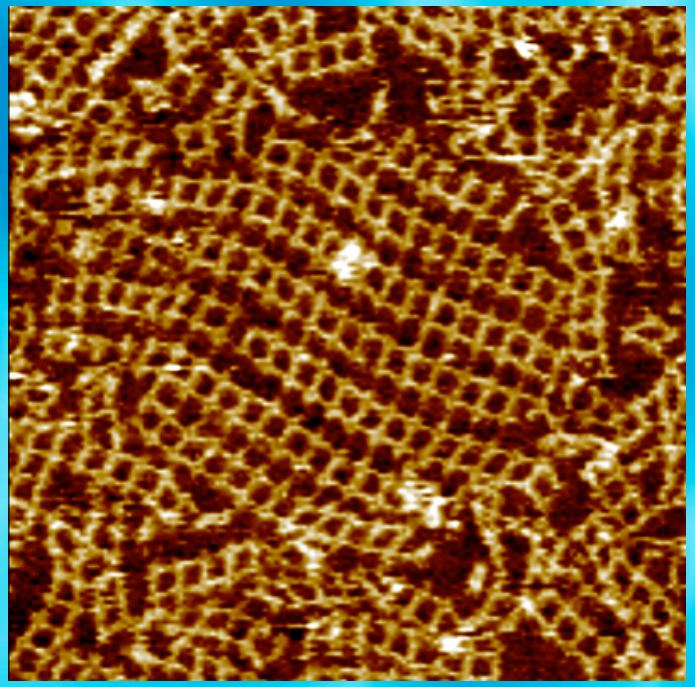


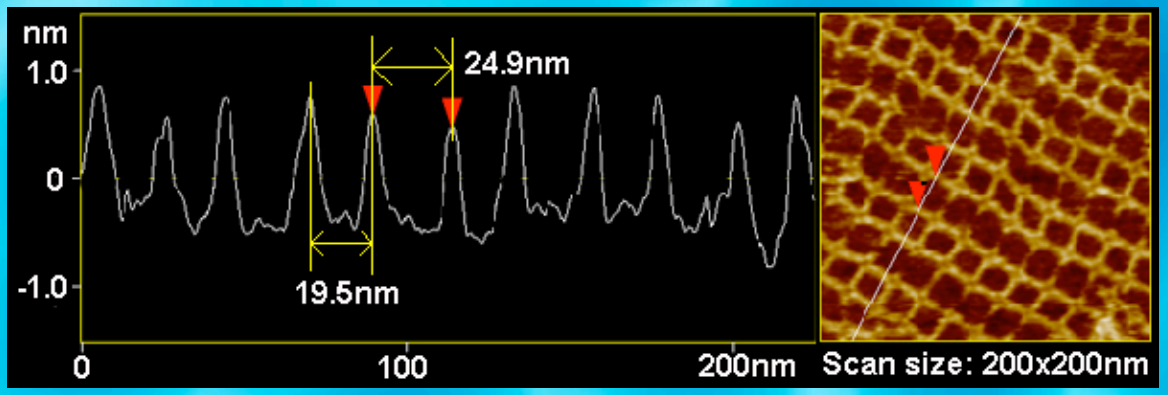
S-H. Park, R. Barish, H. Li, J.H. Reif , G. Finkelstein , H. Yan, and T.H. LaBean (2005) Three-Helix Bundle DNA Tiles Self-assemble into 2D Lattice or 1D Templates for Silver Nanowires. *Nano Letters* **5**, 693-696.

Bridged Nanotrack



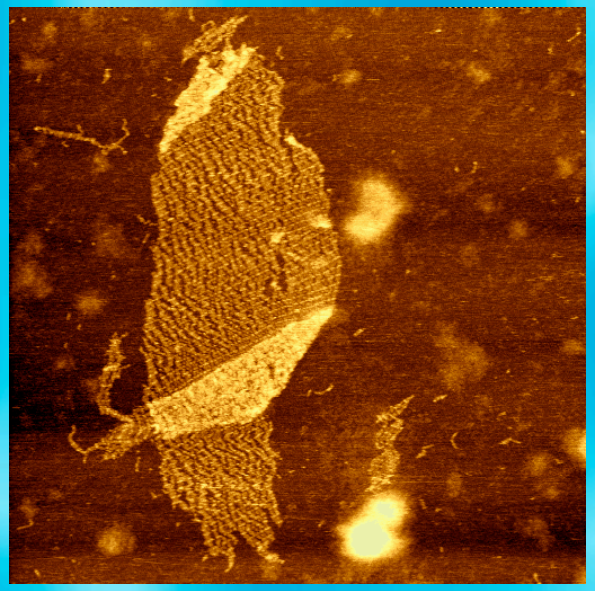


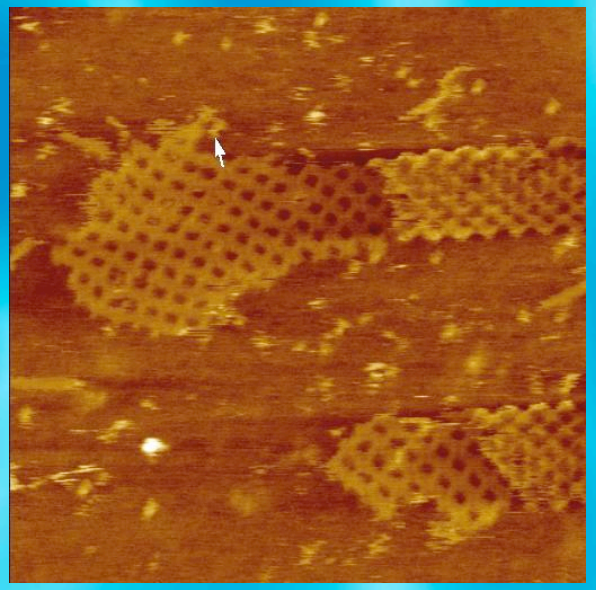




Section profile :
(1) nanotrack center to center distance: designed, 19.3nm, measured, 19.5nm
(2) distance between nanotracks after adding multipath dsDNA Bridge: designed, 24.4nm, measured, 24.9nm.

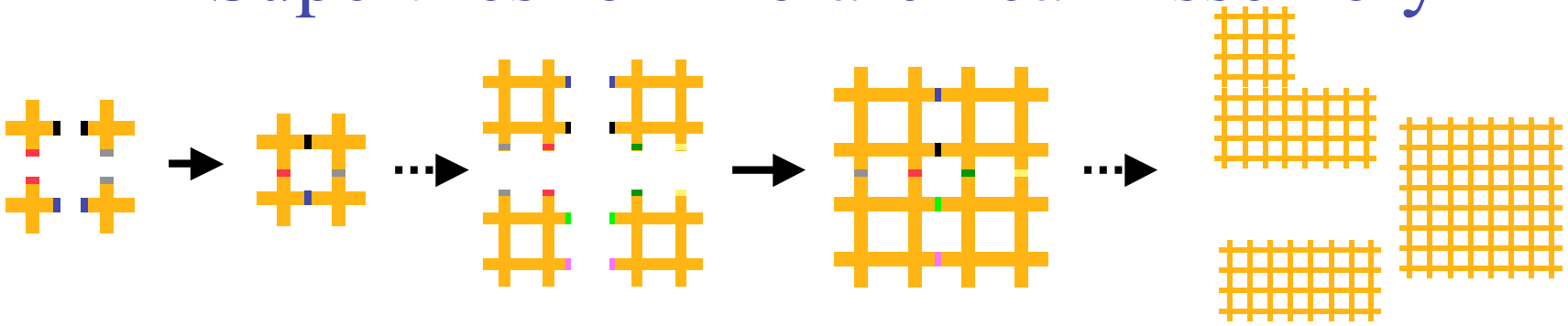
Self-Assembly Strategies

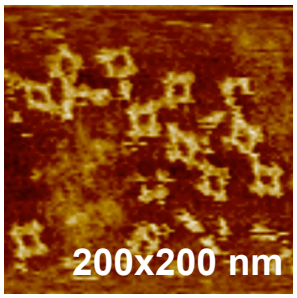


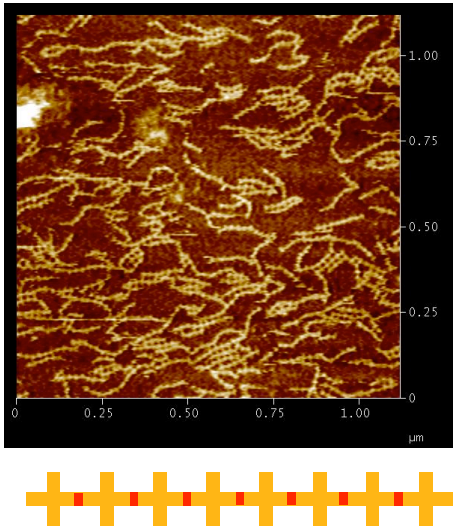


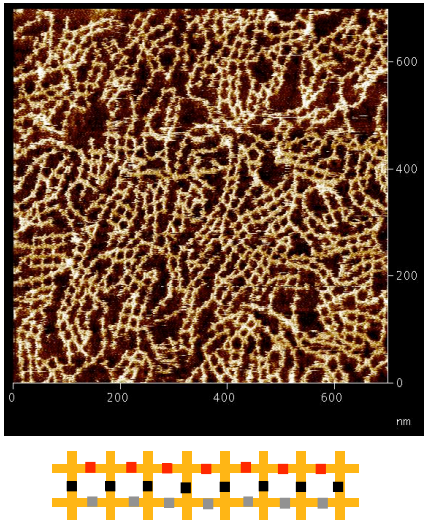
- Unmediated (single step).
- Nucleated (scaffold strand).
- Serial or Sequential (multi stage).
- Hierarchical (multi stage).
- Algorithmic.

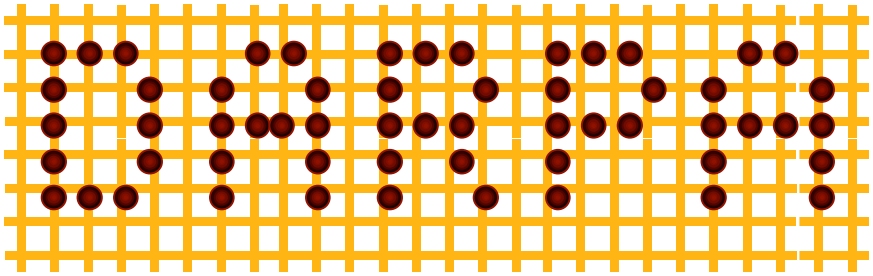
Supertiles for Hierarchical Assembly





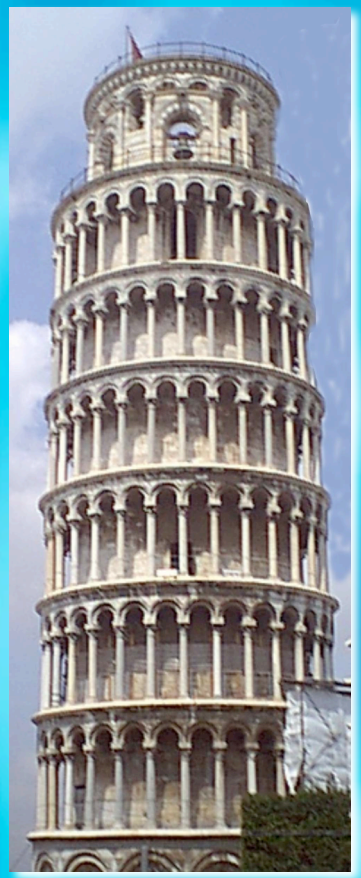


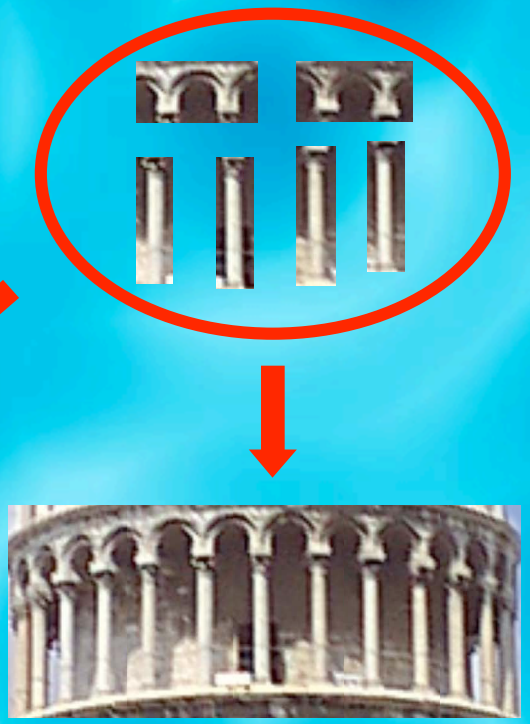




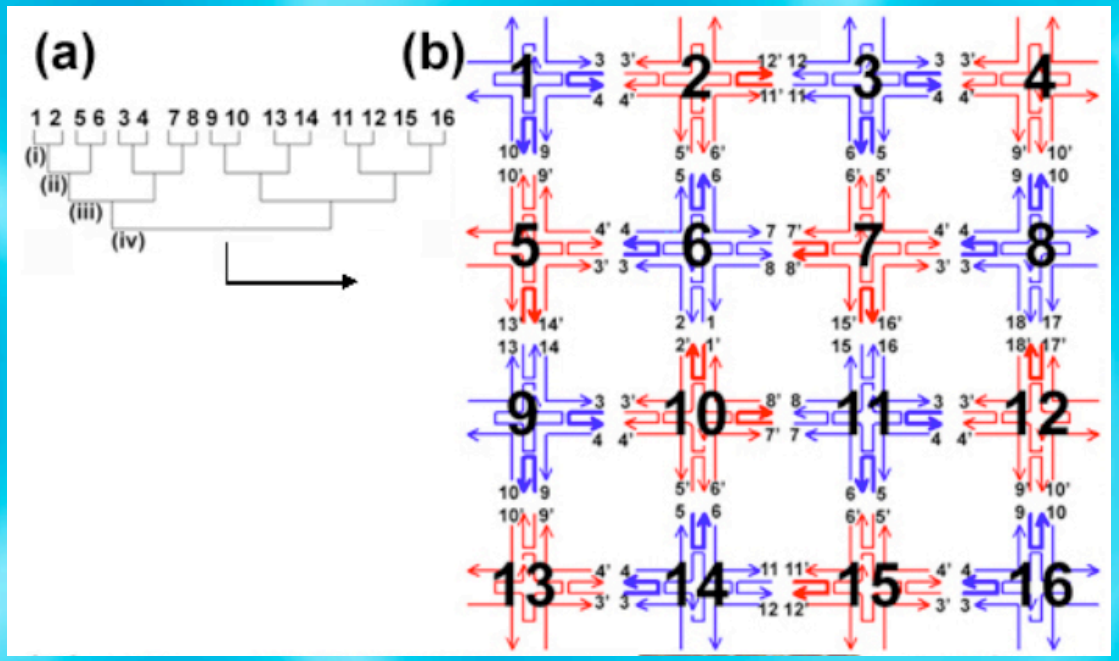
- Fully addressable arrays from smaller sets of tile types.
- Versatile and reprogrammable superstructures.

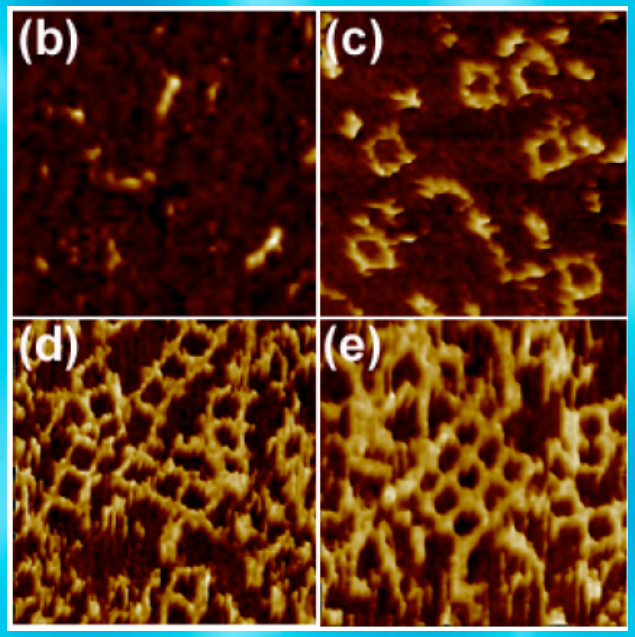
Hierarchical & Segmental Assembly

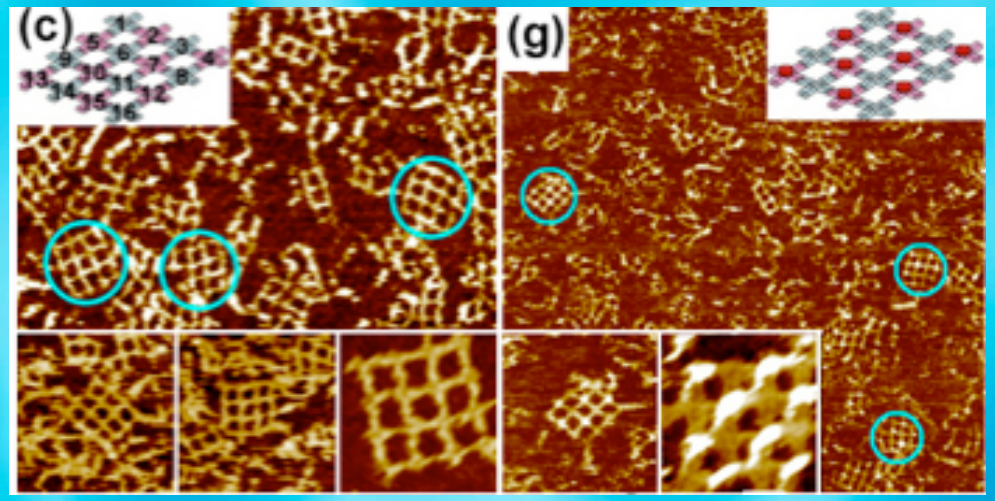


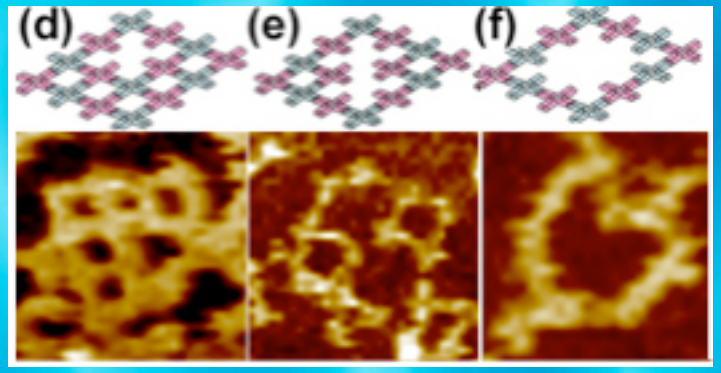


Fixed-size Addressable Arrays



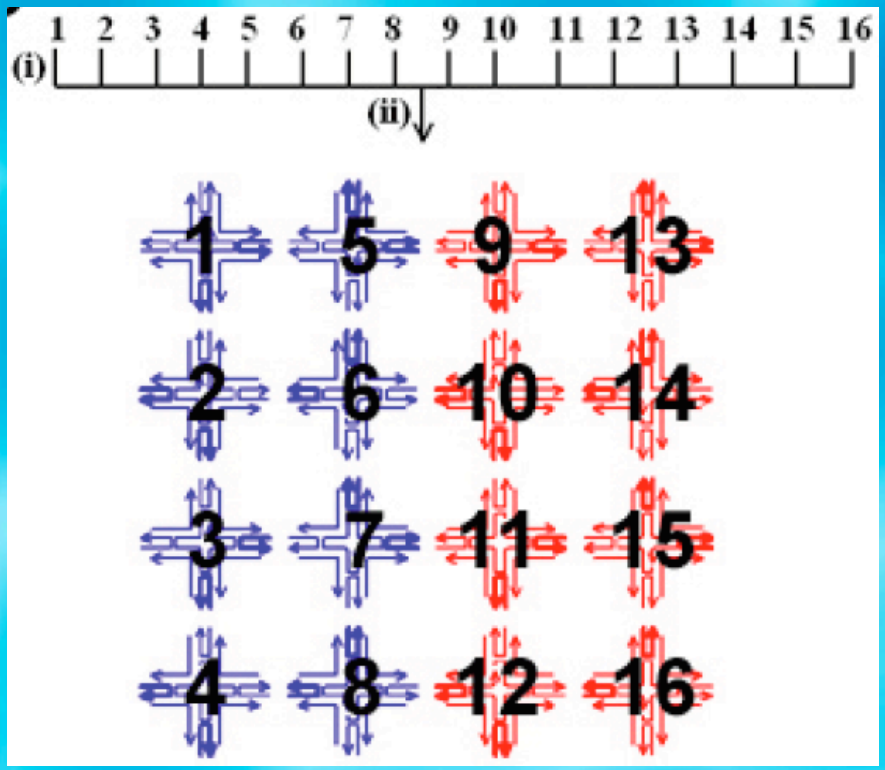


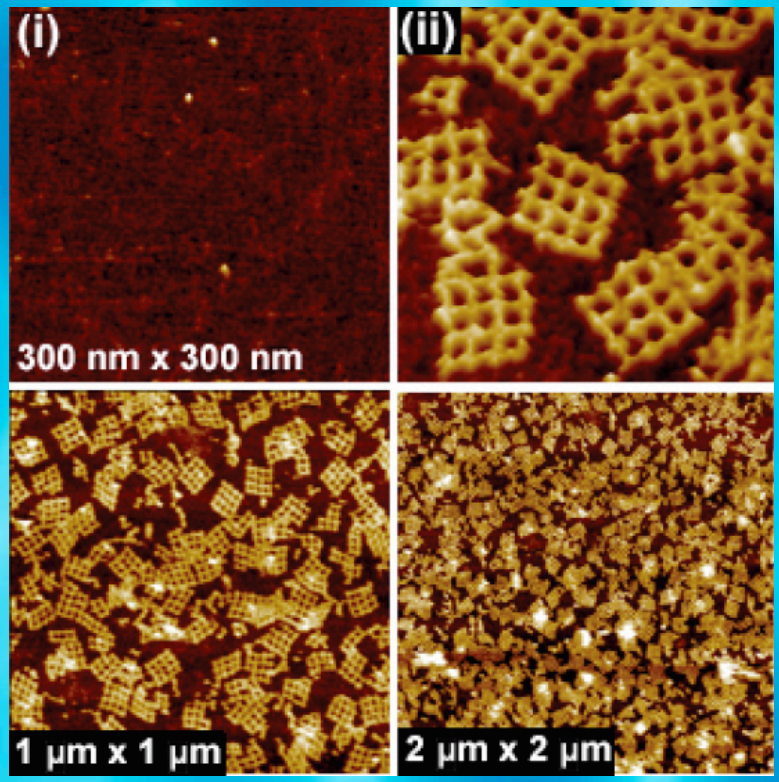


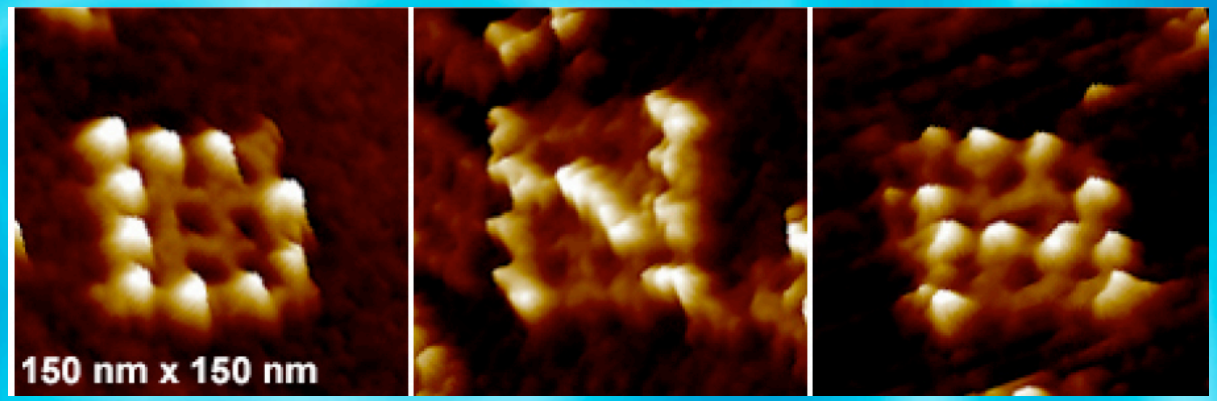


Park, Pistol, Ahn, Reif, Lebeck, Dwyer, LaBean (2006*) Angew. Chem, Int. Ed.* **45**, 735-739

Fixed-size Addressable Arrays



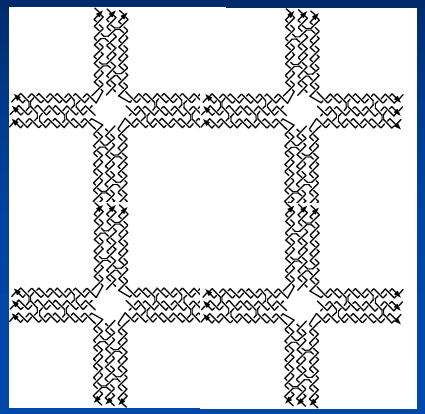


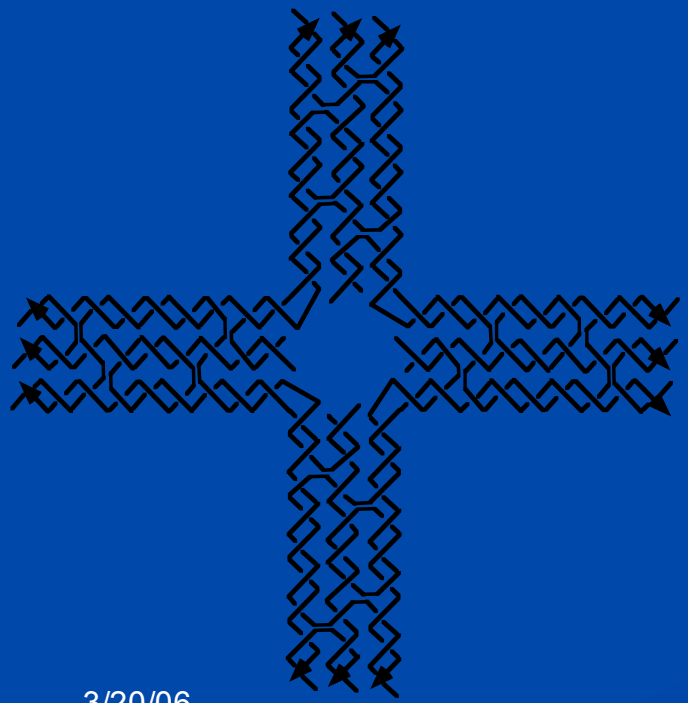


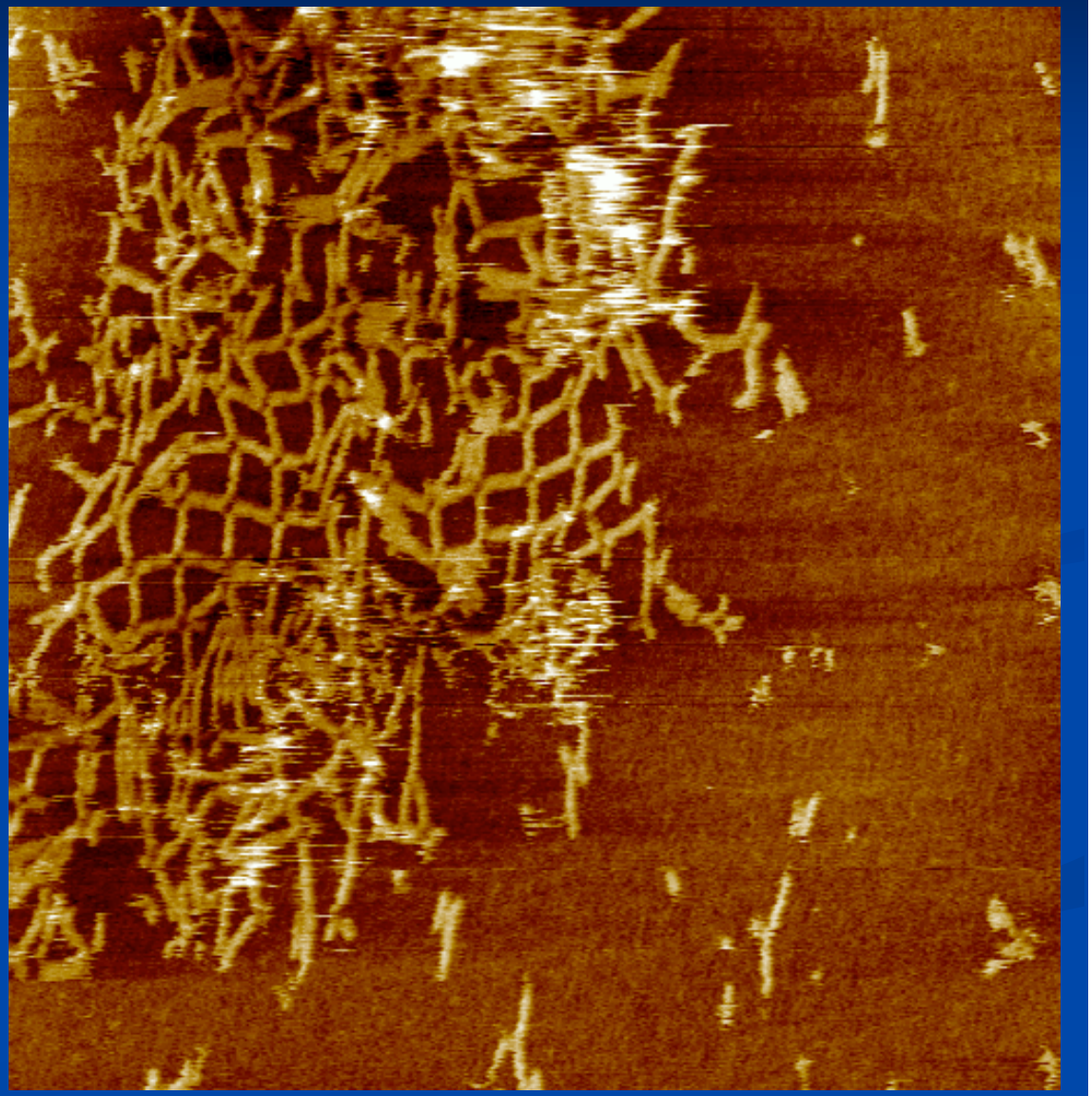
Park, Pistol, Ahn, Reif, Lebeck, Dwyer, LaBean (2006*) Angew. Chem, Int. Ed.* **45**, 735-739

TX x 4 Tiles and Lattices

|– 38nm –|







800x800nm

Jpn. J. Appl. Phys. Vol. 39 (2000) pp. L 269–L 270
Part 2, No. 4A, 1 April 2000

Express Letter

A New Self-Fabrication of Large-Scale Deoxyribonucleic Acid Network on Mica Surfaces

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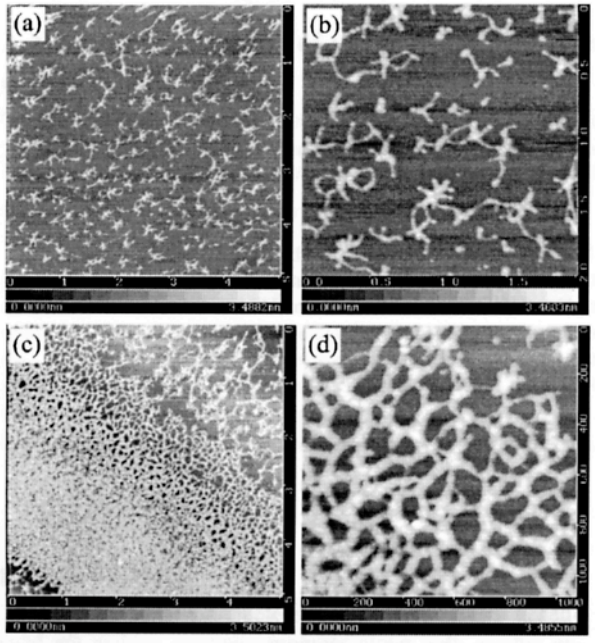
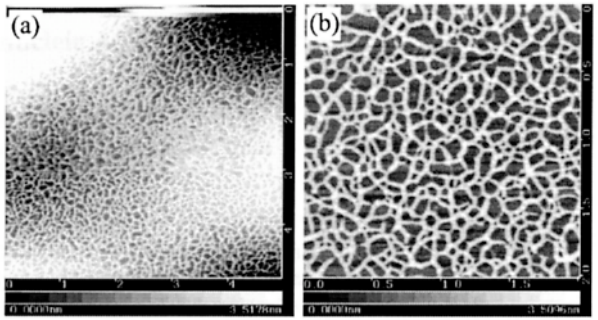
(Received March 1, 2000; accepted for publication March 8, 2000)

We have successfully fabricated large-scale deoxyribonucleic acid (DNA) networks on mica surfaces using a simple and easy fabrication method for the first time. Sample drops of poly(dA-dT)·poly(dA-dT) which is a synthetic linear DNA were spotted on freshly cleaved mica and blown off with air. At low DNA concentrations, clusters of DNA molecules were separated from each other. However at high concentrations, substrates were covered with a two-dimensional DNA network measuring more than 12 mm laterally. The DNA network discovered in our study seems highly practical due to its simple and easy fabrication method and its length. We believe this DNA network has the potential to serve as a biomaterial for medical, engineering and environmental applications.

KEYWORDS: deoxyribonucleic acid (DNA), poly(dA-dT)·poly(dA-dT), mica, surface atomic force microscopy (AFM), DNA network, DNA film



25 mg/mL



250 mg/mL

A 1.7-kilobase single-stranded DNA that folds into a nanoscale octahedron

NATURE | VOL 427 | 12 FEBRUARY 2004 |

William M. Shih[1], Joel D. Quispe[2] & Gerald F. Joyce[1]

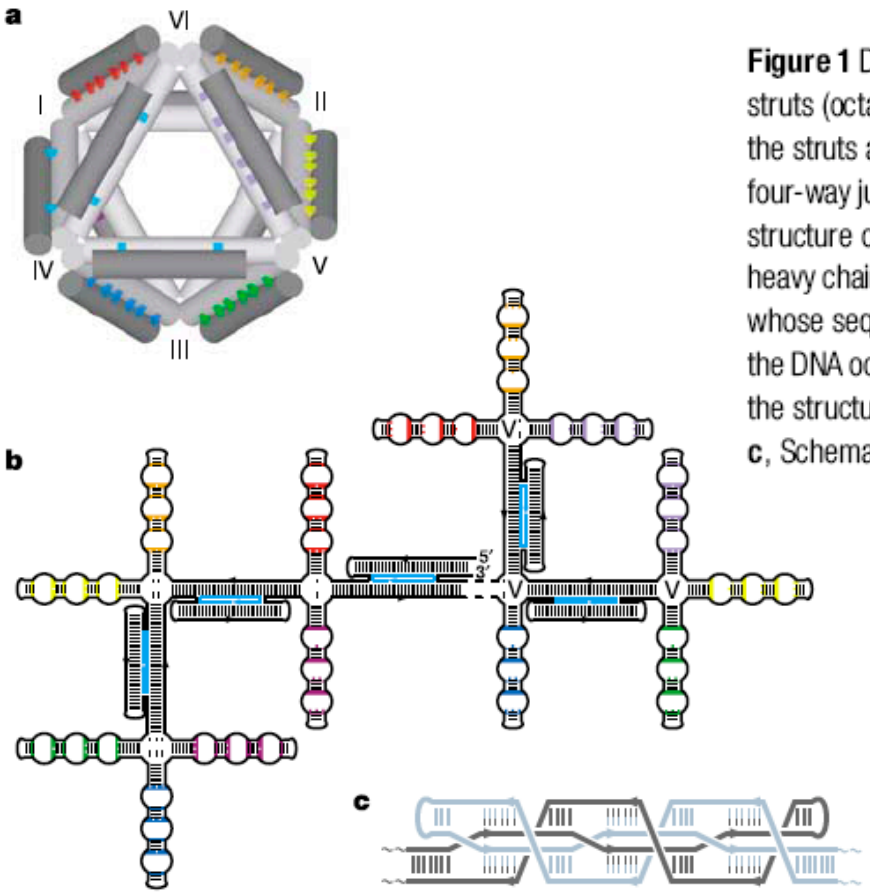


Figure 1 Design of the DNA octahedron. **a**, Three-dimensional structure involving twelve struts (octahedron edges) connected by six flexible joints (octahedron vertices). Five of the struts are DX motifs (cyan) and seven are PX motifs (rainbow colours). The joints are four-way junctions that connect the core-layer double helices of each strut. **b**, Secondary structure of the branched-tree folding intermediate. The structure consists of a single heavy chain (black) and five unique light chains (cyan). Like colours indicate half-PX loops whose sequence-specific cross-association generates a strut that serves as an edge of the DNA octahedron. Coloured stripes coincide with strand crossover positions. Folding to the structure in the upper left is complete when all seven PX struts have formed. **c**, Schematic of a PX strut.

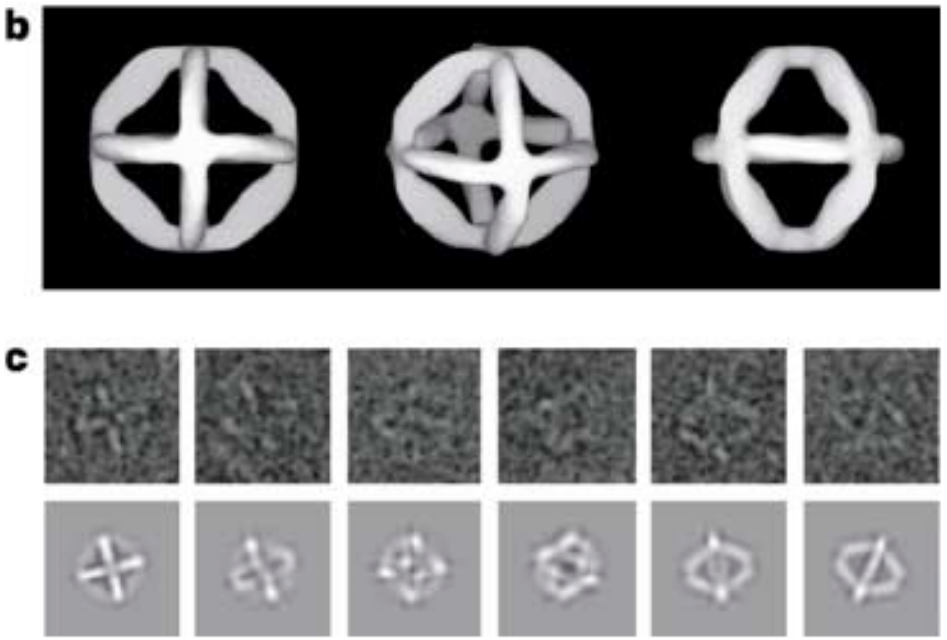
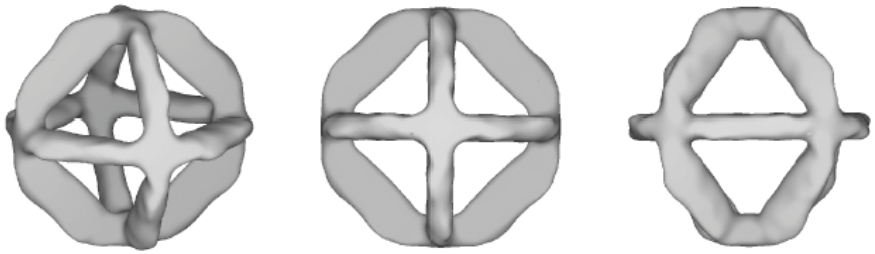
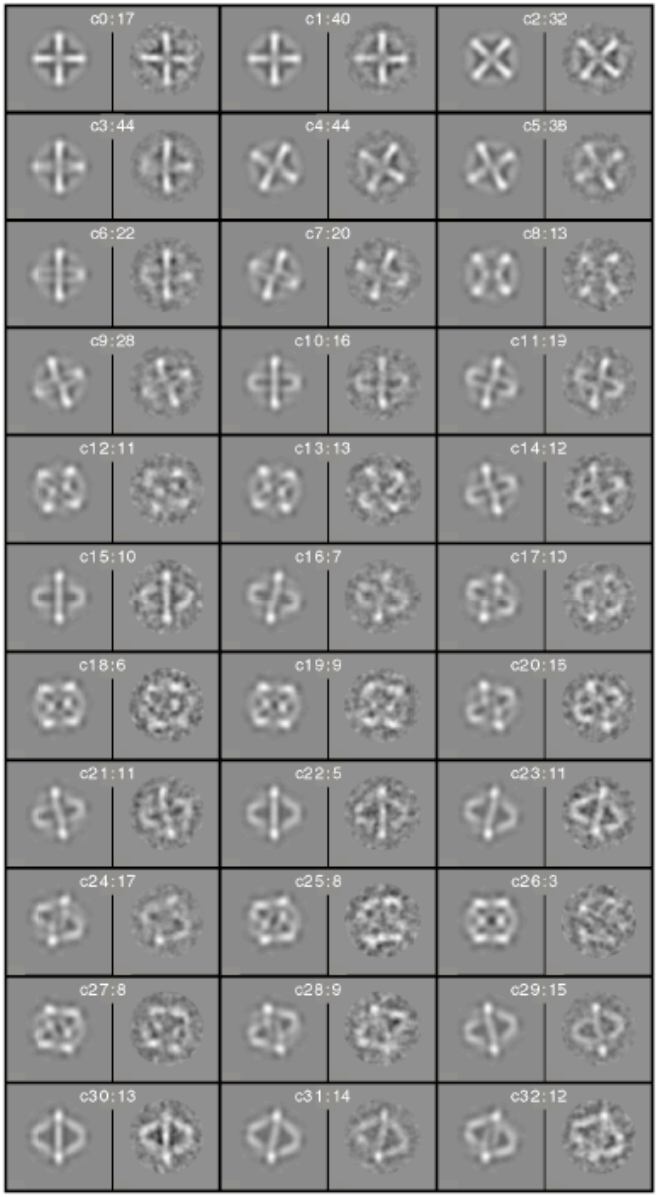


Figure 3 Visualization of the DNA octahedron structure by cryo-electron microscopy. **a**, Representative cryo-electron micrograph, with 25 individual DNA particles boxed. Scale bar, 20 nm. **b**, Three views of the three-dimensional map generated from single-particle reconstruction of the DNA octahedron. **c**, Raw images of individual particles and corresponding projections of the three-dimensional map.

Data from 961 particles used for the reconstruction.
4-fold rotational or octahedral symmetry imposed.





Supplementary Figure 2. Three orientations of a map obtained from a reconstruction performed on images collected at 1.0 μm defocus. For the first dataset (described in the main text), in which paired images were collected at 0.6 and 2.0 μm defocus, the 0.6 μm defocus data could not be used for reconstruction because of poor contrast. A second set of paired images was collected from an independent grid at 1.0 and 2.0 μm defocus. For this second data set, the 1.0 μm defocus images had sufficient contrast for reconstruction. 773 particle images taken at 1.0 μm defocus were used for this reconstruction, for which octahedral symmetry was imposed using a 3 degree angular interval, producing a map with a resolution of 30 Å. The resulting map closely matches the one obtained from the first data set, indicating that radiation damage was not an issue.

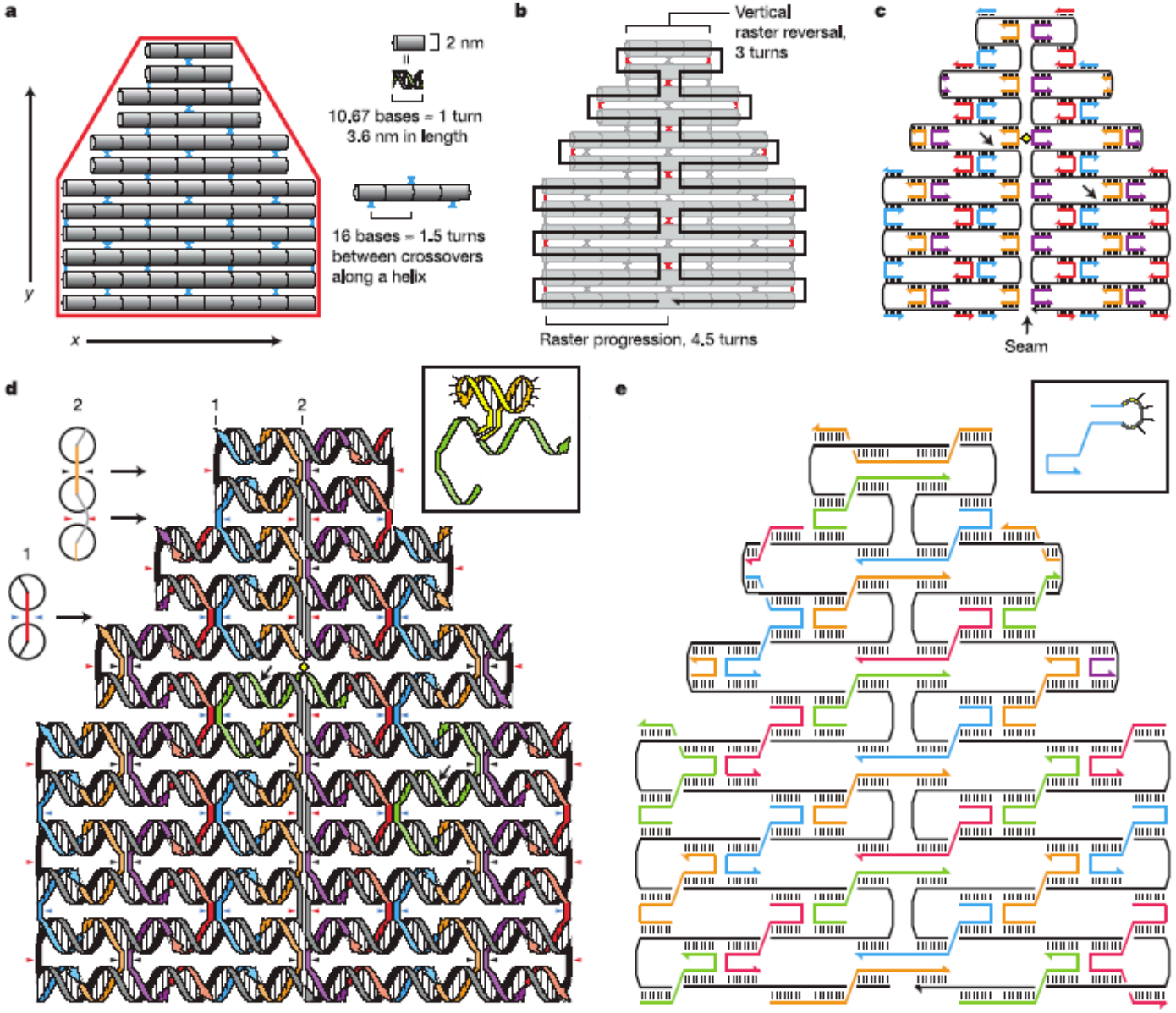
Folding DNA to create nanoscale shapes and patterns

Paul W. K. Rothemund[1]

Vol 440|16 March 2006|doi:10.1038/nature04586

- Long scaffold strand (M13)
- Exposed 3 fallacies
  - Careful sequence design at crossovers
  - Purification of synthetic oligos
  - Equimolar stoichiometries
- Addressable artificial structure with size/complexity of ribosome.

Rothemund, dna origami (2006)



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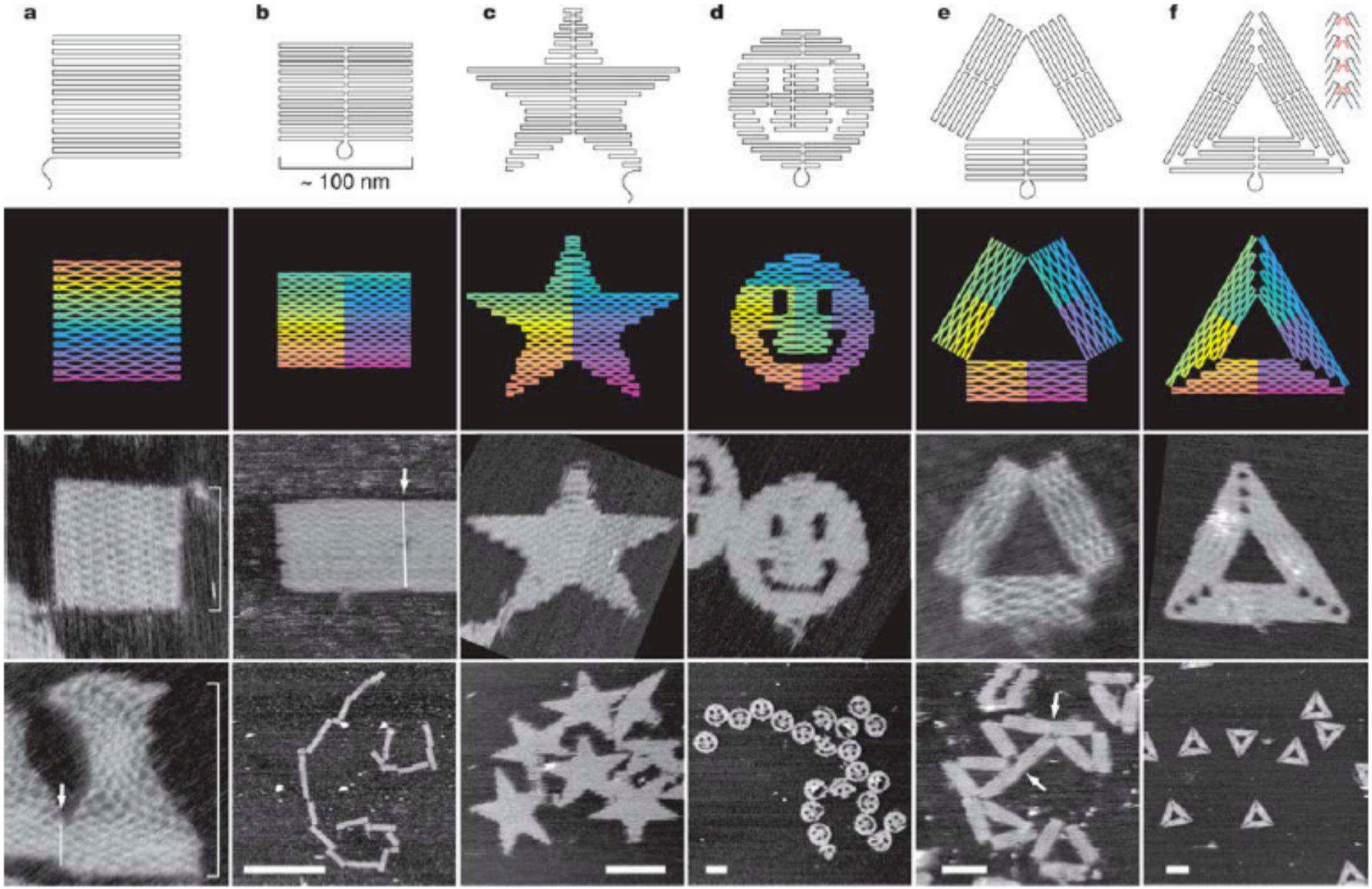

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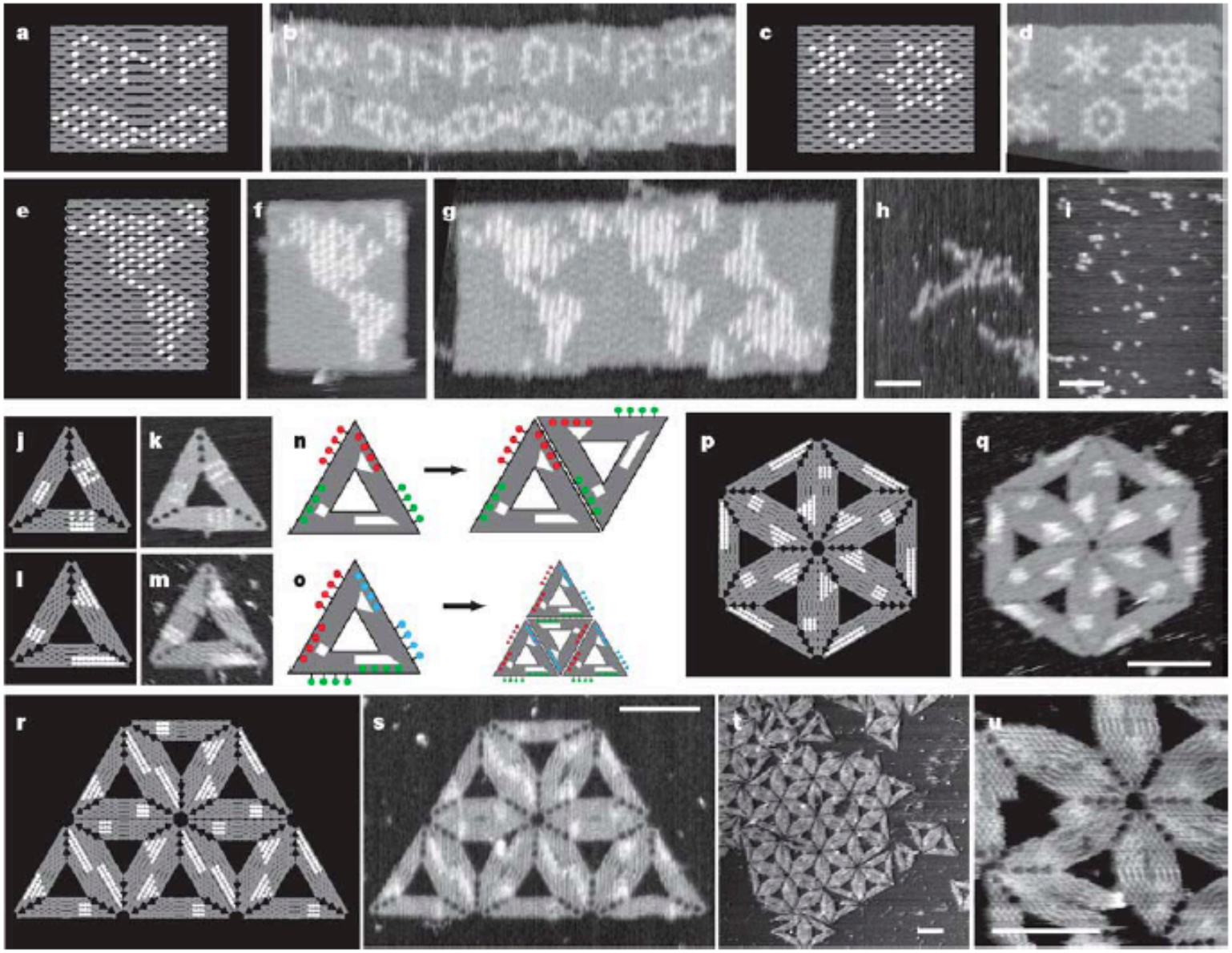

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