Supplementary information

Fast synthesis of DNA origami single crystals at room temperature

*Yifan Yu[1], Min Ji[1], Yong Wang[1], Xuehui Yan[1], Lizhi Dai[1], Ningning Ma[1], Zhaoyu Zhou[1], Hang Xing[2], Ye Tian[1]**

[1]College of Engineering and Applied Sciences, State Key Laboratory of Analytical Chemistry for Life Science, National Laboratory of Solid State Microstructures, Jiangsu Key Laboratory of Artificial Functional Materials, Chemistry and Biomedicine Innovation Center, Collaborative Innovation Center of Advanced Microstructures, Nanjing University, Nanjing 210023, China;

[2]Institute of Chemical Biology and Nanomedicine, State Key Laboratory of Chemo/Biosensing and Chemometrics, Hunan Provincial Key Laboratory of Biomacromolecular Chemical Biology, College of Chemistry and Chemical Engineering, Hunan University, Changsha 410082, China

*Correspondence: ytian@nju.edu.cn;

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h. Sticky ends of elongated-octahedral DNA origami frames-universality verification-2nd system

i. Sticky ends with hairpin DNA conformation of regular-octahedral DNA origami frames-universality verification-3rd system (ULTRAPAGE purified)

Section 6. Supplementary References

Section 1. Experimental Materials and Methods

a. DNA functionalization of gold nanoparticles

The thiol-modified single-strand DNA (ssDNA) sequences were purchased from Shanghai Sangon Biotech Co. Ltd, and the 10 nm gold nanoparticles were purchased from Ted Pella Inc. Prior to modifying the thiol-modified ssDNA on the surface of nanoparticles, we first reduced the thiol-modified ssDNA using TCEP (tris[2-carboxyethyl] phosphine) in an ice bath for 1.5 hour and then purified it using a size exclusion column (G-25, GE Healthcare). Then, we mixed the 10 nm gold nanoparticles with the purified ssDNA at a molar ratio of 1:300 and adjusted the phosphate buffer concentration in solution to 10 mM (pH = 7). The mixed solution was firstly rotated on a rotator for 1.5 hour. Afterward, we gradually introduced NaCl solution (2 M NaCl, 10 mM phosphate) into the mixture in batches until the final NaCl concentration reached 0.1 M. The mixed solution was then rotated on the rotator for 18 hours. After that, we removed excess reduced thiol-modified ssDNA from the mixed solution by centrifugation at 14500 rpm for 1 hour, and replaced the supernatant with buffer (10 mM phosphate, 0.1 M NaCl), repeating this centrifugation and replacement operation three times. The functionalized gold nanoparticles were stored in the refrigerator at 4 °C.

b. Design and synthesis of regular-octahedral DNA origami frames

Regular-octahedral DNA origami frame contained twelve edges, and each edge was composed of a 6-helix bundle (6HB) that had a length of 84 base pairs (~28.56 nm). Detailed design and synthesis process can be found in previous literature[1].To synthesize the regular-octahedral DNA origami frames, we mixed M13mp18 scaffold DNA (Bayou Biolabs, LLC), DNA staples, sticky ends, and inner strands at a molar ratio of 1:10:10:7.5 in the buffer solution containing 1 mM EDTA, 12.5 mM magnesium acetate and 40 mM tris acetate. Thus, the final solution was composed of 10 nM M13mp18 scaffold DNA, 100 nM DNA staples, 100 nM sticky ends and 75 nM inner strands. This solution was firstly heated to 90 °C and then slowly cooled to room temperature over a period of approximately 23 hours. The synthesized regular-octahedral DNA origami frames were stored at room temperature.

c. Encaging functionalized gold nanoparticles inside DNA origami frames

The synthesized regular-octahedral DNA origami frames were firstly mixed with functionalized 10 nm gold nanoparticles at a molar ratio of 1:0.9. Then, the mixed solution was heated to 50 °C and slowly cooled to 20 °C at the rate of 2.4 °C /h, resulting in an efficiency of nearly 99.0% for loading the nanoparticles (Fig. S1b). The DNA origami frames encaged with functionalized gold nanoparticles were uniformly called DNA origami building blocks in this work.

d. Fabrication of DNA origami single crystals at room temperature

Firstly, we mixed two types of DNA origami building blocks at a molar ratio of 1:1, and then use urea solution (9.85 M urea, 1 mM EDTA, 12.5 mM magnesium acetate, 40 mM tris acetate) to adjust the urea concentration of the mixture to our requirement. The required urea concentration was determined based on the fitting curve of T_m (we firstly queried the room temperature from the thermometer, and then regarded this temperature as Tm to calculate the required urea concentration). The mixture was placed directly at room temperature for incubation. During the incubation, no any other operations were required. After the incubation, we used the urea-free buffer (1 mM EDTA, 12.5 mM magnesium acetate and 40 mM tris acetate) to replace the supernatant, and stored the samples at 4 °C.

e. Fabrication of DNA origami single crystals at outdoor temperature

Firstly, we mixed two types of DNA origami building blocks at a molar ratio of 1:1, and then use urea solution (9.85 M urea, 1 mM EDTA, 12.5 mM magnesium acetate, 40 mM tris acetate) to adjust the urea concentration of the mixture to our requirement. The required urea concentration was determined based on the fitting curve of T_m (we firstly queried the temperature fluctuations in the next two days from the weather forecast and determined the average temperature, and then regarded this average temperature as Tm to calculate the required urea concentration). The mixture was placed directly at outdoor temperature for incubation. During the incubation, no any other operations were required. After the incubation, we used the urea-free buffer (1 mM EDTA, 12.5 mM magnesium acetate and 40 mM tris acetate) to replace the supernatant, and stored the samples at 4 °C.

f. Linear fitting of T_m variation curve with urea concentration

We used the linear equation to fit the curve of T_m changing with urea concentration, and the fitting formula is:

$$T_m = 40.8\ °C+1\text{-}4.64\ °C/M \times C_{urea}$$

where T_m is the melting temperature, C_{urea} is the urea concentration, and 40.8 °C is the orignal T_m of the system without urea. The R^2 of this fitting curve is 0.997, confirming the fine fitting. This fitting curve can be used to calculate the required urea concentration for the crystallization of DNA buidling blocks in a specific environment by substituting the temperature parameters into T_m (for room temperature: taking the current temperature; for outdoor temperature: taking the average temperature).

g. Silica-coated DNA origami crystals

To intuitively observe the morphology and packing modes of the assemblies, we had to remove them from the salt solution and expose them to high-energy electron beam irradiation that unfortunately would cause the collapse of structure. Therefore, we encapsulated the bundles of regular-octahedral DNA origami frames and the connection part by a thin layer of silica to preserve their structural integrity. This silica-coated approach was referring to previous work[2]. Firstly, we diluted the concentration of magnesium ion in the solution to 7 mM, followed by adding 0.5-0.8 μL TMAPS (N-trimethoxysilylpropyl-N, N, N-trimethylammonium chloride) at room temperature. Then, this mixture was shaken for 20 minutes at 400 rpm, added 0.4-0.7 μL TEOS (tetraethyl orthosilicate), shaken for another 30 minutes at 500 rpm. Finally, after holding overnight, we replaced the supernatant of the sample with deionized water to interrupt the encapsulation process. The silica-coated samples were stored at room temperature.

Section 2. Electron Microscopy and Confocal Laser Scanning Microscope

a. Sample preparation and transmission electron microscope (TEM)

The carbon-coated grids were firstly discharged in a 0.26 mbar air atmosphere for 30 seconds using PELCO easiGlow (Ted Pella, Inc.). After shaking the sample solution evenly, 5 μL solution was dropped onto this discharged carbon-coated grid. Five minutes later, residual solution was removed from the grid by filter papers, and then 5 μl deionized water was dropped and removed immediately by filter papers to dissolve the deposited salt. This process was repeated twice. Next, 5 μL 2% (w/v) uranyl acetate solution was dropped onto the grid to stain the sample for 10 seconds, and then removed by filter papers. This grid was then held to air dry for several minutes. The prepared carbon-coated grids covered by samples were then observed using JEOL JEM-1400 operated at 120 kV.

b. Sample preparation and scanning electron microscope (SEM)

The silica-coated samples were shaken evenly and then 5 μL solution was taken out to be dropped onto the alcohol-washed silicon slice. To accelerate the drying process, we baked the droplet under infrared light until it was completely dry. This silicon slice was glued to the SEM sample stage using copper conductive tape without any metal deposition. The prepared samples were then observed using HITACHI Regulus 8100 operated at 1.5 kV with current of 2 μA.

c. Sample preparation and confocal laser scanning microscope (CLSM)

Firstly, we shook the samples evenly, and then extracted 2 μL mixture to drop into a confocal dish. This dish was then placed onto the sample stage of CLSM (Leica TCS SP8 STED) for subsequent observation. For higher image resolution, we utilized the bright field mode of CLSM (Leica TCS SP8 STED) to observe the mesoscopic morphology of our samples. The crystals did not exhibit their true colors under CLSM which highlighted the contrast, because the imaging principles was different from that of the ordinary optical microscope which can retain the authentic color (dark red) of the samples. However, this did not affect our data collection as we required the size and shape information of samples, and the advantages of CLSM was that it could help us to obtain data with more accurate size.

Section 3. Small Angle X-ray Scattering (SAXS)

a. Experimental method and data analysis

The SAXS experiments were carried out at the BL19U2 beamline at Shanghai Synchrotron Radiation Facility (SSRF). Before characterization, the samples were transformed from the tube into a glass capillary (inner diameter 1 mm), and then positioned them between the X-ray source and detector. The distance between the detector and samples was about 2-3 m. The 2D SAXS patterns were collected by detecting X-ray exposure, and the 1D scattering curves (scattering intensity I(q) as a function of scattering vector (q) were derived from the integration of 2D SAXS patterns. The scattering vector $q = 4\frac{\pi}{\lambda}\sin\left(\frac{\theta}{2}\right)$, where λ represents the wavelength of incident X-ray and θ is the scattering angle of the X-ray. To highlight the structural information of assembly more effectively, we extracted the structure factor S(q) from the scattering curve I(q) by deducting the corresponding particle form factor P(q), based on the formula $\mathrm{I}(q) = \mathrm{P}(q) \times \mathrm{S}(q)$. The fitting of the 1D scattering curves was carried out with the PowderCell software by comparing the position of experimental scattering peaks with those of the corresponding standard model until obtaining the optimize result. Specifically, we first calculated the unit cell parameters based on the calculation formula for crystal plane spacing (($d = \frac{2\pi}{q}, d_{hkl} = \frac{1}{\sqrt{\frac{h^2+k^2+l^2}{a^2}}}$ (simple cubic system)), and then utilized software to obtain the 1D standard scattering spectra of the theoretical unit cell according to calculated lattice parameters. After that, we compared the positions of the standard scattering peaks with our experimental scattering curves to identify the ultimate structure and parameters. If the theoretical model was not fit well, we finely adjusted the unit cell parameter appropriately to match the scattering peak position and height with those of the experimental 1D SAXS curves as closely as possible.

Section 4. Supplementary Figures

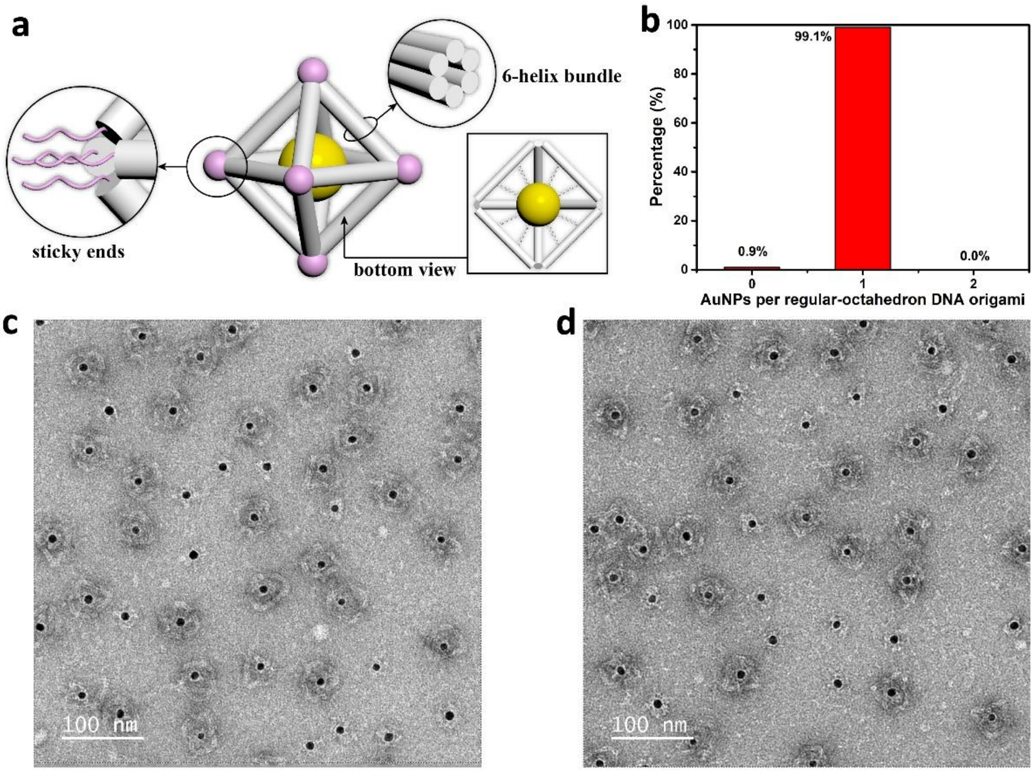


Fig. S1 Schematic illustration of DNA origami building block and the corresponding TEM characterization. (a) 6-helix-bundle edges of the regular-octahedron DNA origami were simplified into single-helix-bundle edge, and the four sticky ends extending from the vertices were simplified into a small color ball for the convenience of description. The inserted 10 nm gold nanoparticle was captured by 8 inner strands to fix the nanoparticle in the center of regular-octahedron DNA origami. (b) Statistical analysis of the number of gold nanoparticles inserted into the regular-octahedron DNA origami. (c) (d) TEM images of DNA origami building blocks (scale bars, 100 nm).

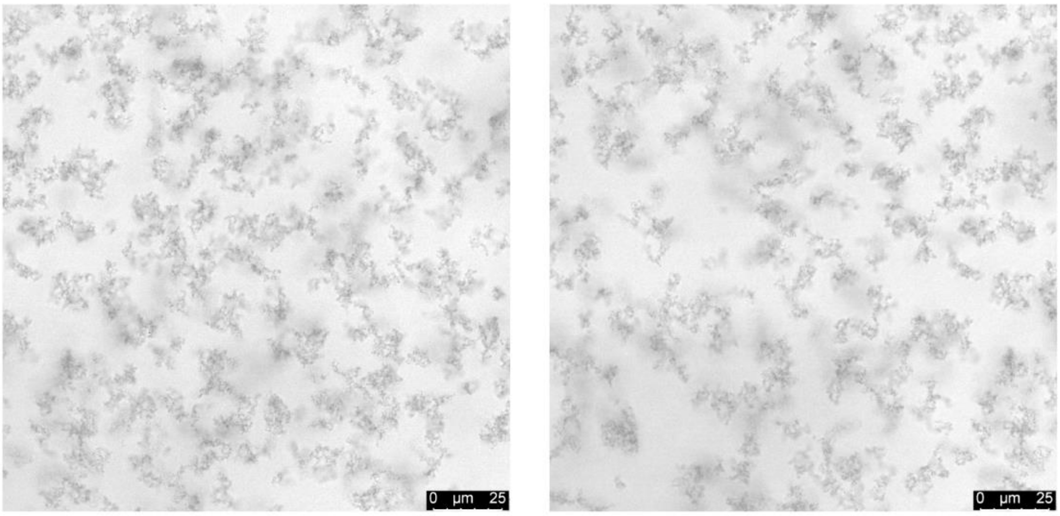


Fig. S2 Large-scaled CLSM images of the assemblies grown at room temperature for 48 h without urea.

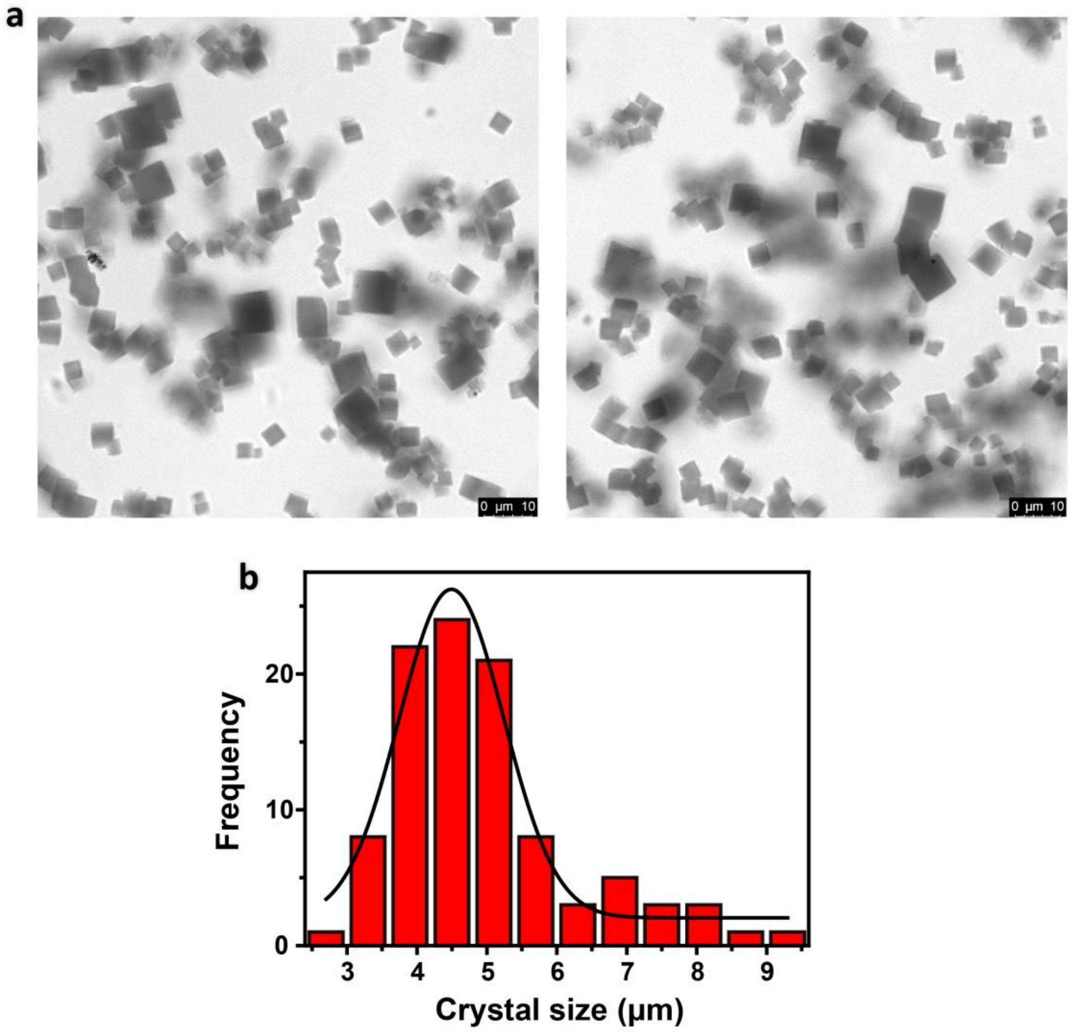


Fig. S3 (a) Large-scaled CLSM images of the assemblies grown at room temperature for 48 h with 3.8 M urea. (b) Crystal size distribution histogram of the crystals incubated at room temperature for 48 h with 3.8 M urea.

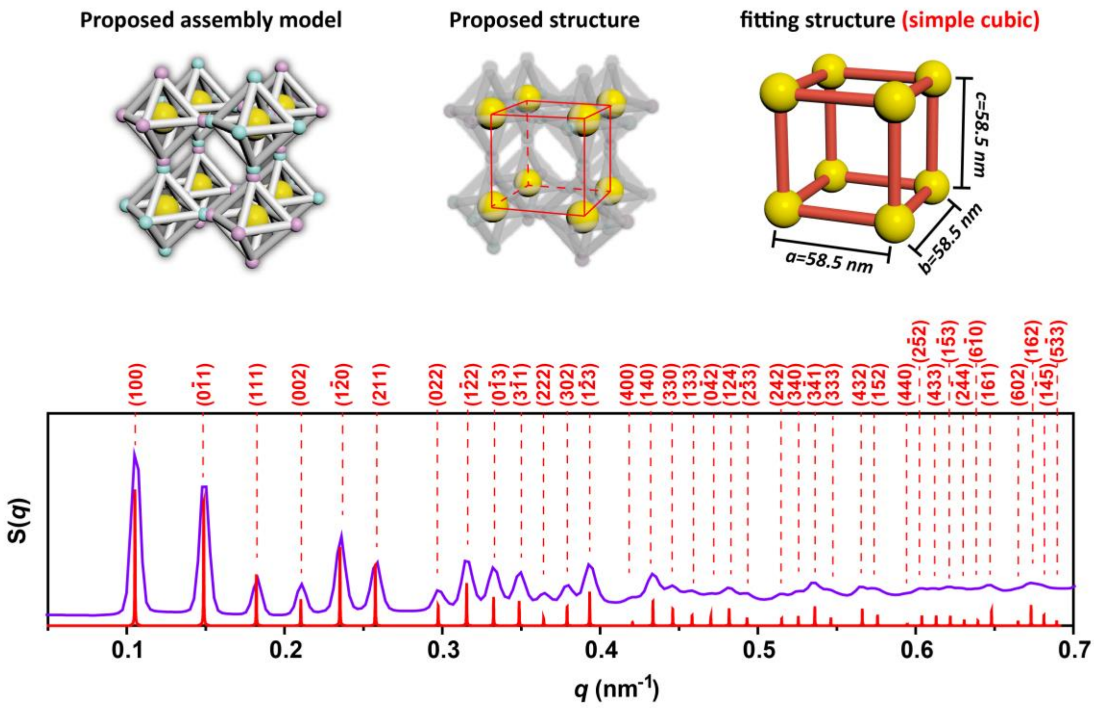


Fig. S4 The fitting result of SAXS curves of crystals incubated at room temperature.

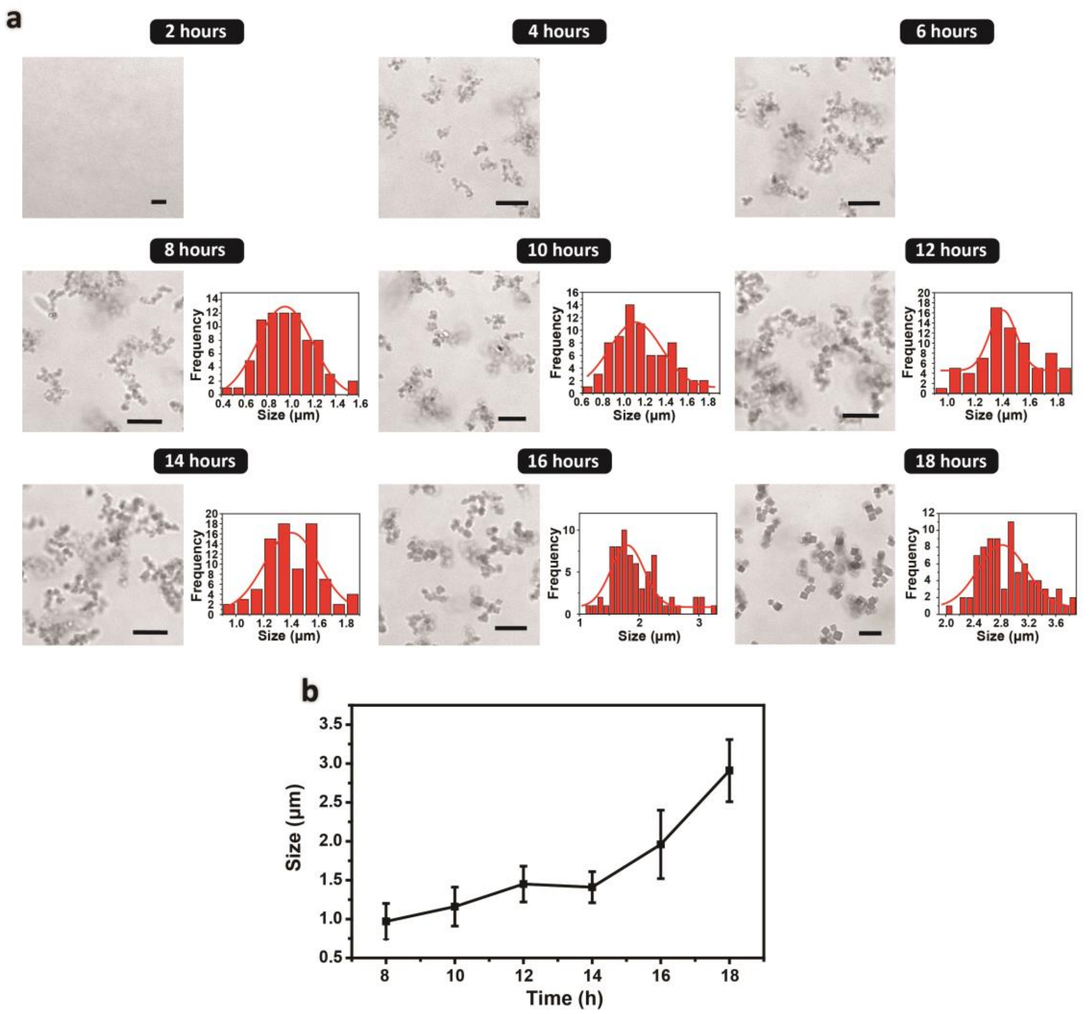


Fig. S5 The development of crystal size over time. (a) Representative CLSM images of crystals with different growth time and the responding crystal size frequency distribution. Scale bars, 10 μm. Since the crystal with growth time less than six hours cannot distinguish the sides of cubic shape, we did not make size statistics, and we started to make size statistics from the eight hours. At each time point, the size of more than 70 crystals was counted. (b) development trend of average crystal size measured from CLSM images over time.

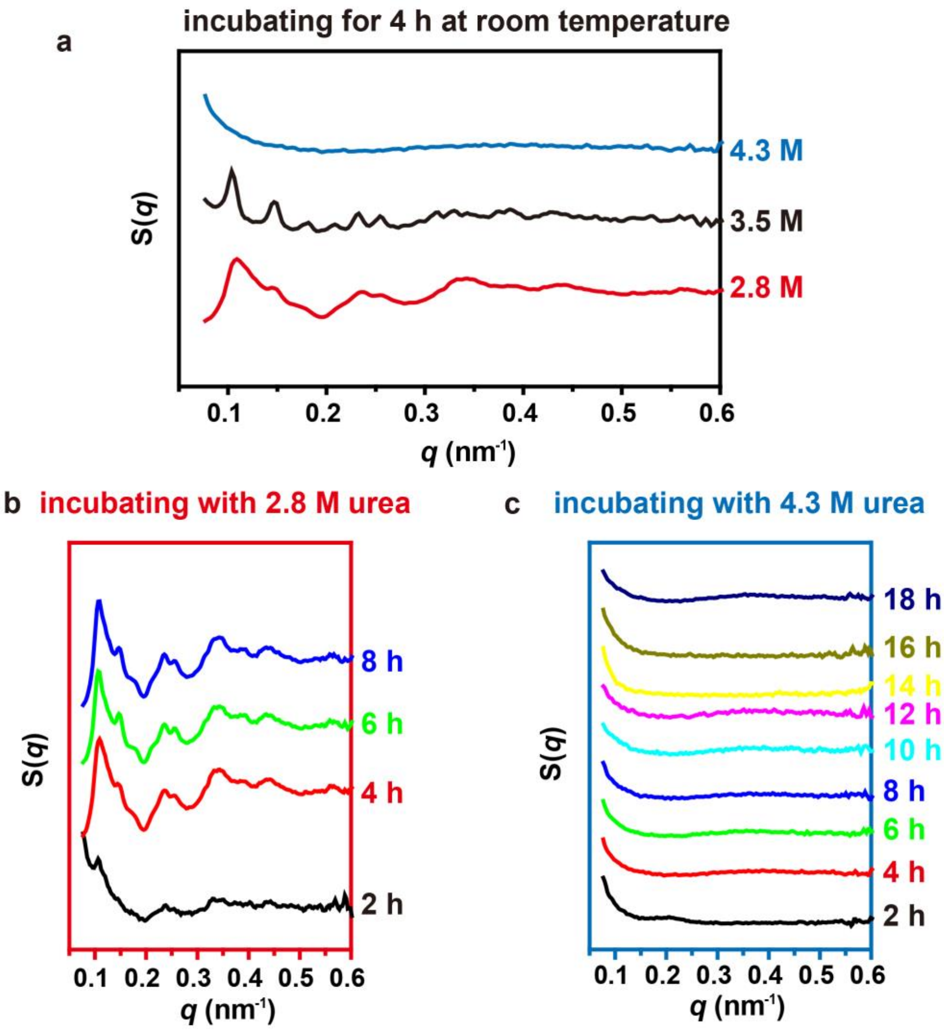
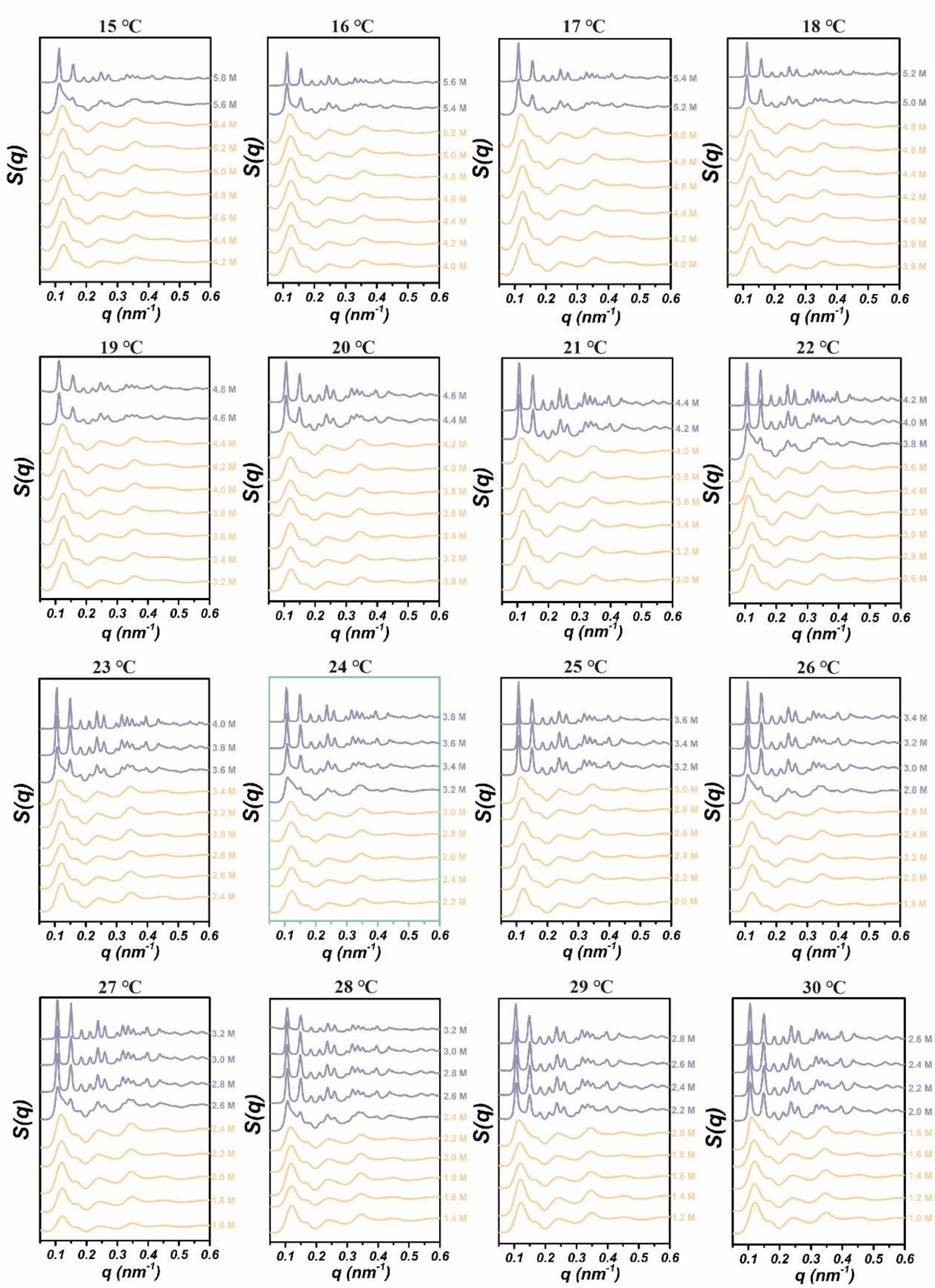


Fig. S6 Comparison of DNA origami building blocks crystallized in 4.3 M, 3.5 M, and 2.8 M urea solution respectively at room temperature. (a) SAXS curves of samples after incubating with 4.3 M, 3.5 M, and 2.8 M urea respectively for 4 h at room temperature. From these SAXS curves, The DNA origami building blocks crystallized in 3.5 M urea solution, the DNA origami building blocks formed amorphous aggregates in 2.7 M urea solution, and the DNA origami building blocks were not assembled in 4.3 M urea solution. (b) SAXS curves of DNA origami building block assembling with time in 2.7 M urea solution. DNA origami building blocks cannot crystallize into ordered assemblies in 2.7 M urea solution. (c) SAXS curves of DNA origami building block assembling with time in 4.3 M urea solution. DNA origami building blocks remained monodisperse state within 18 hours.



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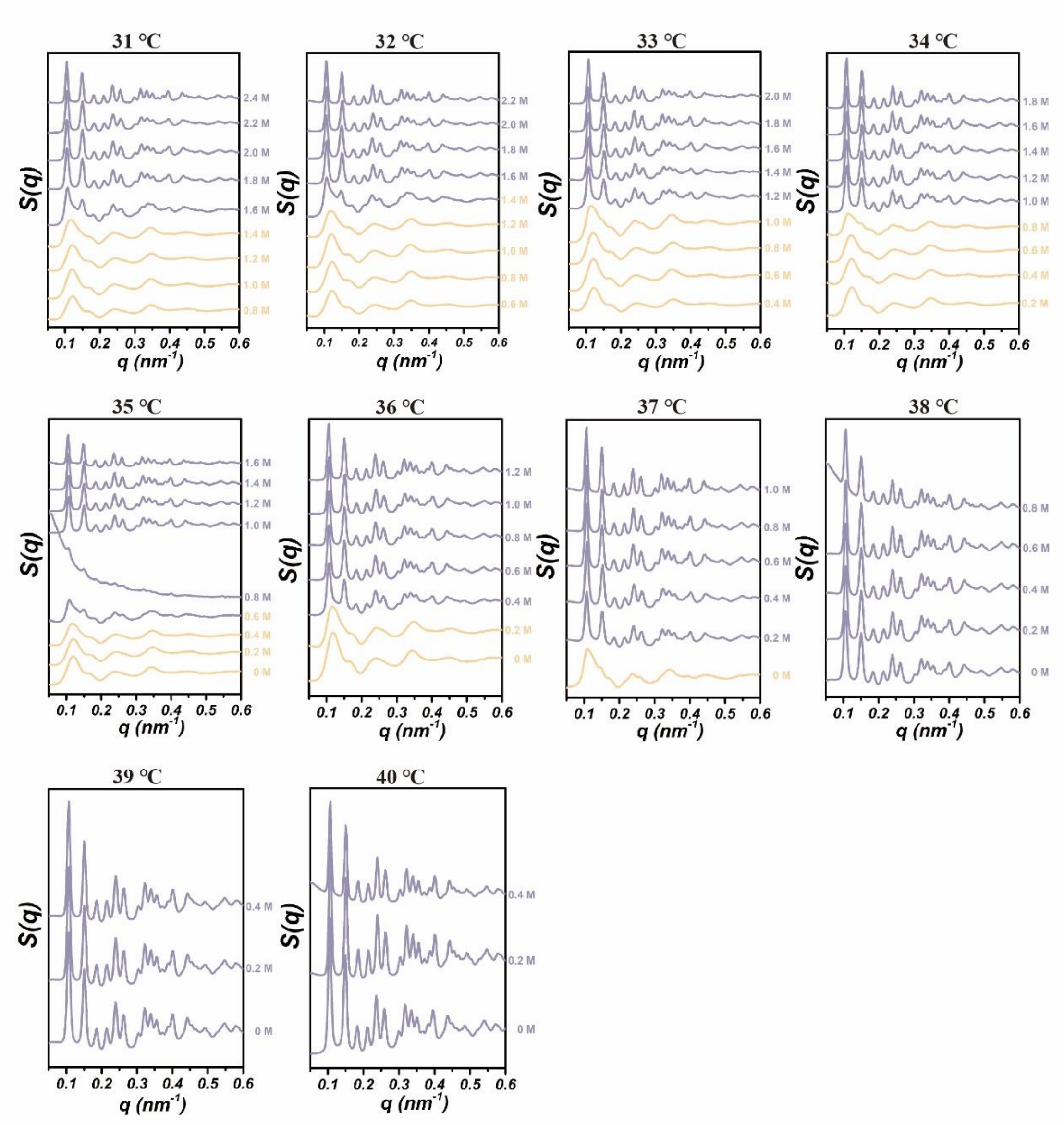

Fig. S7 1D SAXS curves of assemblies grown isothermally at fixed temperature with different urea concentration for 48 h.

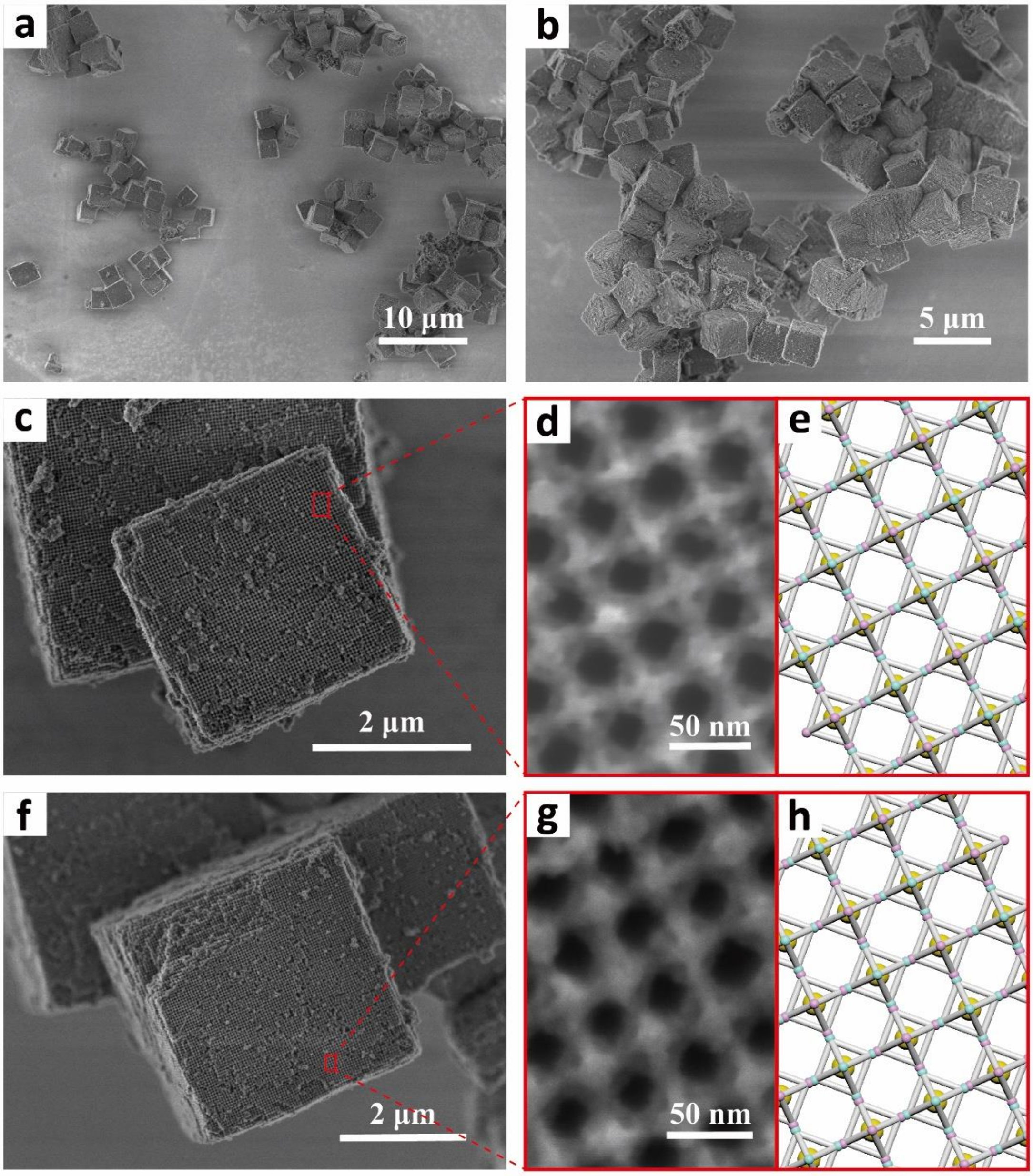

Fig. S8 SEM images of the silica-coated DNA origami crystal incubated isothermally at 24 °C with 3.8 M urea concentration for 48 h. (a) (b) Large-scaled SEM image showed that the crystals had cubic Wulff shape. (c) (f) Representative SEM images of the single DNA origami crystals (scale bars, 2 μm). (d) (g) Enlarged SEM images of the region framed by red rectangle respectively in c and f, and the relative orientations between adjacent DOBs were identical (scale bars, 50 nm). (e) (h) Assembly models respectively corresponding to (d) and (g), in which the vertices of DNA origami building blocks are fully utilized for assembly.

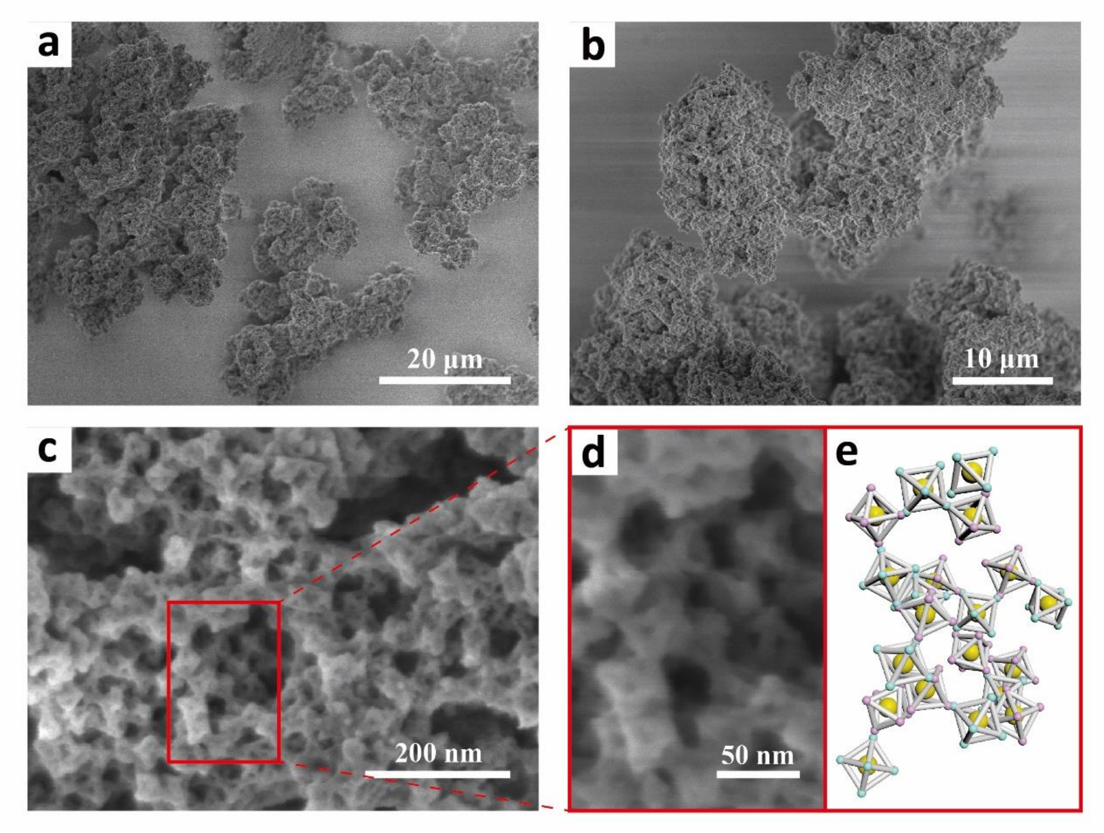

Fig. S9 SEM images of the silica-coated amorphous aggregation incubated isothermally at 24 °C with 2.0 M urea concentration for 48 h. (a) (b) Large-scaled SEM image showed that the assembly were amorphous with no distinguishable shape. (c) Representative SEM image of the assembly details showed that the arrangement of DOBs was disordered and the relative orientation between the adjacent DNA origami building blocks was chaotic (scale bar, 200 nm). (d) Enlarged SEM image of the region framed by red rectangle in (c) (scale bar, 50 nm). (e) Assembly model corresponding to the aggregate shown in (d), in which the vertices were not fully utilized for assembly.

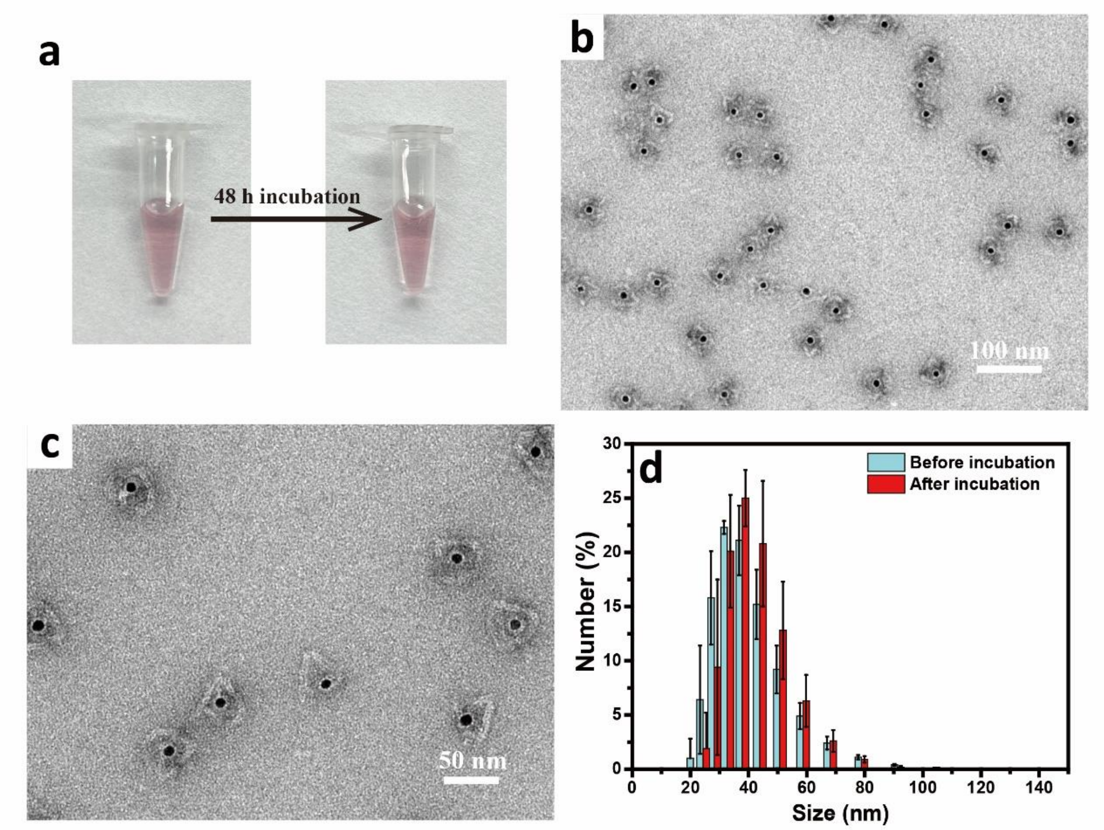

Fig. S10 Characterization of the liquid phase incubated isothermally at 24 °C with 5.0 M urea concentration for 48 h. (a) Images of the samples before and after 48-hour incubation, and there was no precipitation at the bottom of the tube after incubation. (b) Large-scaled TEM image of samples after 48-hour incubation, which showed that there was no connection between most of DNA origami building blocks (scale bar, 100 nm). (c) Closed-up TEM images of samples after 48-hour incubation (scale bar, 50 nm). (d) Characterization results of dynamic light scattering for samples before and after incubation (samples before incubation: blue rectangle; samples after incubation: red rectangle), which was a distribution histogram of number (y axis, %) versus aggregate size (x axis, nm).

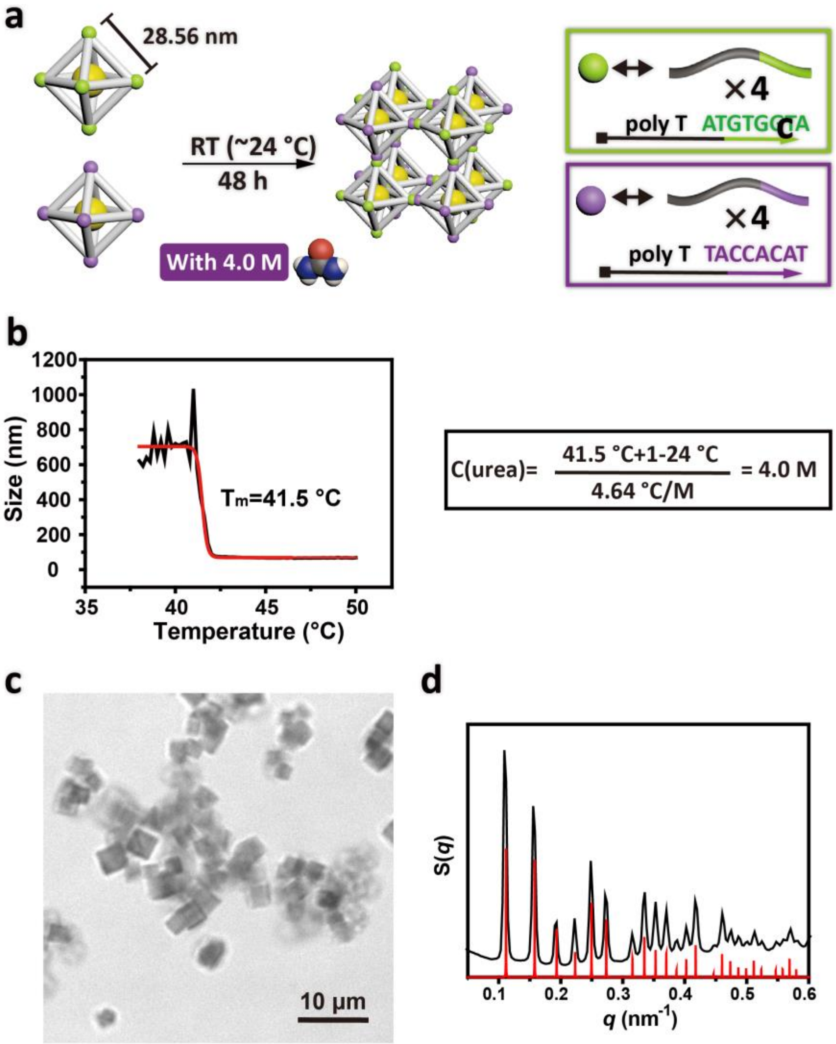

Fig. S11 Universal validation of room-temperature synthesis approach. (a) The first system changed the sequence of the sticky ends extending from the vertices of regular-octahedral DNA origami framework. We anticipate that this system can be crystallized at room temperature (24 °C) with 4.0 M urea. (b) The original T_m of the first system measured by DLS, and the calculation of urea concentration required for crystallization at 24 °C. (c) The representative CLSM images of the first system after incubating at room temperature (24 °C) for 48 hours. Scale bar, 10 µm. (d) The 1D SAXS curve of the first system after incubating at room temperature (24 °C) for 48 hours.

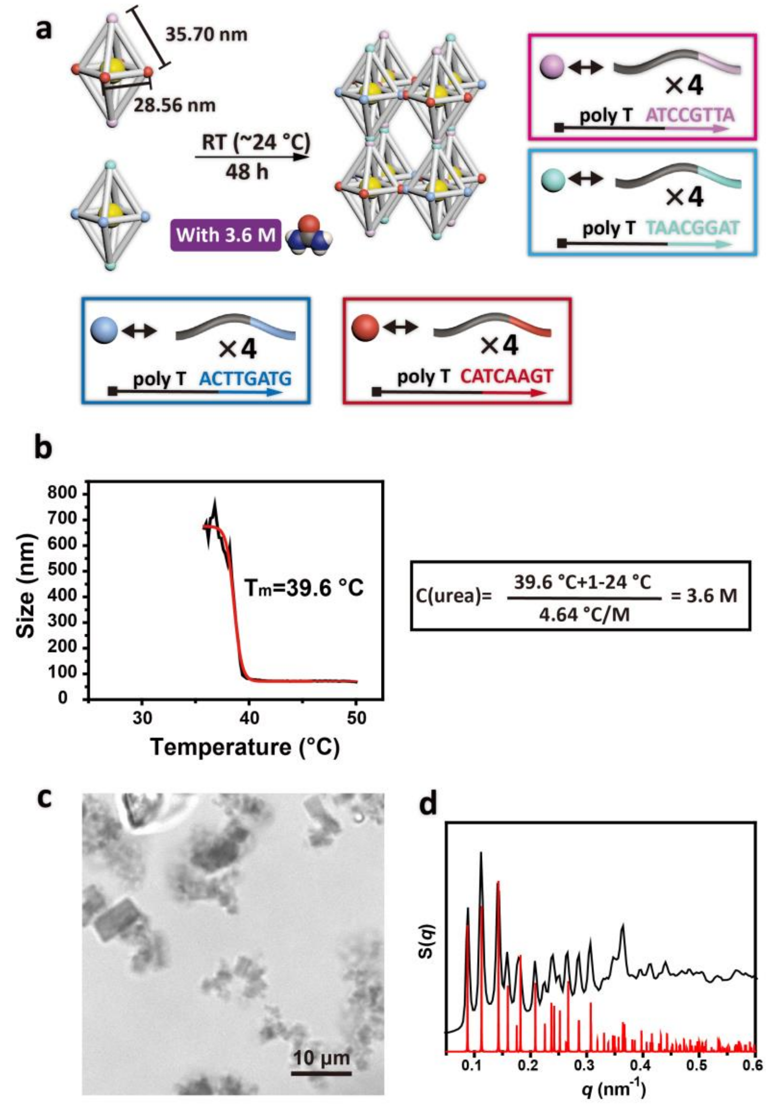

Fig. S12 Universal validation of room-temperature synthesis approach. (a) The second system changed the shape of DNA origami frameworks and the sequence of sticky ends at the same time. The DNA origami used in this system is elongated-octahedral DNA origami framework. We anticipate that this system can be crystallized at room temperature (24 °C) with 3.6 M urea. (b) The original T_m of the second system measured by DLS, and the calculation of urea concentration required for crystallization at 24 °C. (c) The representative CLSM images of the second system after incubating at room temperature (24 °C) for 48 hours. Scale bar, 10 μm. (d) The 1D SAXS curve of the second system after incubating at room temperature (24 °C) for 48 hours.

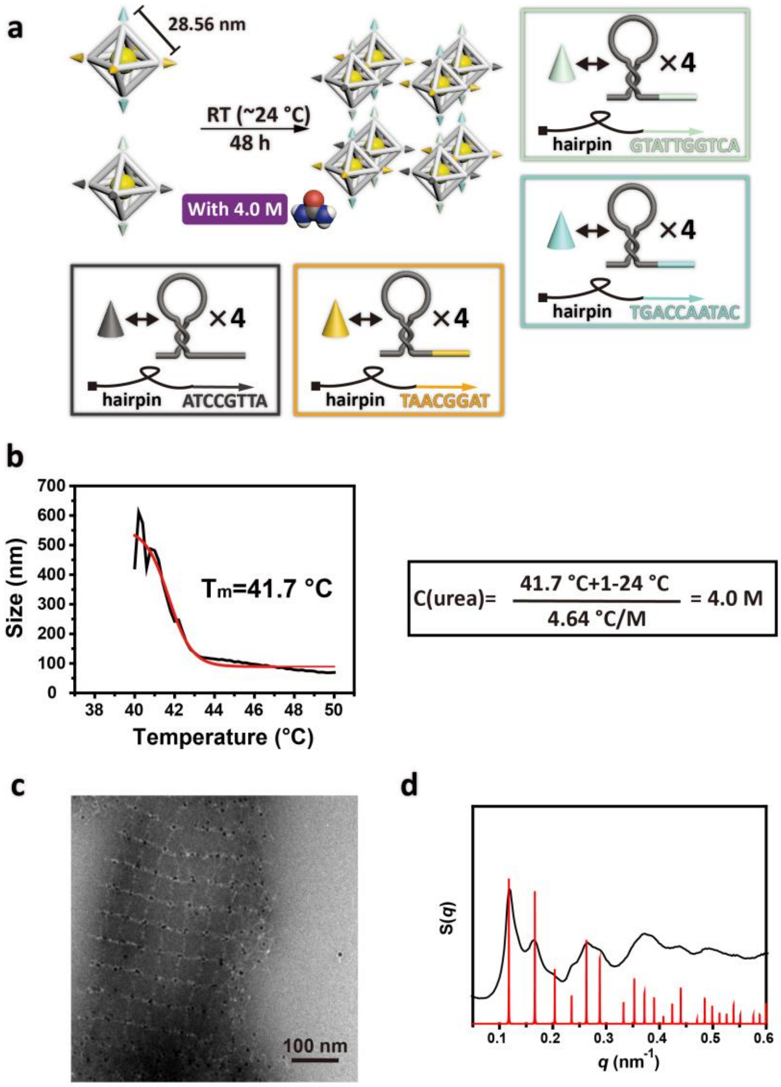

Fig. S13 Universal validation of room-temperature synthesis approach. (a) The third system changed the flexible region of sticky ends into a hairpin DNA conformation, and the complementary base number was increased to 10 bases. We anticipate that this system can be crystallized at room temperature (24 °C) with 4.0 M urea. (b) The original T_m of the third system measured by DLS, and the calculation of urea concentration required for crystallization at 24 °C. (c) The representative TEM images of the third system after incubating at room temperature (24 °C) for 48 hours. Scale bar, 100 nm. (d) The 1D SAXS curve of the third system after incubating at room temperature (24 ° C) for 48 hours.

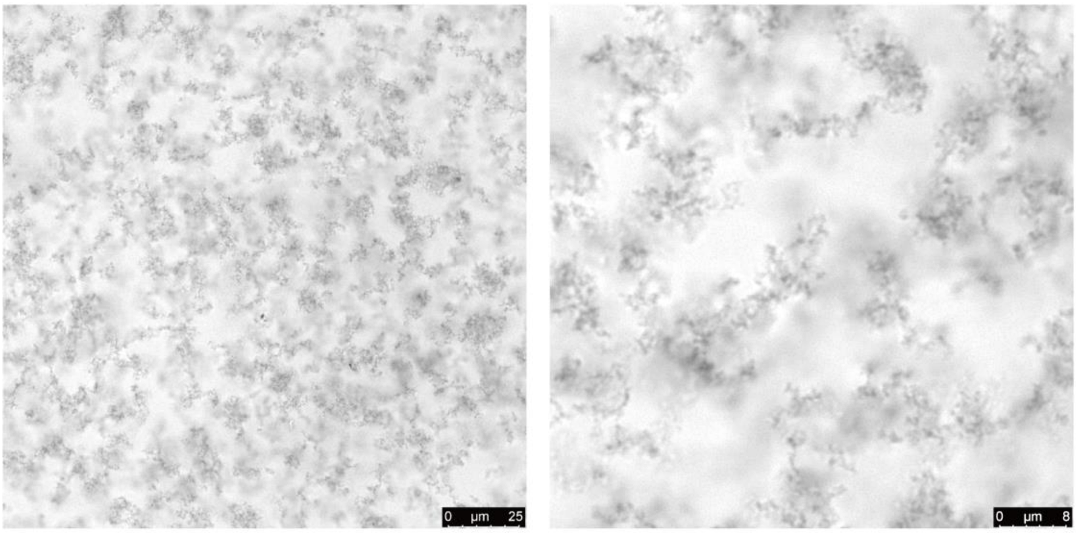

Fig. S14 Large-scaled CLSM images of the assemblies grown at outdoor temperature for 48 h without urea.

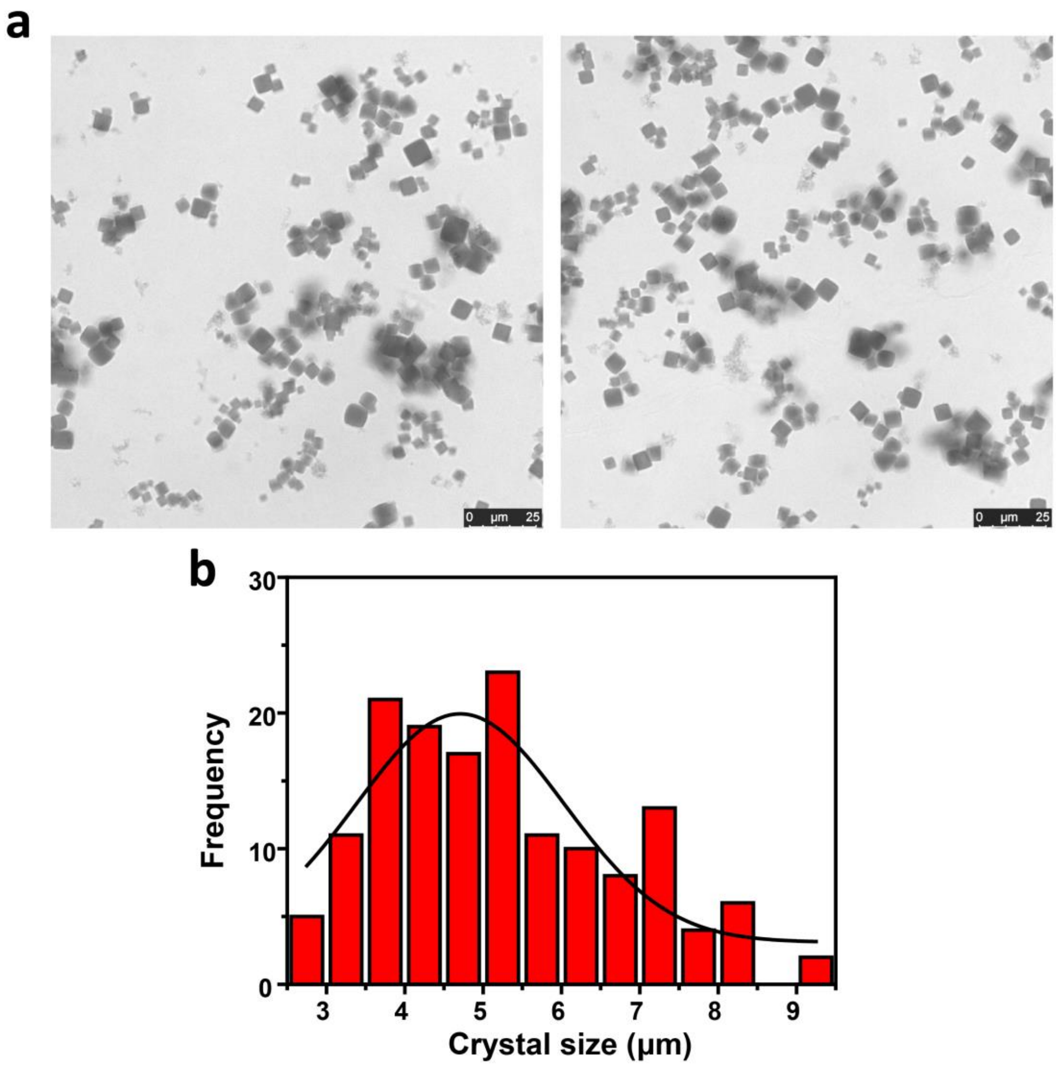

Fig. S15 (a) Large-scaled CLSM images of the assemblies grown at outdoor temperature for 48 h with 3.0 M urea. (b) Crystal size distribution histogram of the crystals incubated at outdoor temperature for 48 h with 3.0 M urea.

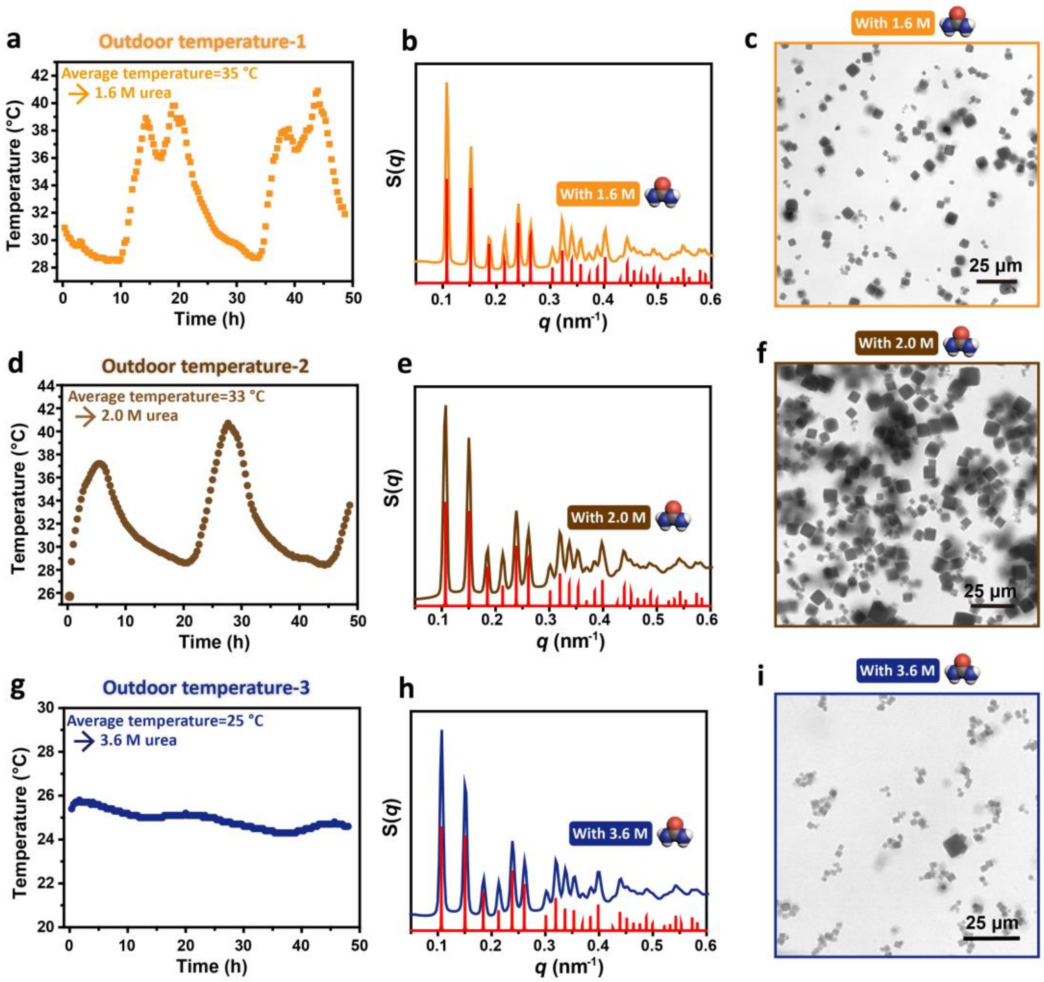

Fig. S16 Crystallization of DNA origami building blocks at different outdoor conditions. (a) (d) (g) Temperature variation curves of 48 h outdoor temperature. (b) (e) (h) 1D SAXS curves and fitting curve (red) of assemblies incubated with 1.6 M (b), 2.0 M (e), and 3.6 M (h) urea, respectively, at outdoor temperature. (c) (f) (i) Representative CLSM image of the crystals incubated with 1.6 M (c), 2.0 M (f), and 3.6 M (i) urea, respectively, at outdoor temperature.

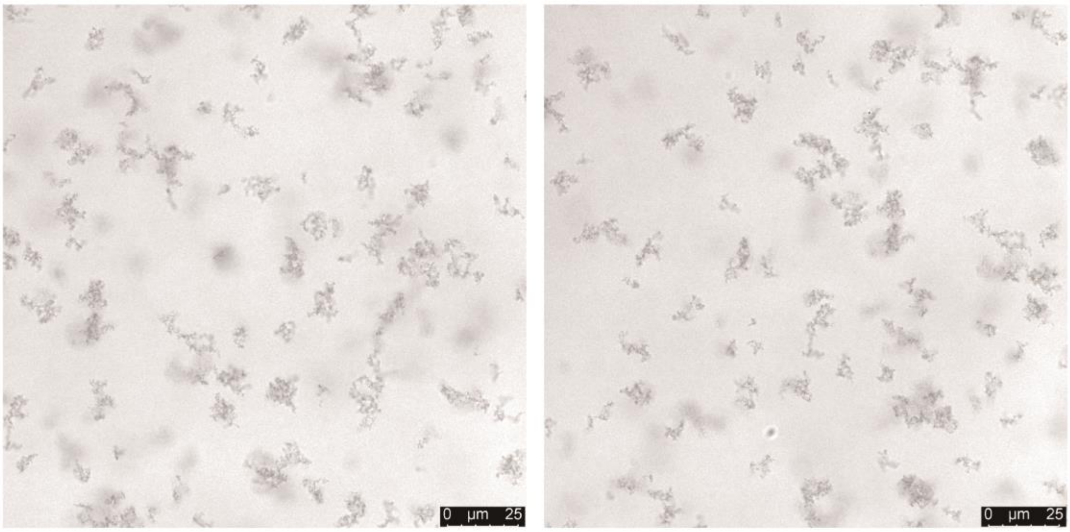

Fig. S17 Large-scaled CLSM images of the assemblies grown at simulated outdoor temperature for 48 h without urea.

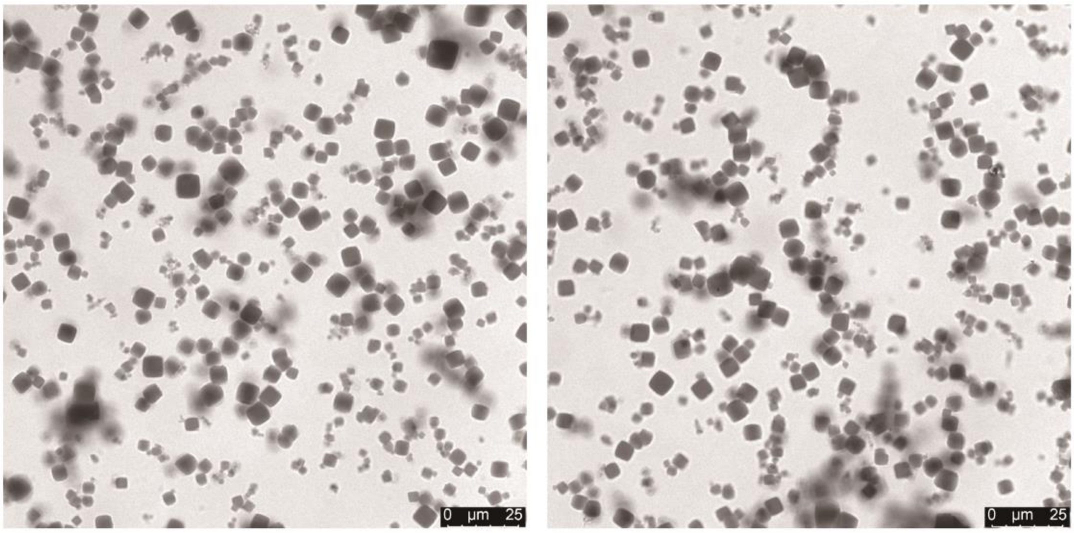

Fig. S18 Large-scaled CLSM images of the assemblies grown at simulated outdoor temperature for 48 h with 2.8 M urea.

Section 5. DNA Sequence (all sequences are in order 5' to 3')

a. Staples of regular-octahedral DNA origami frames (PAGE purified)

Staple-1: TCAAAGCGAACCAGACCGTTTTATATAGTC

Staple-2: GCTTTGAGGACTAAAGAGCAACGGGGAGTT

Staple-3: GTAAATCGTCGCTATTGAATAACTCAAGAA

Staple-4: AAGCCTTAAATCAAGACTTGCGGAGCAAAT

Staple-5: ATTTTAAGAACTGGCTTGAATTATCAGTGA

Staple-6: GTTAAAATTCGCATTATAAACGTAAACTAG

Staple-7: AGCACCATTACCATTACAGCAAATGACGGA

Staple-8: ATTGCGTAGATTTTCAAAACAGATTGTTTG

Staple-9: TAACCTGTTTAGCTATTTTCGCATTCATTC

Staple-10: GTCAGAGGGTAATTGAGAACACCAAAATAG

Staple-11: CTCCAGCCAGCTTTCCCCTCAGGACGTTGG

Staple-12: GTCCACTATTAAAGAACCAGTTTTGGTTCC

Staple-13: TAAAGGTGGCAACATAGTAGAAAATAATAA

Staple-14: GATAAGTCCTGAACAACTGTTTAAAGAGAA

Staple-15: GGTAATAGTAAAATGTAAGTTTTACACTAT

Staple-16: TCAGAACCGCCACCCTCTCAGAGTATTAGC

Staple-17: AAGGGAACCGAACTGAGCAGACGGTATCAT

Staple-18: GTAAAGATTCAAAAGGCCTGAGTTGACCCT

Staple-19: AGGCGTTAAATAAGAAGACCGTGTCGCAAG

Staple-20: CAGGTCGACTCTAGAGCAAGCTTCAAGGCG

Staple-21: CAGAGCCACCACCCTCTCAGAACTCGAGAG

Staple-22: TTCACGTTGAAAATCTTGCGAATGGGATTT

Staple-23: AAGTTTTAACGGGGTCGGAGTGTAGAATGG

Staple-24: TTGCGTATTGGGCGCCCGCGGGGTGCGCTC

Staple-25: GTCACCAGAGCCATGGTGAATTATCACCAATCAGAAAAGCCT

Staple-26: GGACAGAGTTACTTTGTCGAAATCCGCGTGTATCACCGTACG

Staple-27: CAACATGATTTACGAGCATGGAATAAGTAAGACGACAATAAA

Staple-28 AACCAGACGCTACGTTAATAAAACGAACATACCACATTCAGG

Staple-29: TGACCTACTAGAAAAAGCCCCAGGCAAAGCAATTTCATCTTC

Staple-30: TGCCGGAAGGGGACTCGTAACCGTGCATTATATTTTAGTTCT

Staple-31: AGAACCCCAAATCACCATCTGCGGAATCGAATAAAAATTTTT

Staple-32: GCTCCATTGTGTACCGTAACACTGAGTTAGTTAGCGTAACCT

Staple-33: AGTACCGAATAGGAACCCAAACGGTGTAACCTCAGGAGGTTT

Staple-34: CAGTTTGAATGTTTAGTATCATATGCGTAGAATCGCCATAGC

Staple-35: AAGATTGTTTTTAACCAAGAAACCATCGACCCAAAAACAGG

Staple-36: TCAGAGCGCCACCACATAATCAAAATCAGAACGAGTAGTATG

Staple-37: GATGGTTGGGAAGAAAAATCCACCAGAAATAATTGGGCTTGA

Staple-38: CTCCTTAACGTAGAAACCAATCAATAATTCATCGAGAACAGA

Staple-39: AGACACCTTACGCAGAACTGGCATGATTTTCTGTCCAGACAA

Staple-40: GCCAGCTAGGCGATAGCTTAGATTAAGACCTTTTTAACCTGT

Staple-41: CCGACTTATTAGGAACGCCATCAAAAATGAGTAACAACCCCA

Staple-42: GTCCAATAGCGAGAACCAGACGACGATATTCAACGCAAGGGA

Staple-43: CCAAAATACAATATGATATTCAACCGTTAGGCTATCAGGTAA

Staple-44: AACAGTACTTGAAAACATATGAGACGGGTCTTTTTAATGGA

Staple-45: TTTCACCGCATTAAAGTCGGGAAACCTGATTTGAATTACCCA

Staple-46: GAGAATAGAGCCTTACCGTCTATCAAATGGAGCGGAATTAGA

Staple-47: ATAATTAAATTTAAAAAACTTTTTCAAACTTTTAACAACGCC

Staple-48: GCACCCAGCGTTTTTTATCCGGTATTCTAGGCGAATTATTCA

Staple-49: GGAAGCGCCCACAAACAGTTAATGCCCCGACTCCTCAAGATA

Staple-50: GTTTGCCTATTCACAGGCAGGTCAGACGCCACCACACCACCC

Staple-51: CGCGAGCTTAGTTTTTCCCAATTCTGCGCAAGTGTAAAGCCT

Staple-52: AGAAGCAACCAAGCCAAAAGAATACACTAATGCCAAAACTCC

Staple-53: ATTAAGTATAAAGCGGCAAGGCAAAGAAACTAATAGGGTACC

Staple-54: CAGTGCCTACATGGGAATTTACCGTTCCACAAGTAAGCAGAT

Staple-55: ATAAGGCGCCAAAAGTTGAGATTTAGGATAACGGACCAGTCA

Staple-56: TGCTAAACAGATGAAGAAACCACCAGAATTTAAAAAAAGGCT

Staple-57: CAGCCTTGGTTTTGTATTAAGAGGCTGACTGCCTATATCAGA

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Staple-63: AAAGCGCCAAAGTTTATCTTACCGAAGCCCAATAATGAGTAA

Staple-64: GAGCTCGTTGTAAACGCCAGGGTTTTCCAAAGCAATAAAGCC

Staple-65: AATTATTGTTTTCATGCCTTTAGCGTCAGATAGCACGGAAAC

Staple-66: AAGTTTCAGACAGCCGGGATCGTCACCCTTCTGTAGCTCAAC

Staple-67: ACAAAGAAATTTAGGTAGGGCTTAATTGTATACAACGGAATC

Staple-68: AACAAAAATAACTAGGTCTGAGAGACTACGCTGAGTTTCCCT

Staple-69: CATAACCTAAATCAACAGTTCAGAAAACGTCATAAGGATAGC

Staple-70: CACGACGAATTCGTGTGGCATCAATTCTTTAGCAAAATTACG

Staple-71: CCTACCAACAGTAATTTTATCCTGAATCAAACAGCCATATGA

Staple-72: GATTATAAAGAAACGCCAGTTACAAAATTTACCAACGTCAGA

Staple-73: AGTAGATTGAAAAGAATCATGGTCATAGCCGGAAGCATAAGT

Staple-74: TAGAATCCATAAATCATTTAACAATTTCTCCCGGCTTAGGTT

Staple-75: AAAGGCCAAATATGTTAGAGCTTAATTGATTGCTCCATGAGG

Staple-76: CCAAAAGGAAAGGACAACAGTTTCAGCGAATCATCATATTCC

Staple-77: GAAATCGATAACCGGATACCGATAGTTGTATCAGCTCCAACG

Staple-78: TGAATATTATCAAAATAATGGAAGGGTTAATATTTATCCCAA

Staple-79: GAGGAAGCAGGATTCGGGTAAAATACGTAAAACACCCCCCAG

Staple-80: GGTTGATTTTCCAGCAGACAGCCCTCATTCGTCACGGGATAG

Staple-81: CAAGCCCCCACCCTTAGCCCGGAATAGGACGATCTAAAGTTT

Staple-82: TGTAGATATTACGCGGCGATCGGTGCGGGCGCCATCTTCTGG

Staple-83: CATCCTATTCAGCTAAAAGGTAAAGTAAAAAGCAAGCCGTTT

Staple-84: CAGCTCATATAAGCGTACCCCGGTTGATGTGTCGGATTCTCC

Staple-85: CATGTCACAAACGGCATTAAATGTGAGCAATTCGCGTTAAAT

Staple-86: AGCGTCACGTATAAGAATTGAGTTAAGCCCTTTTTAAGAAAG

Staple-87: TATAAAGCATCGTAACCAAGTACCGCACCGGCTGTAATATCC

Staple-88: ATAGCCCGCGAAAATAATTGTATCGGTTCGCCGACAATGAGT

Staple-89: AGACAGTTCATATAGGAGAAGCCTTTATAACATTGCCTGAGA

Staple-90: AACAGGTCCCGAAATTGCATCAAAAAGATCTTTGATCATCAG

Staple-91: ACTGCCCTTGCCCCGTTGCAGCAAGCGGCAACAGCTTTTTCT

Staple-92: TCAAAGGGAGATAGCCCTTATAAATCAAGACAACAACCATCG

Staple-93: GTAATACGCAAACATGAGAGATCTACAACTAGCTGAGGCCGG

Staple-94: GAGATAACATTAGAAGAATAACATAAAAAGGAAGGATTAGGA

Staple-95: CAGATATTACCTGAATACCAAGTTACAATCGGGAGCTATTTT

Staple-96: CATATAACTAATGAACACAACATACGAGCTGTTTCTTTGGGG

Staple-97:

ATGTTTTGCTTTTGATCGGAACGAGGGTACTTTTTCTTTTGATAAGAGGTCATT

Staple-98:

CTTCGCTGGGCGCAGACGACAGTATCGGGGCACCGTCGCCATTCAGGCTGCGCA

Staple-99:

GATATTCTAAATTGAGCCGGAACGAGGCCCAACTTGGCGCATAGGCTGGCTGAC

Staple-100:

TGTCGTCATAAGTACAGAACCGCCACCCATTTTCACAGTACAAACTACAACGCC

Staple-101:

CGATTATAAGCGGAGACTTCAAATATCGCGGAAGCCTACGAAGGCACCAACCTA

Staple-102:

AACATGTACGCGAGTGGTTTGAAATACCTAAACACATTCTTACCAGTATAAAGC

Staple-103:

GTCTGGATTTTGCGTTTTAAATGCAATGGTGAGAAATAAATTAATGCCGGAGAG

Staple-104:

GCCTTGAATCTTTTCCGGAACCGCCTCCCAGAGCCCAGAGCCGCCGCCAGCATT

Staple-105:

CGCTGGTGCTTTCCTGAATCGGCCAACGAGGGTGGTGATTGCCCTTCACCGCCT

Staple-106:

ACATAACTTGCCCTAACTTTAATCATTGCATTATAACAACATTATTACAGGTAG

Staple-107:

TTATTTTTACCGACAATGCAGAACGCGCGAAAAATCTTTCCTTATCATTCCAAG

Staple-108:

TTTCAATAGAAGGCAGCGAACCTCCCGATTAGTTGAAACAATAACGGATTCGCC

Staple-109:

GGGCGACCCCAAAAGTATGTTAGCAAACTAAAAGAGTCACAATCAATAGAAAAT

Staple-110:

ATGACCACTCGTTTGGCTTTTGCAAAAGTTAGACTATATTCATTGAATCCCCCT

Staple-111:

TCCAAATCTTCTGAATTATTTGCACGTAGGTTTAACGCTAACGAGCGTCTTTCC

Staple-112:

GGGTTATTTAATTACAATATATGTGAGTAATTAATAAGAGTCAATAGTGAATTT

b. Sticky ends of regular-octahedral DNA origami frames (ULTRAPAGE purified)

SE-A-1:

CAAATGCTTTAAAAAATCAGGTCTTTAAGAGCAGCCAGAGGGTTTTTTTTTTTTTTT

TTTTTATCCGTTA

SE-A-2:

AAAGATTCATCAGGAATTACGAGGCATGCTCATCCTTATGCGTTTTTTTTTTTTTTTTT

TTTTATCCGTTA

SE-A-3:

CTTCATCAAGAGAAATCAACGTAACAGAGATTTGTCAATCATTTTTTTTTTTTTTTTTT

TTTTATCCGTTA

SE-A-4:

AAACGAAAGAGGGCGAAACAAAGTACTGACTATATTCGAGCTTTTTTTTTTTTTTTTT

TTTTTATCCGTTA

SE-A-5:

GGTAGCTATTTTAGAGAATCGATGAAAACATTAAATGTGTAGTTTTTTTTTTTTTTTTT

TTTTATCCGTTA

SE-A-6:

ATAAATCATACATAAATCGGTTGTACTGTGCTGGCATGCCTGTTTTTTTTTTTTTTTTTT

TTTATCCGTTA

SE-A-7:

ACTGTTGGGAAGCAGCTGGCGAAAGGATAGGTCAAGATCGCATTTTTTTTTTTTTTTTT

TTTTTATCCGTTA

SE-A-8:

AGCTTTCATCAACGGATTGACCGTAAAATCGTATAATATTTTTTTTTTTTTTTTTTTTTT

TTTATCCGTTA

SE-A-9:

GACAGGAGGTTGAAACAAATAAATCCGCCCCCTCCGCCACCCTTTTTTTTTTTTTTTTT

TTTTTATCCGTTA

SE-A-10:

CAGAATCAAGTTTCGGCATTTTCGGTTAAATATATCACCAGTTTTTTTTTTTTTTTTTTTT

TTTATCCGTTA

SE-A-11:

TCATATGGTTTACGATTGAGGGAGGGAAACGCAATACATACATTTTTTTTTTTTTTTTTT

TTTTATCCGTTA

SE-A-12:

AATAGCAATAGCACCAGAAGGAAACCTAAAGCCACTGGTAATTTTTTTTTTTTTTTTTT

TTTTTATCCGTTA

SE-A-13:

TGTAGCATTCCAACGTTAGTAAATGAAGTGCCGCGCCACCCTTTTTTTTTTTTTTTTTTT

TTTTATCCGTTA

SE-A-14:

GAAACATGAAAGCTCAGTACCAGGCGAAAAATGCTGAACAAATTTTTTTTTTTTTTTTT

TTTTTATCCGTTA

SE-A-15:

AGAGCCTAATTTGATTTTTGTTTAAATCCTGAAATAAAGAATTTTTTTTTTTTTTTTTTTT

TTTATCCGTTA

SE-A-16:

TTTGCGGAACAATGGCAATTCATCAATCTGTATAATAATTTTTTTTTTTTTTTTTTTTTTT

TTTATCCGTTA

SE-A-17:

TTTGCGGATGGCCAACTAAAGTACGGGCTTGCAGCTACAGAGTTTTTTTTTTTTTTTT

TTTTTATCCGTTA

SE-A-18:

CTTAAACAGCTTATATATTCGGTCGCTTGATGGGGAACAAGATTTTTTTTTTTTTTTT

TTTTATCCGTTA

SE-A-19:

GGCCCTGAGAGAAGCAGGCGAAAATCATTGCGTAGAGGCGGTTTTTTTTTTTTTTTT

TTTTTATCCGTTA

SE-A-20:

GCTCACAATTCCGTGAGCTAACTCACTGGAAGTAATGGTCAATTTTTTTTTTTTTTTT

TTTTATCCGTTA

SE-A-21:

CAACGCTCAACAGCAGAGGCATTTTCAATCCAATGATAAATATTTTTTTTTTTTTTTT

TTTTATCCGTTA

SE-A-22:

ATCAAAATCATATATGTAAATGCTGAACAAACACTTGCTTCTTTTTTTTTTTTTTTTT

TTTATCCGTTA

SE-A-23:

TGATTGCTTTGAGCAAAAGAAGATGAAATAGCAGAGGTTTTGTTTTTTTTTTTTTTTT

TTTTTATCCGTTA

SE-A-24:

AACGGGTATTAAGGAATCATTACCGCCAGTAATTCAACAATATTTTTTTTTTTTTTTT

TTTTATCCGTTA

SE-B-1:

CAAATGCTTTAAAAAATCAGGTCTTTAAGAGCAGCCAGAGGGTTTTTTTTTTTTTTTT

TTTTTTAACGGAT

SE-B-2:

AAAGATTCATCAGGAATTACGAGGCATGCTCATCCTTATGCGTTTTTTTTTTTTTTTT

TTTTTAACGGAT

SE-B-3:

CTTCATCAAGAGAAATCAACGTAACAGAGATTTGTCAATCATTTTTTTTTTTTTTTTTT

TTTTTAACGGAT

SE-B-4:

AAACGAAAGAGGGCGAAACAAAGTACTGACTATATTCGAGCTTTTTTTTTTTTTTTTT

TTTTTTAACGGAT

SE-B-5:

GGTAGCTATTTTAGAGAATCGATGAAAACATTAAATGTGTAGTTTTTTTTTTTTTTTTT

TTTTTAACGGAT

SE-B-6:

ATAAATCATACATAAATCGGTTGTACTGTGCTGGCATGCCTGTTTTTTTTTTTTTTTTT

TTTTAACGGAT

SE-B-7:

ACTGTTGGGAAGCAGCTGGCGAAAGGATAGGTCAAGATCGCATTTTTTTTTTTTTTTT

TTTTTTAACGGAT

SE-B-8:

AGCTTTCATCAACGGATTGACCGTAAAATCGTATAATATTTTTTTTTTTTTTTTTTTTT

TTTTAACGGAT

SE-B-9:

GACAGGAGGTTGAAACAAATAAATCCGCCCCCTCCGCCACCCTTTTTTTTTTTTTTTT

TTTTTTAACGGAT

SE-B-10:

CAGAATCAAGTTTCGGCATTTTCGGTTAAATATATCACCAGTTTTTTTTTTTTTTTTTT

TTTTAACGGAT

SE-B-11:

TCATATGGTTTACGATTGAGGGAGGGAAACGCAATACATACATTTTTTTTTTTTTTTT

TTTTTAACGGAT

SE-B-12:

AATAGCAATAGCACCAGAAGGAAACCTAAAGCCACTGGTAATTTTTTTTTTTTTTTT

TTTTTTAACGGAT

SE-B-13:

TGTAGCATTCCAACGTTAGTAAATGAAGTGCCGCGCCACCCTTTTTTTTTTTTTTTT

TTTTTAACGGAT

SE-B-14:

GAAACATGAAAGCTCAGTACCAGGCGAAAAATGCTGAACAAATTTTTTTTTTTTTTTT

TTTTTTAACGGAT

SE-B-15:

AGAGCCTAATTTGATTTTTTGTTTAAATCCTGAAATAAAGAATTTTTTTTTTTTTTTT

TTTTAACGGAT

SE-B-16:

TTTGCGGAACAATGGCAATTCATCAATCTGTATAATAATTTTTTTTTTTTTTTTTTT

TTTTAACGGAT

SE-B-17:

TTTGCGGATGGCCAACTAAAGTACGGGCTTGCAGCTACAGAGTTTTTTTTTTTTTT

TTTTTTAACGGAT

SE-B-18:

CTTAAACAGCTTATATATTCGGTCGCTTGATGGGGAACAAGATTTTTTTTTTTTTT

TTTTTAACGGAT

SE-B-19:

GGCCCTGAGAGAAGCAGGCGAAAATCATTGCGTAGAGGCGGTTTTTTTTTTTTTTT

TTTTTTAACGGAT

SE-B-20:

GCTCACAATTCCGTGAGCTAACTCACTGGAAGTAATGGTCAATTTTTTTTTTTTTTT

TTTTTAACGGAT

SE-B-21:

CAACGCTCAACAGCAGAGGCATTTTCAATCCAATGATAAATATTTTTTTTTTTTTT

TTTTTAACGGAT

SE-B-22:

ATCAAAATCATATATGTAAATGCTGAACAAACACTTGCTTCTTTTTTTTTTTTTTT

TTTTAACGGAT

SE-B-23:

TGATTGCTTTGAGCAAAAGAAGATGAAATAGCAGAGGTTTTGTTTTTTTTTTTTTTTT

TTTTTTAACGGAT

SE-B-24:

AACGGGTATTAAGGAATCATTACCGCCAGTAATTCAACAATATTTTTTTTTTTTTTTTT

TTTTTAACGGAT

c. Inner strands of regular-octahedral DNA origami frames (ULTRAPAGE purified)

Inner-1:

ATCCATCACTTCATACTCTACGTTGTTGTTGTTGTTGTTGTAGCGCCATTAAATTGGGAA

TTAGAGCGCAAGGCGCACCGTAATCAGTAGCGA

Inner-2:

ATCCATCACTTCATACTCTACGTTGTTGTTGTTGTTGTTCCCACGCGCAAAATGGTTGA

GTGTTGTTCGTGGACTTGCTTTCGAGGTGAATTT

Inner-3:

ATCCATCACTTCATACTCTACGTTGTTGTTGTTGTTGTTAGCCGAAAGTCTCTCTTTTGA

TGATACAAGTGCCTTAAGAGCAAGAAACAATGA

Inner-4:

ATCCATCACTTCATACTCTACGTTGTTGTTGTTGTTGTTTTAGCGGTACAGAGCGGGAG

AATTAACTGCGCTAATTTCGGAACCTATTATTCT

Inner-5:

ATCCATCACTTCATACTCTACGTTGTTGTTGTTGTTGTTGGGGTGCCAGTTGAGACCAT

TAGATACAATTTTCACTGTGTGAAATTGTTATCC

Inner-6:

ATCCATCACTTCATACTCTACGTTGTTGTTGTTGTTGTTTCAGAGCTGGGTAAACGACG

GCCAGTGCGATCCCCGTAGTAGCATTAACATCCA

Inner-7:

ATCCATCACTTCATACTCTACGTTGTTGTTGTTGTTGTTGTGGGAAATCATATAAATATTT

AAATTGAATTTTTGTCTGGCCTTCCTGTAGCC

Inner-8:

ATCCATCACTTCATACTCTACGTTGTTGTTGTTGTTGTTTGATTATCAACTTTACAACTA

AAGGAATCCAAAAAGTTTGAGTAACATTATCAT

d. Thiolated DNA for AuNPs function (HPLC purified)

Thiolated-DNA-1: GAAGTGATGGATGAT

e. Sticky ends of regular-octahedral DNA origami frames-universality verification-1st system (ULTRAPAGE purified)

1st system-SE-A-1:

CAAATGCTTTAAAAAATCAGGTCTTTAAGAGCAGCCAGAGGGTTTTTTTTTTTTTTTT

TTTTTATGTGGTA

1st system-SE-A-2:

AAAGATTCATCAGGAATTACGAGGCATGCTCATCCTTATGCGTTTTTTTTTTTTTTTTT

TTTTATGTGGTA

1st system-SE-A-3:

CTTCATCAAGAGAAATCAACGTAACAGAGATTTGTCAATCATTTTTTTTTTTTTTTTTT

TTTTATGTGGTA

1st system-SE-A-4:

AAACGAAAGAGGGCGAAACAAAGTACTGACTATATTCGAGCTTTTTTTTTTTTTTTTT

TTTTTATGTGGTA

1st system-SE-A-5:

GGTAGCTATTTTAGAGAATCGATGAAAACATTAAATGTGTAGTTTTTTTTTTTTTTTTT

TTTTATGTGGTA

1st system-SE-A-6:

ATAAATCATACATAAATCGGTTGTACTGTGCTGGCATGCCTGTTTTTTTTTTTTTTTTT

TTTATGTGGTA

1st system-SE-A-7:

ACTGTTGGGAAGCAGCTGGCGAAAGGATAGGTCAAGATCGCATTTTTTTTTTTTTTTT

TTTTTATGTGGTA

1st system-SE-A-8:

AGCTTTCATCAACGGATTGACCGTAAAATCGTATAATATTTTTTTTTTTTTTTTTTTTTTT

TTTATGTGGTA

1st system-SE-A-9:

GACAGGAGGTTGAAACAAATAAATCCGCCCCCTCCGCCACCCCTTTTTTTTTTTTTTTTT

TTTTTATGTGGTA

1st system-SE-A-10:

CAGAATCAAGTTTCGGCATTTTCGGTTAAATATATCACCAGTTTTTTTTTTTTTTTTTTTT

TTTATGTGGTA

1st system-SE-A-11:

TCATATGGTTTACGATTGAGGGAGGGAAACGCAATACATACATTTTTTTTTTTTTTTTTT

TTTTATGTGGTA

1st system-SE-A-12:

AATAGCAATAGCACCAGAAGGAAACCTAAAGCCACTGGTAATTTTTTTTTTTTTTTTTT

TTTTTATGTGGTA

1st system-SE-A-13:

TGTAGCATTCCAACGTTAGTAAATGAAGTGCCGCGCCACCCCTTTTTTTTTTTTTTTTTTT

TTTTATGTGGTA

1st system-SE-A-14:

GAAACATGAAAGCTCAGTACCAGGCGAAAAATGCTGAACAAATTTTTTTTTTTTTTTTT

TTTTTATGTGGTA

1st system-SE-A-15:

AGAGCCTAATTTGATTTTTTGTTTAAATCCTGAAATAAAGAATTTTTTTTTTTTTTTTTTT

TTTATGTGGTA

1st system-SE-A-16:

TTTGCGGAACAATGGCAATTCATCAATCTGTATAATAATTTTTTTTTTTTTTTTTTTTTTT

TTTATGTGGTA

1st system-SE-A-17:

TTTGCGGATGGCCAACTAAAGTACGGGCTTGCAGCTACAGAGTTTTTTTTTTTTTTTTT

TTTTTATGTGGTA

1st system-SE-A-18:

CTTAAACAGCTTATATATTCGGTCGCTTGATGGGGAACAAGATTTTTTTTTTTTTTTTT
TTTTATGTGGTA

1st system-SE-A-19:

GGCCCTGAGAGAAGCAGGCGAAAATCATTGCGTAGAGGCGGTTTTTTTTTTTTTTTTT
TTTTTATGTGGTA

1st system-SE-A-20:

GCTCACAATTCCGTGAGCTAACTCACTGGAAGTAATGGTCAATTTTTTTTTTTTTTTTT
TTTTATGTGGTA

1st system-SE-A-21:

CAACGCTCAACAGCAGAGGCATTTTCAATCCAATGATAAATATTTTTTTTTTTTTTTTT
TTTTATGTGGTA

1st system-SE-A-22:

ATCAAAATCATATATGTAAATGCTGAACAAACACTTGCTTCTTTTTTTTTTTTTTTTTTT
TTTATGTGGTA

1st system-SE-A-23:

TGATTGCTTTGAGCAAAAGAAGATGAAATAGCAGAGGTTTTGTTTTTTTTTTTTTTTT
TTTTTATGTGGTA

1st system-SE-A-24:

AACGGGTATTAAGGAATCATTACCGCCAGTAATTCAACAATATTTTTTTTTTTTTTTTT
TTTTATGTGGTA

1st system-SE-B-1:

CAAATGCTTTAAAAAATCAGGTCTTTAAGAGCAGCCAGAGGGTTTTTTTTTTTTTTTT
TTTTTTACCACAT

1st system-SE-B-2:

AAAGATTCATCAGGAATTACGAGGCATGCTCATCCTTATGCGTTTTTTTTTTTTTTTT
TTTTTACCACAT

1st system-SE-B-3:

CTTCATCAAGAGAAATCAACGTAACAGAGATTTGTCAATCATTTTTTTTTTTTTTTTTT
TTTTTACCACAT

1st system-SE-B-4:

AAACGAAAGAGGGCGAAACAAAGTACTGACTATATTCGAGCTTTTTTTTTTTTTTTTTT

TTTTTTACCACAT

1st system-SE-B-5:

GGTAGCTATTTTAGAGAATCGATGAAAACATTAAATGTGTAGTTTTTTTTTTTTTTTTTT

TTTTTACCACAT

1st system-SE-B-6:

ATAAATCATACATAAATCGGTTGTACTGTGCTGGCATGCCTGTTTTTTTTTTTTTTTTTTT

TTTTACCACAT

1st system-SE-B-7:

ACTGTTGGGAAGCAGCTGGCGAAAGGATAGGTCAAGATCGCATTTTTTTTTTTTTTTTT

TTTTTTACCACAT

1st system-SE-B-8:

AGCTTTCATCAACGGATTGACCGTAAAATCGTATAATATTTTTTTTTTTTTTTTTTTTTT

TTTTACCACAT

1st system-SE-B-9:

GACAGGAGGTTGAAACAAATAAATCCGCCCCCTCCGCCACCCTTTTTTTTTTTTTTTT

TTTTTTACCACAT

1st system-SE-B-10:

CAGAATCAAGTTTCGGCATTTTCGGTTAAATATATCACCAGTTTTTTTTTTTTTTTTTTTT

TTTTACCACAT

1st system-SE-B-11:

TCATATGGTTTACGATTGAGGGAGGGAAACGCAATACATACATTTTTTTTTTTTTTTTTT

TTTTTACCACAT

1st system-SE-B-12:

AATAGCAATAGCACCAGAAGGAAACCTAAAGCCACTGGTAATTTTTTTTTTTTTTTTT

TTTTTTACCACAT

1st system-SE-B-13:

TGTAGCATTCCAACGTTAGTAAATGAAGTGCCGCGCCACCCTTTTTTTTTTTTTTTTTTT

TTTTTACCACAT

1st system-SE-B-14:

GAAACATGAAAGCTCAGTACCAGGCGAAAAATGCTGAACAAATTTTTTTTTTTTTTTT
TTTTTTACCACAT

1st system-SE-B-15:

AGAGCCTAATTTGATTTTTTGTTTAAATCCTGAAATAAAGAATTTTTTTTTTTTTTTTTT
TTTTACCACAT

1st system-SE-B-16:

TTTGCGGAACAATGGCAATTCATCAATCTGTATAATAATTTTTTTTTTTTTTTTTTTTT
TTTTACCACAT

1st system-SE-B-17:

TTTGCGGATGGCCAACTAAAGTACGGGCTTGCAGCTACAGAGTTTTTTTTTTTTTTTT
TTTTTTACCACAT

1st system-SE-B-18:

CTTAAACAGCTTATATATTCGGTCGCTTGATGGGGAACAAGATTTTTTTTTTTTTTTTT
TTTTTACCACAT

1st system-SE-B-19:

GGCCCTGAGAGAAGCAGGCGAAAATCATTGCGTAGAGGCGGTTTTTTTTTTTTTTTTT
TTTTTTACCACAT

1st system-SE-B-20:

GCTCACAATTCCGTGAGCTAACTCACTGGAAGTAATGGTCAATTTTTTTTTTTTTTTTT
TTTTTACCACAT

1st system-SE-B-21:

CAACGCTCAACAGCAGAGGCATTTTCAATCCAATGATAAATATTTTTTTTTTTTTTTTT
TTTTTACCACAT

1st system-SE-B-22:

ATCAAAATCATATATGTAAATGCTGAACAAACACTTGCTTCTTTTTTTTTTTTTTTTTTT
TTTTACCACAT

1st system-SE-B-23:

TGATTGCTTTGAGCAAAAGAAGATGAAATAGCAGAGGTTTTGTTTTTTTTTTTTTTTT
TTTTTTACCACAT

1st system-SE-B-24:

AACGGGTATTAAGGAATCATTACCGCCAGTAATTCAACAATATTTTTTTTTTTTTTTT

TTTTTACCACAT

f. Staples of elongated-octahedral DNA origami frames-universality verification-2nd system (PAGE purified)

EL-octa-Staple-1: CTCGTTTACCAGACGACAACACTAAAGATT

EL-octa-Staple-2: AAAAGGGACATTCTGGTCACACGTTGCAAC

EL-octa-Staple-3: GCCACTACGAAGGCACGGGTAAAGCGAAAG

EL-octa-Staple-4: TTGGGGCGCGAGCTGATTAGCTATTCCATA

EL-octa-Staple-5: TTCAAATATATTTTAGAACGCGACCTCCGG

EL-octa-Staple-6: CAATATAATCCTGATTGATGATGATTTTAA

EL-octa-Staple-7: CAGACTGTAGCGCGTTAGTTTGCCCAGTAG

EL-octa-Staple-8: GTCCACTATTAAAGAACCAGTTTTGGTTCC

EL-octa-Staple-9: GAATAATAATTTTTTCCAACTAATAACGAT

EL-octa-Staple-10: GGCCGATTAAAGGGATCGGGAGCCCGCCGC

EL-octa-Staple-11: GCCTCTTCGCTATTACAGGGCGAGCACCGC

EL-octa-Staple-12: AAGCCAGAATGGAAAGAAATAAACAGAGCC

EL-octa-Staple-13: CCAGACGACGACAATAGGTAAAGCTCAACA

EL-octa-Staple-14: TACCCAAATCAACGTAAGAACCGACGGTCA

EL-octa-Staple-15: TTGCGCTCACTGCCCGACTCACACATGGTC

EL-octa-Staple-16: AATTACATTTAACAATTCAAGAAATTGCTT

EL-octa-Staple-17: GCCATCAAAAATAATTTTTAACCTAATCAG

EL-octa-Staple-18: AGTCAAATCACCATCAGAGAAAGTTTCAAC

EL-octa-Staple-19: AACAAAGTCAGAGGGTTTAACTGTTATCCC

EL-octa-Staple-20: TTATTTTGTCACAATCACACCACACGCAGT

EL-octa-Staple-21: ATCTGGTCAGTTGGCACAAACCCAGTATTA

EL-octa-Staple-22: TAAGTATAGCCCGGAAGTCGAGAAAACATG

EL-octa-Staple-23: AGCGAACCAGACCGGATTAATTCGTCAGAA

EL-octa-Staple-24: GACTTGCGGGAGGTTTTTTTAGCTTACCGC

EL-octa-Staple-25: ACAGCATGCTCCATAGATTTGTATCATCCCCAGCGAAACGAA

EL-octa-Staple-26: GAAATCGGCCCCCTACGGGGTCAGTGCCCTTTTGATCCAACG

EL-octa-Staple-27: AACGGGTCCTGAACAAGAAAAATAATATCTTATCATTCCAAG

EL-octa-Staple-28: AAAAGCCCTCAGGACGTTGGTGTAGATGGGGAACAGGCCTTC

EL-octa-Staple-29: ATTAAATCAGCTTTCATCAACATTAAATTTGTTAAAATTCGC

EL-octa-Staple-30: TACATTTAATAGTACATCCAATAAATCAAAGCTAACCAAAAA

EL-octa-Staple-31: GCCCAATTTTGCCATAACGAGCGTCTTTGCACCCATTAAATC

EL-octa-Staple-32: ATAGCGAAATTACGTAGGAATACCACATCAGTACAGTACCGT

EL-octa-Staple-33: GTTGGGATGAAAGAGGACAGATGAACGGAGTAGATCATTAGA

EL-octa-Staple-34: CTTTTTCAAAGAATACTCATCTTTGACCGCCTGATGAAATCC

EL-octa-Staple-35: AAGCCTGCGTGCCAGCTGCATTAATGAAAAGCATAAAGTGTA

EL-octa-Staple-36: TCAGTGATCATCAAGAACTGACCAACTTAGAAAAATCTACGT

EL-octa-Staple-37: TAACAGTACCCTGTAGCCTCAGAGCATATACAGGCGCATCAA

EL-octa-Staple-38: CTAATGCGAATATAAGAATCGCCATATTTACCGCACTCATCG

EL-octa-Staple-39: ATAGCTGTTGCCCCCGGGCAACAGCTGAATTGGGCGTCGGGA

EL-octa-Staple-40: GCCGCCATGTAGCGGGAAGGGAAGAAAGAGAGCTTTCTGAAT

EL-octa-Staple-41: GGAATTAAATGGAACTACCATATCAAAACGTCAGAGTAACAG

EL-octa-Staple-42: TCTGAATTCATCATTTATCATTTTGCGGTAATACATGAATGG

EL-octa-Staple-43: AGAGGCAATGAGGAAGGGTAGCAACGGCAGGTGTCAAATTCC

EL-octa-Staple-44: CGTTCTATAGGTAATTTTAGAACCCTCAAGGATGAACGGTAA

EL-octa-Staple-45: TTCTACTCGCAAATCAATTCTGCGAACGTGTTGTAATCGGTA

EL-octa-Staple-46: AGGAAAACCAGCAGACTGATAGCCCTAAACAATATAGATAGA

EL-octa-Staple-47: GAGCCGGTCGTAAGAAAGCGGCCAACGCTGATCGTGCTCAAG

EL-octa-Staple-48: AAACAGGAGATAACCCACAAGAATTGAGAGAGAATAACATAA

EL-octa-Staple-49: GTGCATCACAACCCGTCGGATTCTCCGTGGCGCATCGTAACC

EL-octa-Staple-50: CTAAAGTAGGCCGCACAATGACAACAACTGAATTTAAATCTC

EL-octa-Staple-51: AATCCAACAAAAGAAAGTAAGCAGATAGAATAGCACGCTAAT

EL-octa-Staple-52: TAACGTGAGAATCCGTGAGTGAATAACCACATAGCGATAGCT

EL-octa-Staple-53: GGATTATTGACCTGAATACGTGGCACAGAACATCGTACCGAA

EL-octa-Staple-54: GTACGCCCTTTCCTTACAGGGCGCGTACAGAGTCAATAGTGA

EL-octa-Staple-55: ATCATTTCGAAAGGAGCGGGAATAGCCCGCGAAAAAGCGTCA

EL-octa-Staple-56: TTAATTGATATAATGCTGTGGAAGCCCGATTAGAGAAGGCGA

EL-octa-Staple-57: ATCATAAACGAACTATGCGATTTTAAGAATGGTTTTGCTCAT

EL-octa-Staple-58: AAGCATCGAGGAAGATATCTTTAGGAGCGAAGTATAAACAAT

EL-octa-Staple-59: AAAGTATTCAAAAAGTCATAAATATTCAAAATGTTATCACCG

EL-octa-Staple-60: GCAAGGAACTAGCAGAGAGTCTGGAGCATTTTTGAATTCAAC

EL-octa-Staple-61: ATCAGAGGAAGCGCACGATTTTTTGTTTACGCAATAATAACG

EL-octa-Staple-62: CACCATTACCACCCGCCTCCCTCAGAGCTAATCAAGCATTTT

EL-octa-Staple-63: TTTGCTAAAAGCGTTTATTTTGTATCGGATACCATATGAAAT

EL-octa-Staple-64: TAATGTGGCTGATAAATTATGCTATTTTCCGCAATGCCTGAG

EL-octa-Staple-65: TAGATTAAATATATTGAGAAGTGTTTTTTGGACGAGCACGTA

EL-octa-Staple-66: CGAGGAAAACGTCAAAAATGAAAATAGCTACAGAGCTAAAGA

EL-octa-Staple-67: ATGTTAGTTATACACCGGAATCATAATTGACCGTGAATTCAT

EL-octa-Staple-68: CAAAAGGGAGGCTTGCCACCCTCAGAACAACCCATAACTACA

EL-octa-Staple-69: AAGATTAGTATTCTAAATCAGATATAGATATATTTTAAATAG

EL-octa-Staple-70: AACCGATTTTATCAGCTTGCTTTCGAGGCATCGCCCACGCAT

EL-octa-Staple-71: CAAAAAACGGAGTGTCTTTCCAGACGTTCTGAGGCTTGCAGG

EL-octa-Staple-72: TCGGTCGAGTAAATGAATTTTCTGTATGGTCACCACGATAGC

EL-octa-Staple-73: CAGACCAAAATTAAGTAGCCACCAGAACGGTTGACTTAGTAC

EL-octa-Staple-74: CAGAGGCAAAGAACGGGTTTAGATAAGTATACCAGAAACCTA

EL-octa-Staple-75: GTTTCAGAAGGCTCCAAAAGGAGCCTTTAACAACTTTCAACA

EL-octa-Staple-76: AACCTGTGGGTGCCTGTGAAATTGTTATCAGCAAGCGGTCCA

EL-octa-Staple-77: CAGAAGGAATAAGAGCAAGAAACAATGACCGAACAAAGTTAC

EL-octa-Staple-78: TTTACAGTTAAAACACACTAAGCCCAATAAGAGGAGCTTTAC

EL-octa-Staple-79: GTAGGGCGCAAGCCATCGGCTGTCTTTCCCCATCCTGTTCAG

EL-octa-Staple-80: AAGTTTGTACATCGATTTTCAGGTTTAATTATTTGTTATACT

EL-octa-Staple-81: ACTTGCCATAATCAACAGTACATAAATCAGATTTCTATTCAC

EL-octa-Staple-82: TAATATTGTCTAAAGTTATGAGCGAGTATGATGAAAGCAACC

EL-octa-Staple-83: ATGGTTTACATATAAGAAAATACATACAAACTGTTTAGTATC

EL-octa-Staple-84: CGGTCATTAATCAGGCAAGGCCGGAAACGGAACCGCTCAGAT

EL-octa-Staple-85: ACCCTTCTTACATTTGGAAATACCTACAATAAAAACCATTAC

EL-octa-Staple-86: CAGTTCAGAGAAGGATTAGTTTCGTCACTCAACTAATAACGC

EL-octa-Staple-87: GGTCAGGAAAGACTATCAAAAAGATTAACACCTGCAGGTCGA

EL-octa-Staple-88: TGAGCAAAATGGAAGTGAGGCCACCGAGTTAGTAACTATCGG

EL-octa-Staple-89: AGAGTTGCCGCTCACAATTCCACACAACTTTTGACCTGAAAT

EL-octa-Staple-90: AGCACCGAGCCCCCTTGCCATCTTTTCACGCCACCCCACCCT

EL-octa-Staple-91: CTTTTTTAAGAAGACAAAATCGCGCAGAACTCAAATAACATC

EL-octa-Staple-92: AGGAATTACCTTGCAGTGCCACGCTGAGACTTTACTAGACGT

EL-octa-Staple-93: CCAGTCAGAGTAGTAAATTGGGCTTGAGACTGGCTCATTATA

EL-octa-Staple-94: GCAAAGCGGATCCCACGACGGCCAGTGCGGGTAACTCCAACA

EL-octa-Staple-95: AACACTGCAGAACCTTGCAAAAGAAGTTTAGATACATGCAAA

EL-octa-Staple-96: CCACCCTAGGATTAGCGGGGTTTTGCTCGAGGTTTAGGGGGT

EL-octa-Staple-97: GCTGAGATATGGTTGCTTTAGTAGAAGAGGCGAATAATTACC

EL-octa-Staple-98: AGTTTGAAAGCAAATATTTAAATTGTAAAGCCAGCAAATCTA

EL-octa-Staple-99: GCTTAATAAAATCATAGAATCCTTGAAATTGCTTCAGGAACG

EL-octa-Staple-100: TCAAAGGGAGATAGCCCTTATAAATCAAAGGCCCGTATAAAC

EL-octa-Staple-101: TTCTGGTATGCAACAGCTTAATTGCTGACTCCTTTGGCGAAA

EL-octa-Staple-102: AATAAGAAGAACGCGCCTGTTTATCAACATTTTCGAGCCAGT

EL-octa-Staple-103: CTTAGGTGAGCCATGACGGAAATTATTCGCGACATCATCTTC

EL-octa-Staple-104: AAATACCACTAGAAAAAGCTGCTGATGCAATTTAACCAAAGA

EL-octa-Staple-105: TGAATACGGTAATACAATACTTCTTTGATAAAAGAGAATTAC

EL-octa-Staple-106: TGACCTAAAATCCATATAACTATATGTATATTATCACCGTCA

EL-octa-Staple-107: CTGTAGCTTTTGTTCAGGAAGATTGTATGGGGACGACGACAG

EL-octa-Staple-108: GGGGGATCAGGCTGACCAGGCAAAGCGCGAAGCTCAACATGT

EL-octa-Staple-109: ACACCGCCTCGTATCATTTGAGGATTTAACTAACAAGTTGAA

EL-octa-Staple-110: CTGGCCCGCGGGGAGAGGCGGTTTGCGTTTGCCCTTCACCGC

EL-octa-Staple-111: TACTCAGAGTACCACTGAGACTCCTCAAGAAAACGAGAATGA

EL-octa-Staple-112: AATAGTATTGAATCCCCCTCAAATGCTTTTGCCAGAGTACCG

EL-octa-Staple-113: CAAAAGGATTAAAGGTGAAAAGGTGGCAACCAGCGTGGTTTG

EL-octa-Staple-114: TTACCGTTTGGCCTCAGGAGGTTGAGGCAAGCGCTAGGGCGC

EL-octa-Staple-115: TACATGGTTGAGTAACAGTGTCAGACGATCCAGTAACCGTCT

EL-octa-Staple-116: TTAAGTTCAAGCTTGCATGTTCGCCATTGTGCTGCAGTACCT

EL-octa-Staple-117: TTATCCGGTATGCCGGAGAGGGTAGCTAAACAAGAGAATCGC

EL-octa-Staple-118: CTGACCTATAAGGCTTGCCCTGACGAGAGGCGCATAGGCTGG

EL-octa-Staple-119: AACCAAGTAACAACGCCAACATGTAATTAACAAAGAAGGAGC

EL-octa-Staple-120: CATCAGTTAGCATTGCAAGCCCAATAGGCGCCACCAACCAAA

EL-octa-Staple-121:

GAATACCATAAGAAATTAGACGGGAGAAAATTGAGATAGCTATCTTACCGAAGC

EL-octa-Staple-122:

GCGACCTCGGAACGAGTTTCCATTAAACCAACCTAATTATACCAAGCGCGAAAC

EL-octa-Staple-123:

TATCGGCCCAAAAAAAATCAGCTCATTTCGCGTCTAACGGCGGATTGACCGTAA

EL-octa-Staple-124:

CATTATGTGATTCCGGTCAATAACCTGTAAAGGTGAAGGCAAAGAATTAGCAAA

EL-octa-Staple-125:

AGAACAATTAATTGAAGTACCGACAAAAAACAACATAATTTACGAGCATGTAGA

EL-octa-Staple-126:

ACGCCTGTGAGATTAGGCATAGTAAGAGCGATAAACTCAGAGCCACCACCCTCA

EL-octa-Staple-127:

CGCTGGTTTTCCTGTAATGAGTGAGCTACTTTCCAGCCAGGGTGGTTTTTCTTT

EL-octa-Staple-128:

CGAACCAACGCTCAGGCAGATTCACCAGCCAACAGTTTTGAATGGCTATTAGTC

EL-octa-Staple-129:

TAATAAAGGGAACCGAGTAATCTTGACAACAAAGCAATTTCAACTTTAATCATT

EL-octa-Staple-130:

CCTTGCTCAAGTTATGATGAAACAAACATTCATTTGTCTGTCCATCACGCAAAT

EL-octa-Staple-131:

GAGTTAATTTGTCGAGAATAGAAAGGAAACGTTGACTTAAACAGCTTGATACCG

EL-octa-Staple-132:

TCGACAACTGCAACTGAACCTCAAATATAATCAACACTAATAGATTAGAGCCGT

EL-octa-Staple-133:

CAGAGCCACCATTATAGCGACAGAATCATTCATCGAATCACCGGAACCAGAGCC

EL-octa-Staple-134:

TACCTTTAGTAACAATTCCTGATTATCAGTTTGGACACGTAAAACAGAAATAAA

EL-octa-Staple-135:

ATTTATCGCGCCGCCGTTAGAATCAGAGTTTAGACTGTAAATCGTCGCTATTAA

EL-octa-Staple-136:

CCATAAATAAGAGGGGCGGATAAGTGCCTAGGTGTTAGACTGGATAGCGTCCAA

g. Inner strands of elongated-octahedral DNA origami frames-universality verification-2nd system (ULTRAPAGE purified)

EL-octa-inner-1:

ATCCATCACTTCATACTCTACGTTGTTGTTGTTGTTGTTAGCCTAAAGCAAGCAAGAAC GCGAGGCGTGAAGCCGCTACAATTTTATCCTGAA

EL-octa-inner-2:

ATCCATCACTTCATACTCTACGTTGTTGTTGTTGTTGTTTCGTAAATAAAAATAGATTCA AAAGGGTATATGATGAGATCTACAAAGGCTATC

EL-octa-inner-3:

ATCCATCACTTCATACTCTACGTTGTTGTTGTTGTTGTTATATGCGCAAACGTAAAGAA ACGCAAAGAATAGAATGATAAATAAGGCGTTAAA

EL-octa-inner-4:

ATCCATCACTTCATACTCTACGTTGTTGTTGTTGTTGTTCCGACTTTGGGTTAATCGCAA GACAAAGTTAATTTTCAACCGATTGAGGGAGGG

EL-octa-inner-5:

ATCCATCACTTCATACTCTACGTTGTTGTTGTTGTTGTTAGTTAATGCAAAATGGTTGAG TGTTGTTCGTGGACTGATACAGGAGTGTACTGG

EL-octa-inner-6:

ATCCATCACTTCATACTCTACGTTGTTGTTGTTGTTGTTTGGCAAGGCATTGATGATATT CACAAACCGCAGTCGACGGGGAAAGCCGGCGAA

EL-octa-inner-7:

ATCCATCACTTCATACTCTACGTTGTTGTTGTTGTTGTTCTCTAGAGGATTGCTCAAATA

TCGCGTTAGCAAACGCCAGGGTTTTCCCAGTCA

EL-octa-inner-8:

ATCCATCACTTCATACTCTACGTTGTTGTTGTTGTTGTTTTTAAATGCCGGAACGCAACT

GTTGGGAGCCAGCTTGATAAGAGGTCATTTTTG

h. Sticky ends of elongated-octahedral DNA origami frames-universality verification-2nd system (ULTRAPAGE purified)

EL-octa-SE-A-1:

AAAGTACAACGGGTTACTTAGCCGGACTCAGCAATACGTAATTTTTTTTTTTTTTTTTT

TTTTATCCGTTA

EL-octa-SE-A-2:

ATAGTTGCGCCGTTTTGCGGGATCGTGTTAGCGAGGAATTGCTTTTTTTTTTTTTTTTT

TTTTATCCGTTA

EL-octa-SE-A-3:

GTGAATTACCTTAACGGAACAACATTGGCGCAGGATATTCATTTTTTTTTTTTTTTTTT

TTTTATCCGTTA

EL-octa-SE-A-4:

TTTTCAGGGATACCACAGACAGCCCTCAGGTAGATCATAACCTTTTTTTTTTTTTTTTT

TTTTATCCGTTA

EL-octa-SE-A-5:

AGGTCATTGCCTTGTCAATCATATGTGCCTTTAGCCGGAGACTTTTTTTTTTTTTTTTT

TTTTCATCAAGT

EL-octa-SE-A-6:

TGGGATAGGTCAAGATCGCACTCCAGCGGTTGAAATAGGAACTTTTTTTTTTTTTTTTT

TTTTTCATCAAGT

EL-octa-SE-A-7:

ATTAAGCAATAAAATACTTTTGCGGGAGTTTCATATTTCATTTTTTTTTTTTTTTTTTT

TTTCATCAAGT

EL-octa-SE-A-8:

CGGATGGCTTAGTAAAGTACGGTGTCCTTTCCGTCGGTGCGGTTTTTTTTTTTTTTTTT

TTTTCATCAAGT

EL-octa-SE-A-9:

TCACCAGTGAGAAGCAGGCGAAAATCTCGTAATTTAATTGCGTTTTTTTTTTTTTTTTT

TTTTCATCAAGT

EL-octa-SE-A-10:

TAATAAGTTTTAGCCTATTTCGGAACTTGATGGGGAACAAGATTTTTTTTTTTTTTTTT

TTTTCATCAAGT

EL-octa-SE-A-11:

CGACGTTGTAAACGGGTACCGAGCTCTATTATAGAGCTTCAATTTTTTTTTTTTTTTTT

TTTTCATCAAGT

EL-octa-SE-A-12:

TACTGCGGAATCTCAGGTCTTTACCCTATTCTGGGGTTGATATTTTTTTTTTTTTTTTTT

TTTCATCAAGT

EL-octa-SE-A-13:

TTAATTTTCCCTTAGGTCTGAGAGACACCACACTAAACAGGATTTTTTTTTTTTTTTTT

TTTTCATCAAGT

EL-octa-SE-A-14:

ACCACCGGAACCTCAGAGCCGCCACCAAAATCACTTTAGCGTTTTTTTTTTTTTTTTT

TTTTTCATCAAGT

EL-octa-SE-A-15:

AAGGTAAATATTTTGGGAATTAGAGCTTTTTAAGAAAACTTTTTTTTTTTTTTTTTTT

TTTTCATCAAGT

EL-octa-SE-A-16:

CGTGGCGAGAAAGTCACGCTGCGCGTCCACCACTCCTCATTATTTTTTTTTTTTTTTTTT

TTTTCATCAAGT

EL-octa-SE-A-17:

CCTTTTTAAGAAACTGGCATGATTAAATATTATAACACCCTGTTTTTTTTTTTTTTTTT

TTTCATCAAGT

EL-octa-SE-A-18:

TCTTACCAACGCGTTACAAAATAAACGGAATCAGAACCTCCCTTTTTTTTTTTTTTTTT

TTTTCATCAAGT

EL-octa-SE-A-19:

AACCAATCAATAGTTTTATTTTCATGCCAACGTAATTCTGTTTTTTTTTTTTTTTTTTTT

TTTCATCAAGT

EL-octa-SE-A-20:

TAAGAATAAACAAATTCTTACCAGTACCTTATTGGAATAAGTTTTTTTTTTTTTTTTTTTT

TTTCATCAAGT

EL-octa-SE-A-21:

CAATAGATAATATAAATCCTTTGCCCGGCGGTCTCAATCAATTTTTTTTTTTTTTTTTTTT

TTTATCCGTTA

EL-octa-SE-A-22:

TTTAATGCGCGAAAGATAAAACAGAGCCAGCCAACCAGTAATTTTTTTTTTTTTTTTT

TTTTTATCCGTTA

EL-octa-SE-A-23:

TAACCGTTGTAGTCCAGAACAATATTTCGCCTGAACAAAATTTTTTTTTTTTTTTTTT

TTTTATCCGTTA

EL-octa-SE-A-24:

GAAATTGCGTAGGGAGAAACAATAACGTTATTAGCAATTCATTTTTTTTTTTTTTTTTT

TTTTATCCGTTA

EL-octa-SE-B-1:

AAAGTACAACGGGTTACTTAGCCGGACTCAGCAATACGTAATTTTTTTTTTTTTTTTTT

TTTTTAACGGAT

EL-octa-SE-B-2:

ATAGTTGCGCCGTTTTGCGGGATCGTGTTAGCGAGGAATTGCTTTTTTTTTTTTTTTTT

TTTTTAACGGAT

EL-octa-SE-B-3:

GTGAATTACCTTAACGGAACAACATTGGCGCAGGATATTCATTTTTTTTTTTTTTTTTT

TTTTTAACGGAT

EL-octa-SE-B-4:

TTTTCAGGGATACCACAGACAGCCCTCAGGTAGATCATAACCTTTTTTTTTTTTTTTTT

TTTTTAACGGAT

EL-octa-SE-B-5:

AGGTCATTGCCTTGTCAATCATATGTGCCTTTAGCCGGAGACTTTTTTTTTTTTTTTTT

TTTTACTTGATG

EL-octa-SE-B-6:

TGGGATAGGTCAAGATCGCACTCCAGCGGTTGAAATAGGAACTTTTTTTTTTTTTTTT

TTTTTACTTGATG

EL-octa-SE-B-7:

ATTAAGCAATAAAATACTTTTGCGGGAGTTTCATATTTTCATTTTTTTTTTTTTTTTTT

TTTACTTGATG

EL-octa-SE-B-8:

CGGATGGCTTAGTAAAGTACGGTGTCCTTTCCGTCGGTGCGGTTTTTTTTTTTTTTTTT

TTTTACTTGATG

EL-octa-SE-B-9:

TCACCAGTGAGAAGCAGGCGAAAATCTCGTAATTTAATTGCGTTTTTTTTTTTTTTTTT

TTTTACTTGATG

EL-octa-SE-B-10:

TAATAAGTTTTAGCCTATTTCGGAACTTGATGGGGAACAAGATTTTTTTTTTTTTTTT

TTTTACTTGATG

EL-octa-SE-B-11:

CGACGTTGTAAACGGGTACCGAGCTCTATTATAGAGCTTCAATTTTTTTTTTTTTTTTT

TTTTACTTGATG

EL-octa-SE-B-12:

TACTGCGGAATCTCAGGTCTTTACCCTATTCTGGGGTTGATATTTTTTTTTTTTTTTTTT

TTTACTTGATG

EL-octa-SE-B-13:

TTAATTTTCCCTTAGGTCTGAGAGACACCACACTAAACAGGATTTTTTTTTTTTTTTTT

TTTTACTTGATG

EL-octa-SE-B-14:

ACCACCGGAACCTCAGAGCCGCCACCAAAATCACTTTAGCGTTTTTTTTTTTTTTTTT

TTTTTACTTGATG

EL-octa-SE-B-15:

AAGGTAAATATTTTGGGAATTAGAGCTTTTTAAGAAAACTTTTTTTTTTTTTTTTTTT

TTTTACTTGATG

EL-octa-SE-B-16:

CGTGGCGAGAAAGTCACGCTGCGCGTCCACCACTCCTCATTATTTTTTTTTTTTTTTTT

TTTTACTTGATG

EL-octa-SE-B-17:

CCTTTTTAAGAAACTGGCATGATTAAATATTATAACACCCTGTTTTTTTTTTTTTTTTT

TTTACTTGATG

EL-octa-SE-B-18:

TCTTACCAACGCGTTACAAAATAAACGGAATCAGAACCTCCCTTTTTTTTTTTTTTTTT

TTTTACTTGATG

EL-octa-SE-B-19:

AACCAATCAATAGTTTTTATTTTCATGCCAACGTAATTCTGTTTTTTTTTTTTTTTTTT

TTTACTTGATG

EL-octa-SE-B-20:

TAAGAATAAACAAATTCTTACCAGTACCTTATTGGAATAAGTTTTTTTTTTTTTTTTTT

TTTACTTGATG

EL-octa-SE-B-21:

CAATAGATAATATAAATCCTTTGCCCGGCGGTCTCAATCAATTTTTTTTTTTTTTTTTT

TTTTAACGGAT

EL-octa-SE-B-22:

TTTAATGCGCGAAAGATAAAACAGAGCCAGCCAACCAGTAATTTTTTTTTTTTTTTTT

TTTTTTAACGGAT

EL-octa-SE-B-23:

TAACCGTTGTAGTCCAGAACAATATTTCGCCTGAACAAAATTTTTTTTTTTTTTTTTT

TTTTTAACGGAT

EL-octa-SE-B-24:

GAAATTGCGTAGGGAGAAACAATAACGTTATTAGCAATTCATTTTTTTTTTTTTTTTTT

TTTTTAACGGAT

i. Sticky ends with hairpin DNA conformation of regular-octahedral DNA origami frames-universality verification-3rd system (ULTRAPAGE purified)

R-Octa-SE-hairpin-XY-A-1:

GGTAGCTATTTTAGAGAATCGATGAAAACATTAAATGTGTAGTTTTACTCTTTTTTTAGA

GTTTTTATCCGTTA

R-Octa-SE-hairpin-XY-A-2:

ATAAATCATACATAAATCGGTTGTACTGTGCTGGCATGCCTGTTTTACTCTTTTTTTAGA

GTTTTTATCCGTTA

R-Octa-SE-hairpin-XY-A-3:

ACTGTTGGGAAGCAGCTGGCGAAAGGATAGGTCAAGATCGCATTTTACTCTTTTTTTA

GAGTTTTTATCCGTTA

R-Octa-SE-hairpin-XY-A-4:

AGCTTTCATCAACGGATTGACCGTAAAATCGTATAATATTTTTTTTACTCTTTTTTTAGA

GTTTTTATCCGTTA

R-Octa-SE-hairpin-XY-A-5:

GACAGGAGGTTGAAACAAATAAATCCGCCCCCTCCGCCACCCTTTTACTCTTTTTTTAG

AGTTTTTATCCGTTA

R-Octa-SE-hairpin-XY-A-6:

CAGAATCAAGTTTCGGCATTTTCGGTTAAATATATCACCAGTTTTACTCTTTTTTTAGA

GTTTTTATCCGTTA

R-Octa-SE-hairpin-XY-A-7:

TCATATGGTTTACGATTGAGGGAGGGAAACGCAATACATACATTTTACTCTTTTTTTAGA

GTTTTTATCCGTTA

R-Octa-SE-hairpin-XY-A-8:

AATAGCAATAGCACCAGAAGGAAACCTAAAGCCACTGGTAATTTTACTCTTTTTTTAG

AGTTTTTATCCGTTA

R-Octa-SE-hairpin-XY-A-9:

TGTAGCATTCCAACGTTAGTAAATGAAGTGCCGCGCCACCCTTTTTACTCTTTTTTTAG

AGTTTTTATCCGTTA

R-Octa-SE-hairpin-XY-A-10:

GAAACATGAAAGCTCAGTACCAGGCGAAAAATGCTGAACAAATTTTACTCTTTTTTTA

GAGTTTTTATCCGTTA

R-Octa-SE-hairpin-XY-A-11:

AGAGCCTAATTTGATTTTTTGTTTAAATCCTGAAATAAAGAATTTTACTCTTTTTTTAGA

GTTTTTATCCGTTA

R-Octa-SE-hairpin-XY-A-12:

TTTGCGGAACAATGGCAATTCATCAATCTGTATAATAATTTTTTTTACTCTTTTTTTAGA

GTTTTTATCCGTTA

R-Octa-SE-hairpin-XY-A-13:

TTTGCGGATGGCCAACTAAAGTACGGGCTTGCAGCTACAGAGTTTTACTCTTTTTTTAG

AGTTTTTATCCGTTA

R-Octa-SE-hairpin-XY-A-14:

CTTAAACAGCTTATATATTCGGTCGCTTGATGGGGAACAAGATTTTACTCTTTTTTTAGA

GTTTTTATCCGTTA

R-Octa-SE-hairpin-XY-A-15:

GGCCCTGAGAGAAGCAGGCGAAAATCATTGCGTAGAGGCGGTTTTTACTCTTTTTTTA

GAGTTTTTATCCGTTA

R-Octa-SE-hairpin-XY-A-16:

GCTCACAATTCCGTGAGCTAACTCACTGGAAGTAATGGTCAATTTTACTCTTTTTTTAG

AGTTTTTATCCGTTA

R-Octa-SE-hairpin-Z-A-1:

CAAATGCTTTAAAAAATCAGGTCTTTAAGAGCAGCCAGAGGGTTCCGAGTCAATTAAG

ACTCCCTTGTATTGGTCA

R-Octa-SE-hairpin-Z-A-2:

AAAGATTCATCAGGAATTACGAGGCATGCTCATCCTTATGCGTTCCGAGTCAATTAAGA

CTCCCTTGTATTGGTCA

R-Octa-SE-hairpin-Z-A-3:

CTTCATCAAGAGAAATCAACGTAACAGAGATTTGTCAATCATTTCCGAGTCAATTAAG

ACTCCCTTGTATTGGTCA

R-Octa-SE-hairpin-Z-A-4:

AAACGAAAGAGGGCGAAACAAAGTACTGACTATATTCGAGCTTTCCGAGTCAATTAA

GACTCCCTTGTATTGGTCA

R-Octa-SE-hairpin-Z-A-5:

CAACGCTCAACAGCAGAGGCATTTTCAATCCAATGATAAATATTCCGAGTCAATTAAG

ACTCCCTTGTATTGGTCA

R-Octa-SE-hairpin-Z-A-6:

ATCAAAATCATATATGTAAATGCTGAACAAACACTTGCTTCTTTCCGAGTCAATTAAGA

CTCCCTTGTATTGGTCA

R-Octa-SE-hairpin-Z-A-7:

TGATTGCTTTGAGCAAAAGAAGATGAAATAGCAGAGGTTTTGTTCCGAGTCAATTAAG

ACTCCCTTGTATTGGTCA

R-Octa-SE-hairpin-Z-A-8:

AACGGGTATTAAGGAATCATTACCGCCAGTAATTCAACAATATTCCGAGTCAATTAAGA

CTCCCTTGTATTGGTCA

R-Octa-SE-hairpin-XY-B-1:

GGTAGCTATTTTAGAGAATCGATGAAAACATTAAATGTGTAGTTTTAGCTATTTTTTTAG

CTTTTTTAACGGAT

R-Octa-SE-hairpin-XY-B-2:

ATAAATCATACATAAATCGGTTGTACTGTGCTGGCATGCCTGTTTTAGCTATTTTTTTAG

CTTTTTTAACGGAT

R-Octa-SE-hairpin-XY-B-3:

ACTGTTGGGAAGCAGCTGGCGAAAGGATAGGTCAAGATCGCATTTTAGCTATTTTTTTA

GCTTTTTTAACGGAT

R-Octa-SE-hairpin-XY-B-4:

AGCTTTCATCAACGGATTGACCGTAAAATCGTATAATATTTTTTTTAGCTATTTTTTTAGC

TTTTTTAACGGAT

R-Octa-SE-hairpin-XY-B-5:

GACAGGAGGTTGAAACAAATAAATCCGCCCCCTCCGCCACCCTTTTAGCTATTTTTTTA

GCTTTTTTAACGGAT

R-Octa-SE-hairpin-XY-B-6:

CAGAATCAAGTTTCGGCATTTTCGGTTAAATATATCACCAGTTTTTAGCTATTTTTTTAG

CTTTTTTAACGGAT

R-Octa-SE-hairpin-XY-B-7:

TCATATGGTTTACGATTGAGGGAGGGAAACGCAATACATACATTTTAGCTATTTTTTTAG

CTTTTTTAACGGAT

R-Octa-SE-hairpin-XY-B-8:

AATAGCAATAGCACCAGAAGGAAACCTAAAGCCACTGGTAATTTTAGCTATTTTTTTA

GCTTTTTTAACGGAT

R-Octa-SE-hairpin-XY-B-9:

TGTAGCATTCCAACGTTAGTAAATGAAGTGCCGCGCCACCCTTTTAGCTATTTTTTTA

GCTTTTTTAACGGAT

R-Octa-SE-hairpin-XY-B-10:

GAAACATGAAAGCTCAGTACCAGGCGAAAAATGCTGAACAAATTTTAGCTATTTTTTT

AGCTTTTTTAACGGAT

R-Octa-SE-hairpin-XY-B-11:

AGAGCCTAATTTGATTTTTTGTTTAAATCCTGAAATAAAGAATTTTAGCTATTTTTTTAG

CTTTTTTAACGGAT

R-Octa-SE-hairpin-XY-B-12:

TTTGCGGAACAATGGCAATTCATCAATCTGTATAATAATTTTTTTTAGCTATTTTTTTAGC

TTTTTTAACGGAT

R-Octa-SE-hairpin-XY-B-13:

TTTGCGGATGGCCAACTAAAGTACGGGCTTGCAGCTACAGAGTTTTAGCTATTTTTTTA

GCTTTTTTAACGGAT

R-Octa-SE-hairpin-XY-B-14:

CTTAAACAGCTTATATATTCGGTCGCTTGATGGGGAACAAGATTTTAGCTATTTTTTTAG

CTTTTTTAACGGAT

R-Octa-SE-hairpin-XY-B-15:

GGCCCTGAGAGAAGCAGGCGAAAATCATTGCGTAGAGGCGGTTTTAGCTATTTTTTT

AGCTTTTTTAACGGAT

R-Octa-SE-hairpin-XY-B-16:

GCTCACAATTCCGTGAGCTAACTCACTGGAAGTAATGGTCAATTTTAGCTATTTTTTTA

GCTTTTTTAACGGAT

R-Octa-SE-hairpin-Z-B-1:

CAAATGCTTTAAAAAATCAGGTCTTTAAGAGCAGCCAGAGGGTTTTGGATGTTTTTTC

ATCCCCCCTGACCAATAC

R-Octa-SE-hairpin-Z-B-2:

AAAGATTCATCAGGAATTACGAGGCATGCTCATCCTTATGCGTTTTGGATGTTTTTTCAT

CCCCCCTGACCAATAC

R-Octa-SE-hairpin-Z-B-3:

CTTCATCAAGAGAAATCAACGTAACAGAGATTTGTCAATCATTTTTGGATGTTTTTTCA

TCCCCCCTGACCAATAC

R-Octa-SE-hairpin-Z-B-4:

AAACGAAAGAGGGCGAAACAAAGTACTGACTATATTCGAGCTTTTTGGATGTTTTTTC

ATCCCCCCTGACCAATAC

R-Octa-SE-hairpin-Z-B-5:

CAACGCTCAACAGCAGAGGCATTTTCAATCCAATGATAAATATTTTGGATGTTTTTTCA

TCCCCCCTGACCAATAC

R-Octa-SE-hairpin-Z-B-6:

ATCAAAATCATATATGTAAATGCTGAACAAACACTTGCTTCTTTTTGGATGTTTTTTCAT

CCCCCCTGACCAATAC

R-Octa-SE-hairpin-Z-B-7:

TGATTGCTTTGAGCAAAAGAAGATGAAATAGCAGAGGTTTTGTTTTGGATGTTTTTTCA

TCCCCCCTGACCAATAC

R-Octa-SE-hairpin-Z-B-8:

AACGGGTATTAAGGAATCATTACCGCCAGTAATTCAACAATATTTTGGATGTTTTTTCAT

CCCCCCTGACCAATAC

Section 6. Supplementary References

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2. Y. Wang, L. Dai, Z. Ding, M. Ji, J. Liu, H. Xing, X. Liu, Y. Ke, C. Fan, P. Wang and Y. Tian, DNA origami single crystals with Wulff shapes, *Nature Communications*, 2021, **12**, 3011.