



## Supporting Information

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Self-Assembly of DNA Origami Heterodimers in High Yields  
and Analysis of the Involved Mechanisms

*Breveruos Sheheade, Miran Liber, Mary Popov, Yaron  
Berger, Dinesh C. Khara, Jürgen Jopp, and Eyal Nir\**

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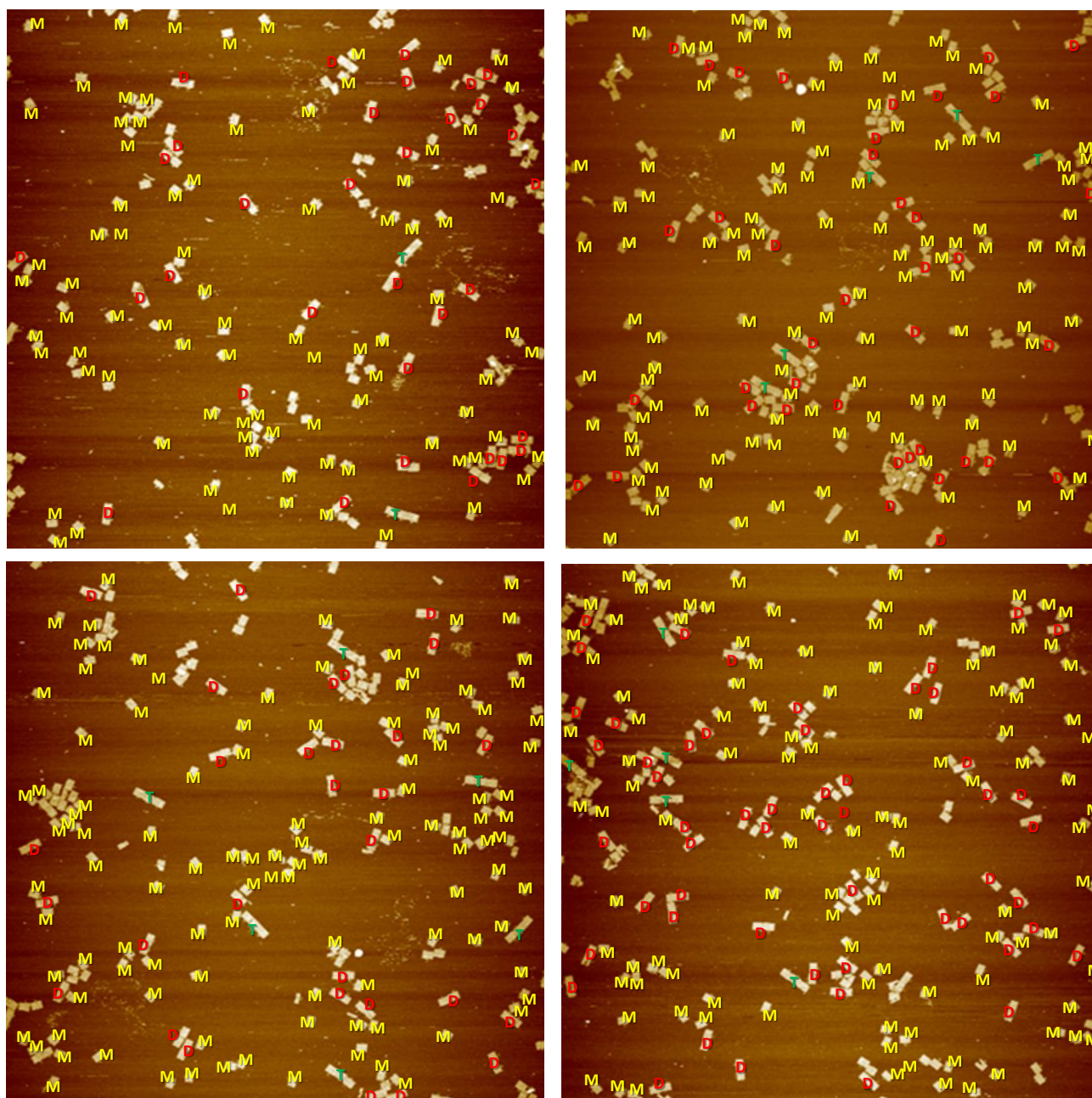
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## 1. Additional Results

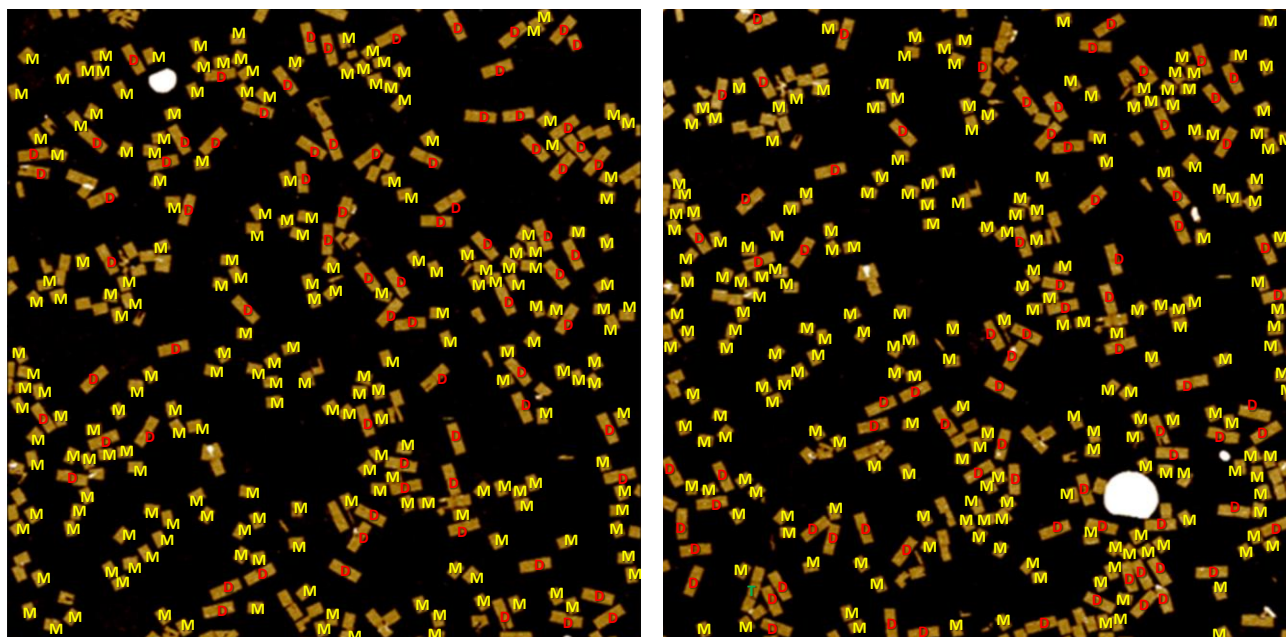
Figures S1 and S3-S11 show only representative AMF images. Shown are selected AFM images of unpurified origami-F23/8 and origami-G23/8 (Figure S1a and S1b, respectively), of the reaction mixtures of gel-purified monomers (FG23/8 and FG11/11, Figures S3 and S4, respectively), of the reaction mixtures of 1xPEG(x12)-purified monomers (FG23/8 and FG11/11, Figures S5 and S6, respectively), of the reaction mixtures of 2xPEG(x5)-purified monomers (FG11/11, Figure S7), of PEG-purified origami-F23/8 and origami-G23/8 (Figures S8 and S9, respectively), and of gel-purified origami-F23/8 and origami-G23/8 (Figures S10 and S11, respectively). Figure S2 show additional gel electrophoresis results.

### AFM images of unpurified origami-F23/8:



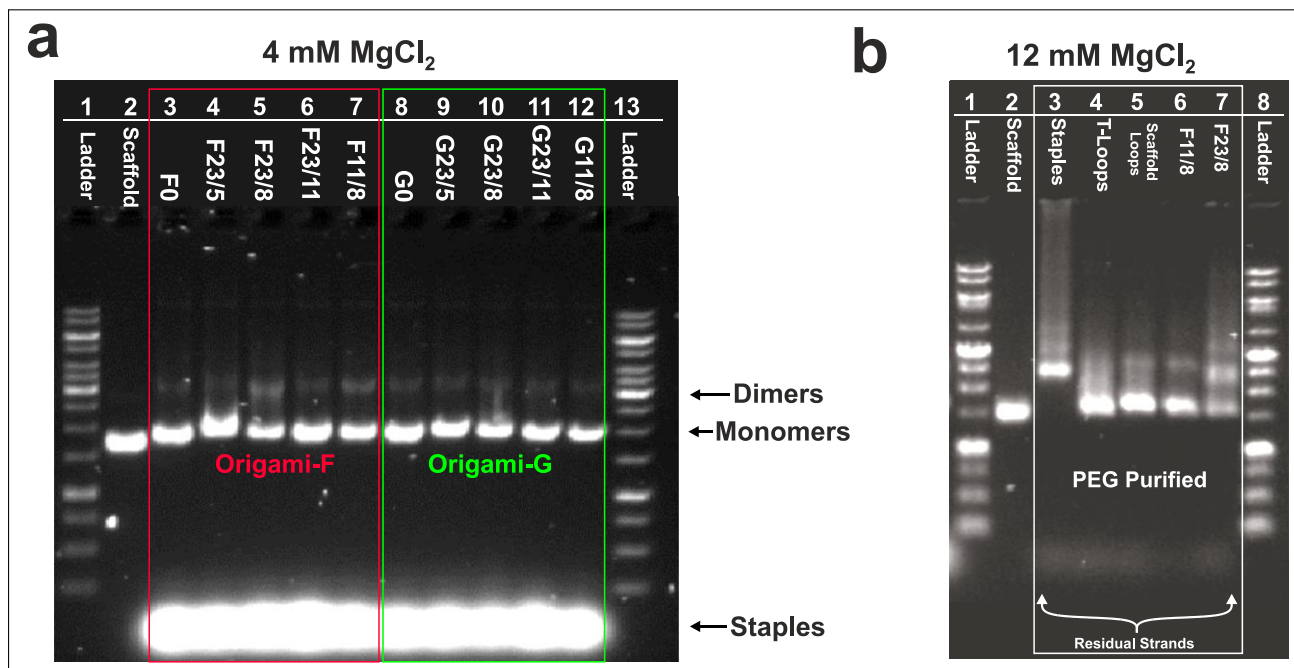
**Figure S1a.** AFM images of unpurified origami-F23/8. Images were collected after the thermal annealing process and without further treatment. Monomers, homodimers, and homotrimers are marked by the letters 'M', 'D', and 'T', respectively.

AFM images of unpurified origami-G23/8:



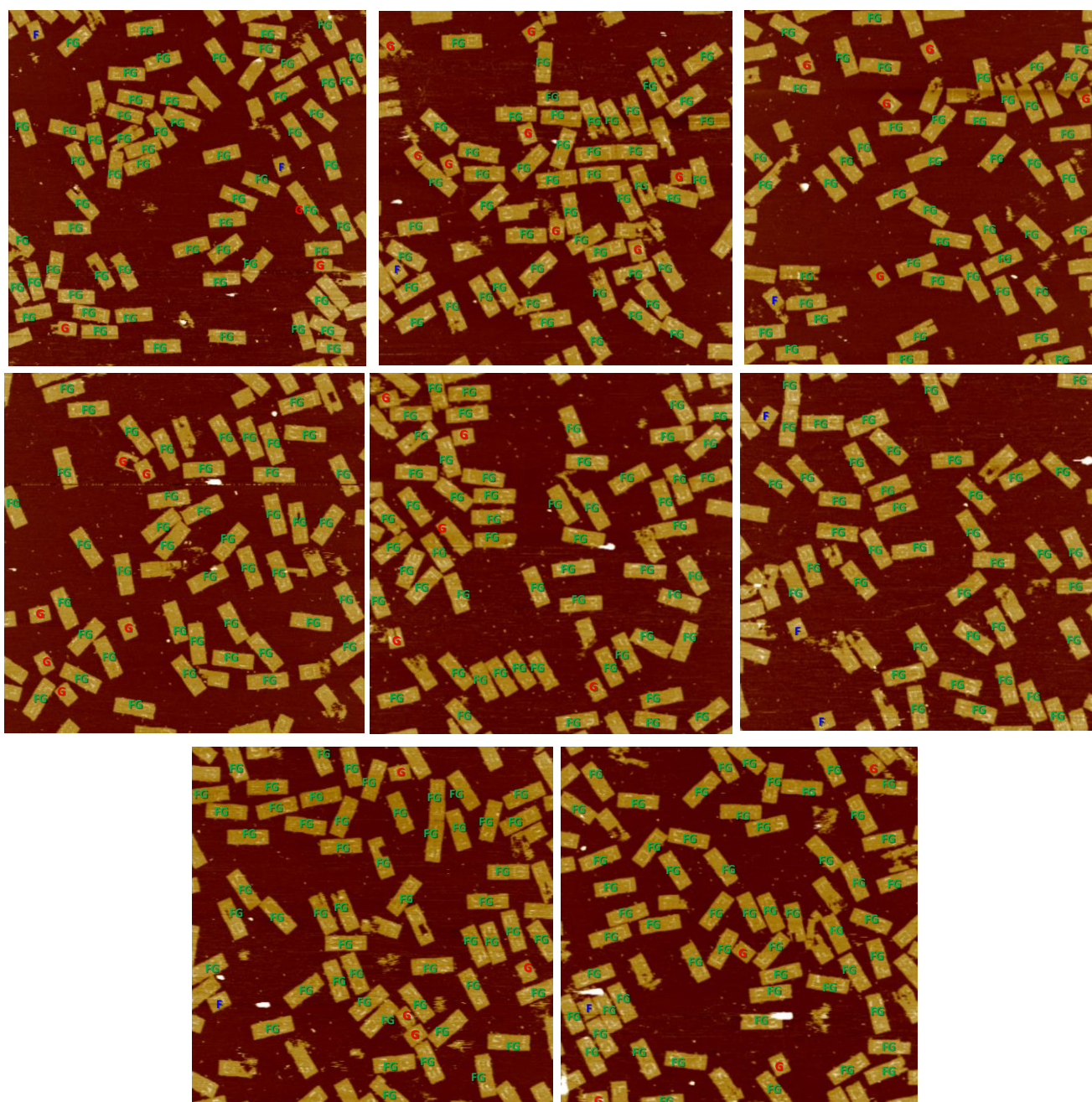
**Figure S1b.** AFM images of unpurified origami-G23/8. Images were collected after the thermal annealing process and without further treatment. Monomers, homodimers, and homotrimers are marked by the letters 'M', 'D', and 'T', respectively.

### Agarose Gel Electrophoresis:



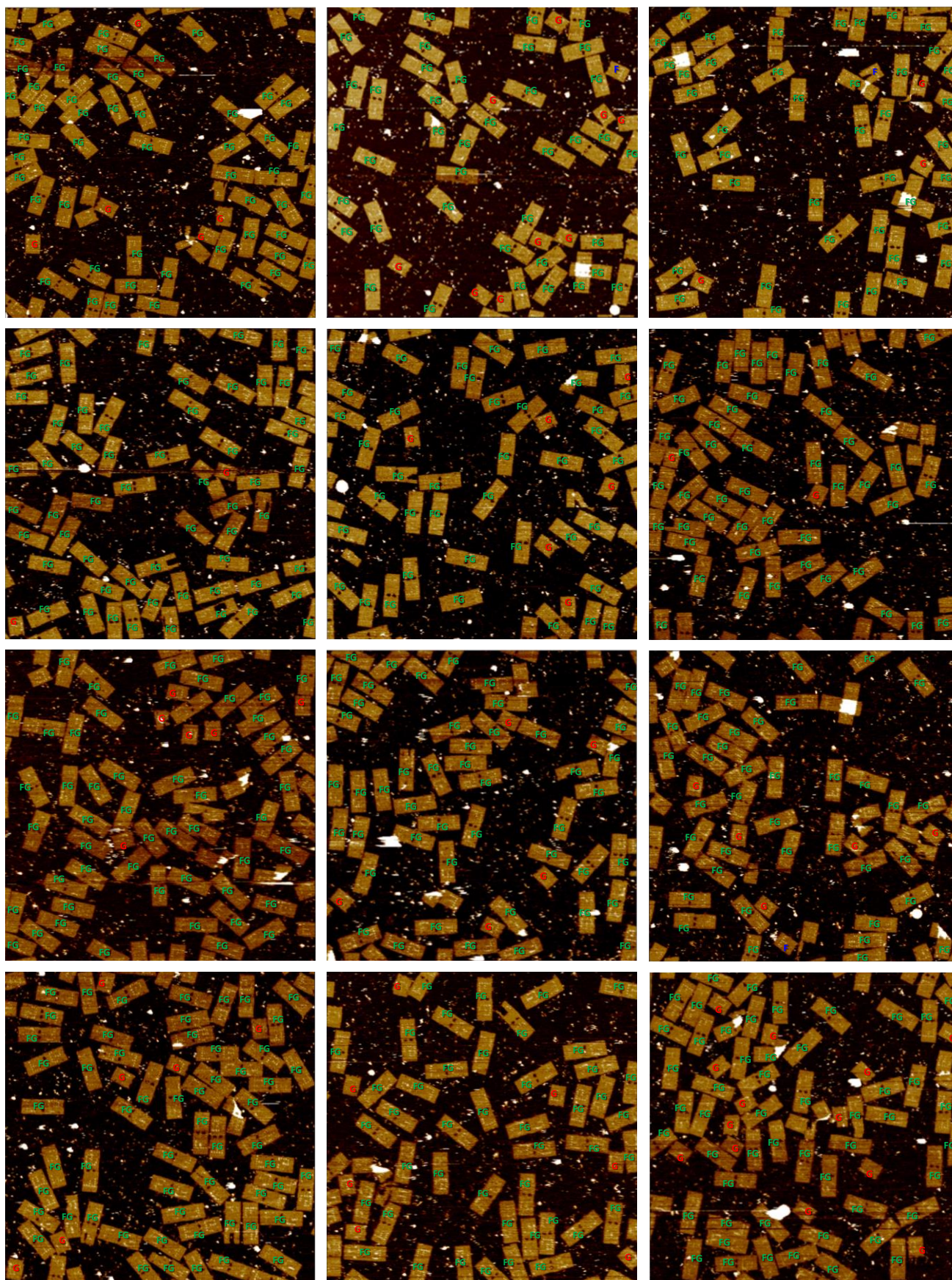
**Figure S2.** Additional agarose gel electrophoresis results. (a) Dissociation of homodimers and larger structures into monomers was evaluated by separation on agarose gels (buffer containing 4 mM MgCl<sub>2</sub>). Shown are origami-F and origami-G without bridging strands (Lanes 3 and 8, respectively), with 12 bridging strands (23 sticky ends) of the lengths 5, 8, and 11 nts (Lanes 4-6 and 9-11, respectively), and with 7 bridging strands (11 sticky ends) of the length 8 nt (Lanes 7 and 12, respectively). Lanes 1 and 13 were loaded with 1-kb ladder and lane 2 with M13mp18 scaffold. (b) Agarose gel chromatogram (12 mM MgCl<sub>2</sub>) of PEG-purified origami-F with different right-side edge designs provides evidence for improper purification of excess strands by PEG-purification procedure. Left-side edge was designed with poly-T-loop strands. Near the bottom of the gel are residual strands that were not removed by PEG precipitation. Shown are origami-F with edges containing edge staples (Lane 3), poly-T-loop strands (Lane 4), no strands (scaffold loops, Lane 5), and bridging strands 11/8 and 23/8 (Lanes 6 and 7, respectively). Lanes 1 and 8 were loaded with 1-kb ladder and lane 2 with M13mp18 scaffold.

AFM images of the reaction mixture of gel-purified origami-F23/8 and origami-G23/8:



**Figure S3.** AFM images of the reaction mixture of origami-F23/8 and origami-G23/8 purified by gel (100 mM NaCl). Monomers, dimers, and trimers are marked with the origami letter or letters involved in the structure.

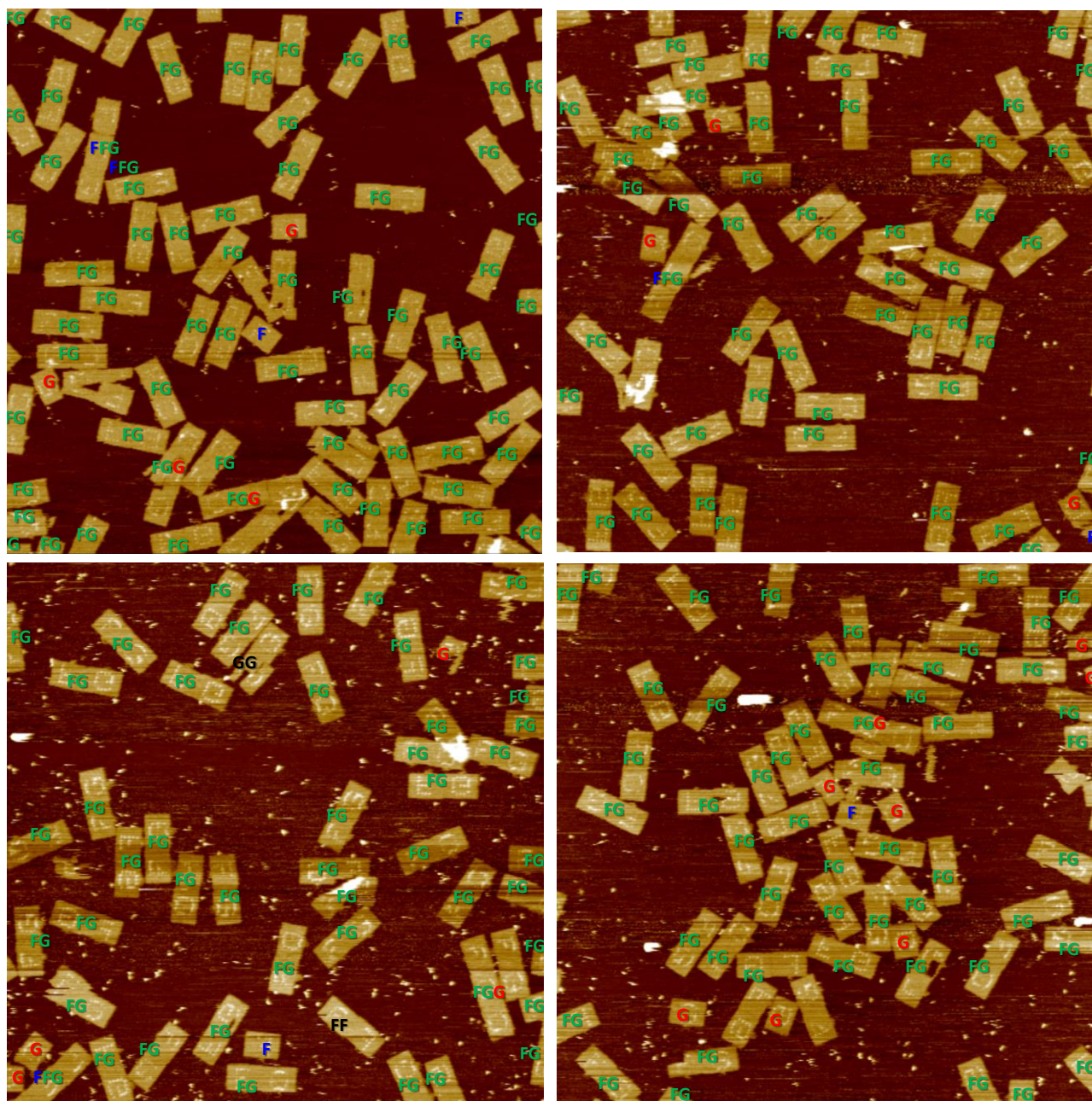
AFM images of the reaction mixture of gel-purified origami-F11/11 and origami-G11/11:



**Figure S4.** AFM images of the reaction mixture of origami-F11/11 and origami-G11/11 purified by gel (100 mM NaCl). Monomers, dimers, and trimers are marked with the origami letter or letters involved in the structure.



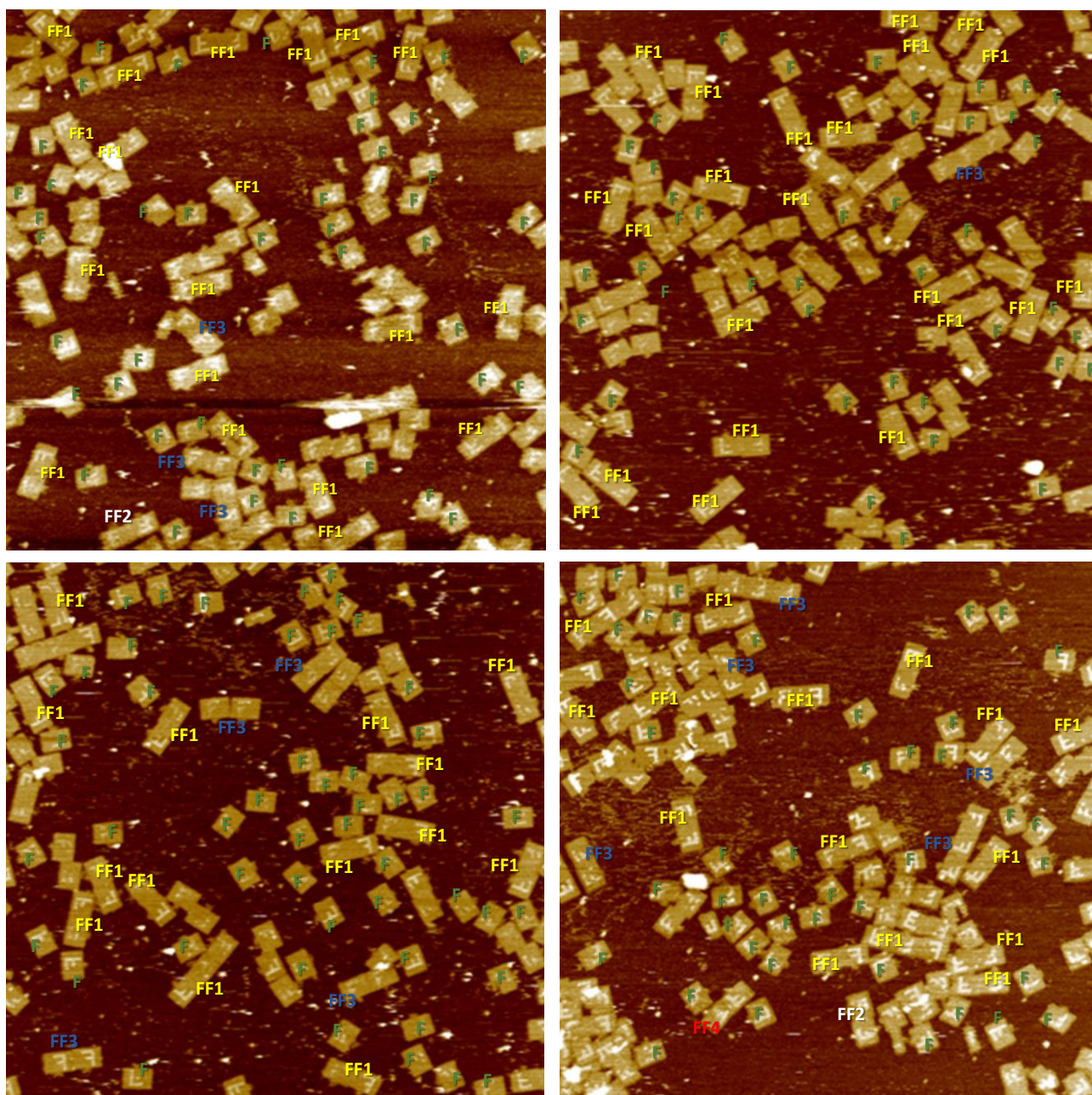
AFM images of the reaction mixture of 1xPEG(x12)-purified origami-F11/11 and origami-G11/11:



**Figure S6.** AFM images of the reaction mixture of origami-F11/11 and origami-G11/11 purified once by PEG (excess poly-T loops and bridging strands; x12). Monomers, dimers, and trimers are marked with the origami letter or letters involved in the structure.

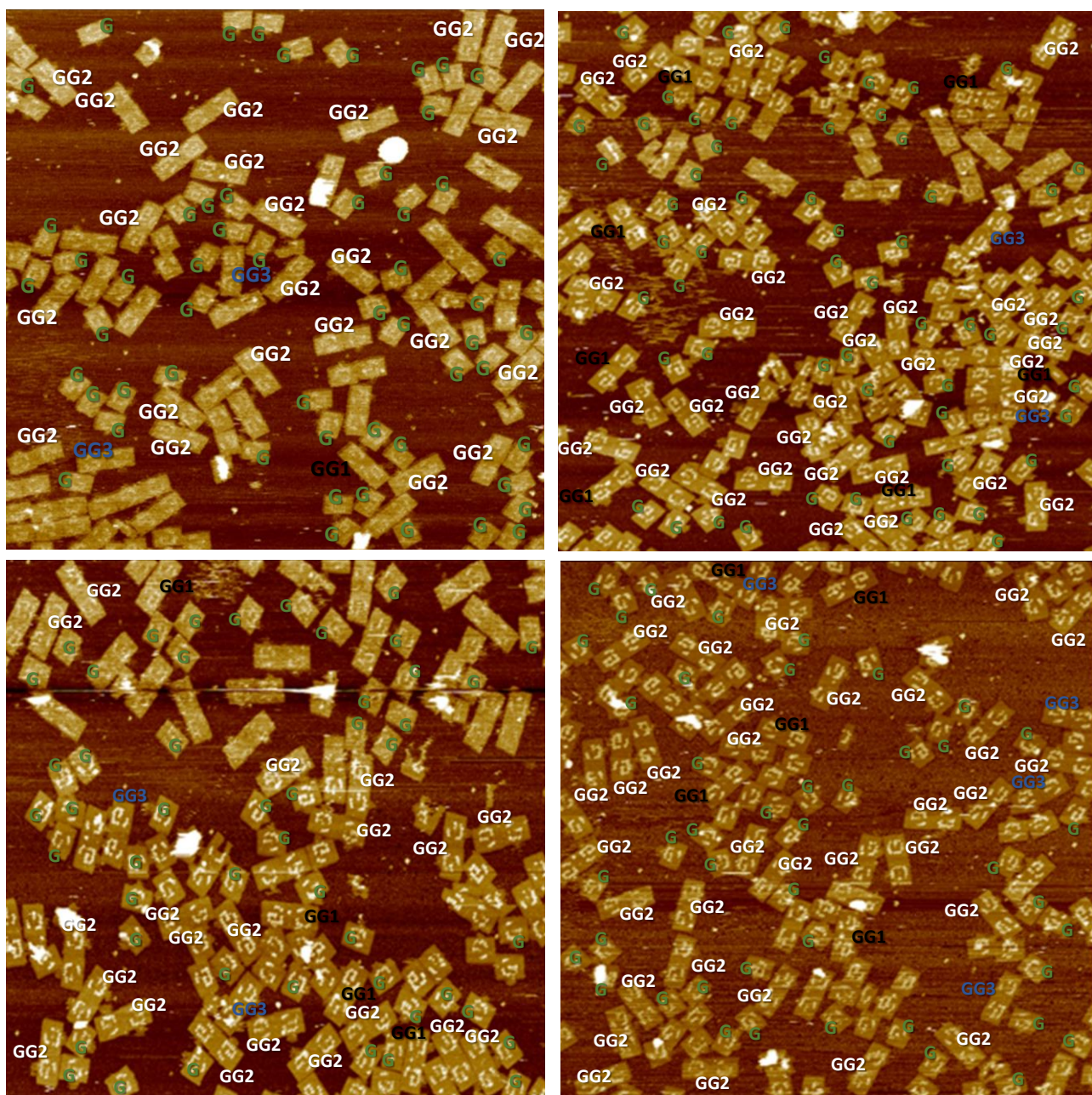


AFM images of PEG-purified origami-F23/8:



**Figure S8.** AFM images of PEG-purified origami-F23/8. Origami monomers are marked with 'F', 'flip' BSE-BSE homodimers with 'FF1', 'rotate' BSE-BSE homodimers with 'FF2', BSE-PTE homodimers with 'FF3', and the minority PTE-PTE homodimers with 'FF4'.

AFM images of PEG-purified origami-G23/8:



**Figure S9.** AFM images of PEG-purified origami-G23/8. Origami monomers are marked with 'G', 'flip' BSE-BSE homodimers with 'GG1', 'rotate' BSE-BSE homodimers with 'GG2', and BSE-PTE homodimers with 'GG3'.

AFM images of gel-purified origami-F23/8:

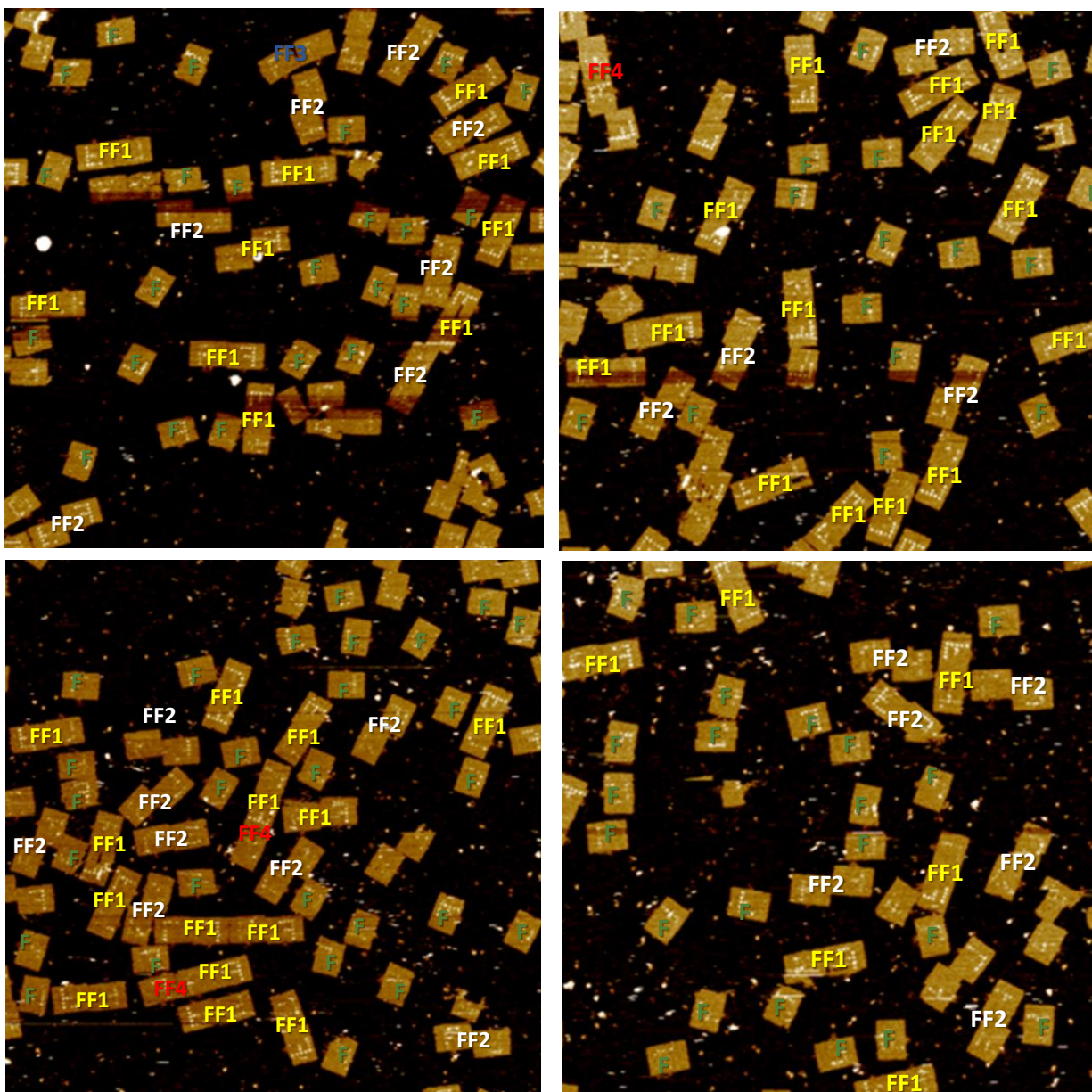
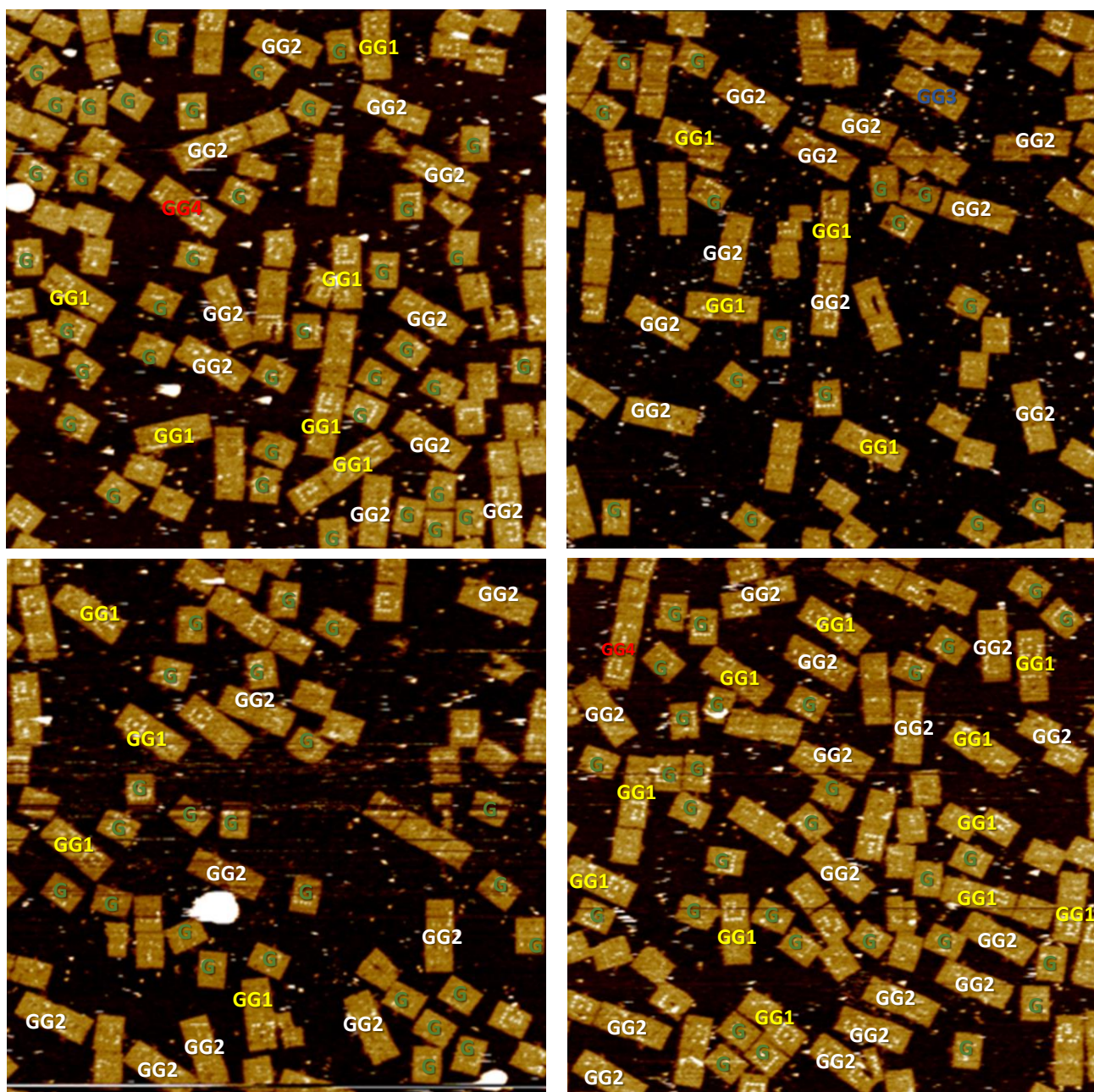


Figure S10. AFM images of gel-purified origami-F23/8. Origami monomers are marked with 'F', 'flip' BSE-BSE homodimers with 'FF1', 'rotate' BSE-BSE homodimers with 'FF2', BSE-PTE homodimers with 'FF3', and minority PTE-PTE homodimers with 'FF4'.

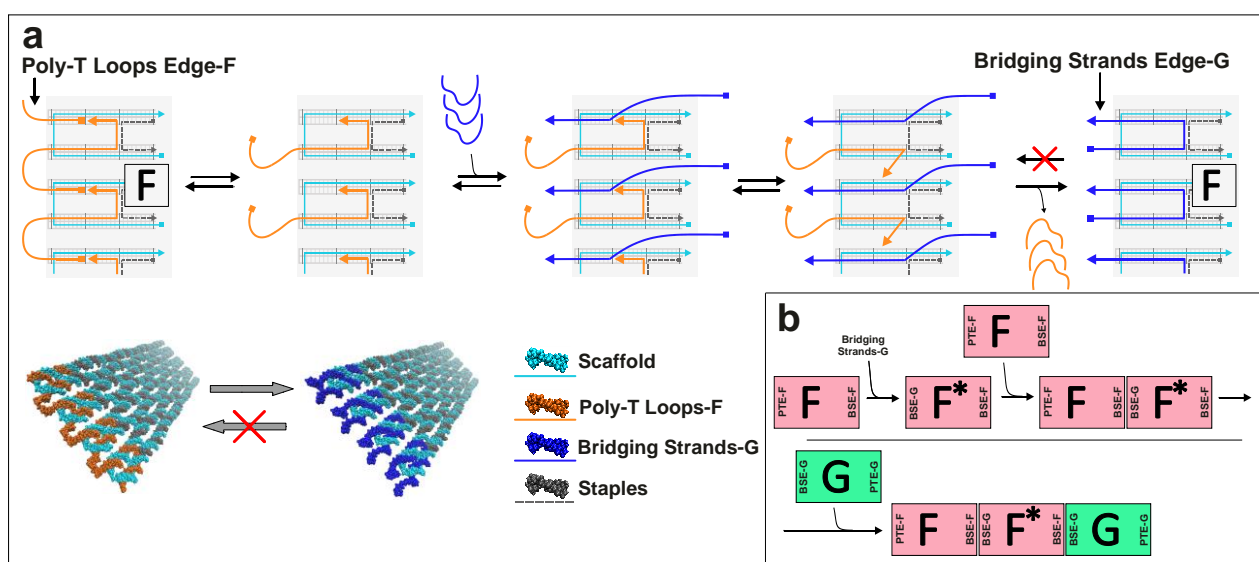
AFM images of gel-purified origami-G23/8:



**Figure S11.** AFM images of gel-purified origami-G23/8. Origami monomers are marked with 'G', 'flip' BSE-BSE homodimers with 'GG1', 'rotate' BSE-BSE homodimers with 'GG2', and BSE-PTE homodimers with 'GG3'.

## 2. Heterotrimer Formation Explained by Changes in Monomer Addressability

The designs of the origami structural core and scaffold were identical for origami-F and origami-G. This means that cross hybridization of unpurified bridging strands and poly-T-loop strands belonging to one origami with the complimentary scaffold of the other is, in principle, possible. A proposed reaction mechanism in which unpurified bridging strands from origami G replace native poly-T loops of origami-F through toehold-mediated strand displacement reaction is presented in Figure S12a. According to this mechanism, the peripheral height nucleotide segments of the native poly-T-loop origami-F strands thermally dissociate from the native scaffold of origami-F, followed by hybridization of invading bridging strands from origami-G with the scaffold of origami-F, a reaction cascade that may be followed by irreversible displacement of the poly-T-loop strands of origami-F. Attachment of a sufficient number of invading origami-G bridging strands to the poly-T-loop edge of origami-F is therefore expected to allow interaction of the corresponding edge with another origami-F through hybridization of the sticky ends resulting in formation of FF homodimers (Figure S12b). In such homodimer structure, the right sides of origami-F are free to interact with origami-G through sticky ends to form the FFG trimer (Figure S12b). Similarly, invading bridging strands from origami-F can change the addressability of origami-G and result in the formation of FGG trimers. We consider the reverse reaction, a replacement of bridging strands by invading poly-T-loop strands (which would result in poly-T loops on both origami edges), significantly less likely because of the unavailability of scaffold-made toeholds that would initiate poly-T-loop strand invasion (Figure S12a, the reverse reaction).



**Figure S12.** Formation of heterotrimers due to change in monomer addressability.

Unfortunately, at this point we cannot determine whether unpurified FF and GG homodimers of the BSE-PTE type or the formation of FF and GG due to bridging-strand invasion were responsible for the

FFG and FGG trimers. Further study of this question may be possible by introduction of bridging strands from a hypothetical origami-X to a solution of gel-purified origami-Y monomer samples and observing the formation (or not) of BSE-PTE homodimers using AFM and by studying the formation of these homodimers in the absence of poly-T loops (which should increase the forward reaction shown in Figure S12a). We plan to perform these experiments in the future.

### 3. DNA Strand Sequences of Origami-F and Origami-G

Strand Name	Original Strand <sup>1</sup>	Sequence 5'→3'
<b>Origami-F Poly-T-Loop Edge Staples <sup>(1)</sup></b>		
Edge 20 - 8T	r-9t2i	CAGCGAAA <b>TTTTTTTT</b> AACTTTCAACAGTTTCTGGGATTTTGCTAAAC <b>TTTTT</b>
Edge 38 - 10T	r-9t4e	ACGGTCAA <b>TTTTTTTT</b> GACAGCATCGGAACGAACCTCAG
Edge 56 - 10T	r-9t6e	GGACGTTG <b>TTTTTTTT</b> TCATAAGGGAACCGAAAGCGCGAG
Edge 74 - 6T	r-9t8e	TAAATAT <b>TTTTTT</b> GGAAGAAAAATCTACGACCAGTCA
Edge 92 - 8T	r-9t10e	ATATAATG <b>TTTTTTTT</b> CATTGAATCCCCTCAAATCGTCA
Edge 110 - 12T	r-9t12e	GCTAAATC <b>TTTTTTTT</b> CTGTAGCTCAACATGTATTGCTGA
Edge 128 - 6T	r-9t14e	AGAGAATC <b>TTTTTT</b> GGTTGTACCAAAAACAAGCATAAA
Edge 146 - 10T	r-9t16e	GATTGACCT <b>TTTTTTTT</b> GATGAACGGTAATCGTAGCAAACA
Edge 164 - 10T	r-9t18e	CACGACGT <b>TTTTTTTT</b> GTAATGGGATAGGTCAAACCGCG
Edge 182 - 10T	r-9t20e	GGGAGAGG <b>TTTTTTTT</b> TGTAACGACGGCCATTCCAGT
Edge 200 - 6T	r-9t22e	TATCAGGG <b>TTTTTT</b> CGGTTTGCATTTGGGAACGCGCG
Edge 209 - 7T	r-9t24e	<b>TTTTTT</b> CGATGGCCACTACGTAACCGTC
<b>Origami-G Poly-T-Loop Edge Staples <sup>(1)</sup></b>		
Edge 10 - 9T	r9t0f	<b>TTTTTTTT</b> TATAAGTATAGCCCGCCGTCGAG
Edge 19 - 6T	r9t2f	AGGGTTGA <b>TTTTTT</b> ATAAATCCTCATTAAATGATATTC
Edge 37 - 10T	r9t4f	ACAAACAA <b>TTTTTTTT</b> AATCAGTAGCGACAGATCGATAGC
Edge 55 - 8T	r9t6f	AGCACCGT <b>TTTTTTTT</b> TAAAGGTGGCAACATAGTAGAAAA
Edge 73 - 10T	r9t8f	TACATACA <b>TTTTTTTT</b> GACGGGAGAATTAACACAGGGAA
Edge 91 - 10T	r9t10f	CGGCATT <b>TTTTTTTT</b> GCTTATCCGGTATTCTAAATCAGA
Edge 109 - 10T	r9t12f	TATAGAAG <b>TTTTTTTT</b> CGACAAAAGGTAAGTAGAGAATA
Edge 127 - 6T	r9t14f	TAAAGTAC <b>TTTTTT</b> CGCGAGAAAACTTTTATCGCAAG
Edge 145 - 8T	r9t16f	ACAAAGAA <b>TTTTTTTT</b> ATTAATTACATTTAACACATCAAG
Edge 163 - 10T	r9t18f	AAAACAAA <b>TTTTTTTT</b> TTTCATCAATATAATCCTATCAGAT
Edge 181 - 12T	r9t20f	GATGGCAA <b>TTTTTTTT</b> TAATCAATATCTGGTCACAAATATC
Edge 199 - 10T	r9t22f	AAACCTC <b>TTTTTTTT</b> ACCAGTAATAAAAGGGATTACCAGTCACACG <b>TTTTT</b>
<sup>(1)</sup> Red indicates poly-T loops		
<b>Origami-F 5-nt Sticky-End Bridging Strands <sup>(2)</sup></b>		
F_to_G-1_Ex_Link_R-5nt's	r9t0f	TTTTTTATAAGTATAGCCCGCCGTCGAGAGGGTTGA <b>ACAGT</b>
F_to_G-2+3_Ex_Link_R-5nt's	r9t2f	<b>CAGAT</b> ATAAATCCTCATTAAATGATATTCACAAACAA <b>GACAC</b>
F_to_G-4+5_Ex_Link_R-5nt's	r9t4f	<b>TCCTCA</b> ATCAGTAGCGACAGATCGATAGCAGCACCGT <b>AGGAA</b>
F_to_G-6+7_Ex_Link_R-5nt's	r9t6f	<b>CCGTATA</b> AAAGGTGGCAACATAGTAGAAAAATACATAC <b>AGTACG</b>
f_to_G-8+9_Ex_Link_R-5nt's	r9t8f	<b>CAAGA</b> GACGGGAGAATTAACACAGGGAAGCGCATT <b>AACTCG</b>
F_to_G-10+11_Ex_Link_R-5nt's	r9t10f	<b>CCATT</b> GCTTATCCGGTATTCTAAATCAGATATAGAAG <b>GGTAC</b>
F_to_G-12+13_Ex_Link_R-5nt's	r9t12f	<b>CATGAC</b> GACAAAAGGTAAGTAGAGAATATAAAGTAC <b>ACTGT</b>
F_to_G-14+15_Ex_Link_R-5nt's	r9t14f	<b>TAGAG</b> CGCGAGAAAACTTTTATCGCAAGACAAAGAA <b>GTGTG</b>
F_to_G-16+17_Ex_Link_R-5nt's	r9t16f	<b>AGACA</b> ATTAATTACATTTAACACATCAAGAAAACAAA <b>ACGAA</b>
F_to_G-18+19_Ex_Link_R-5nt's	r9t18f	<b>TTAGG</b> TTTCATCAATATAATCCTATCAGATGATGGCAA <b>GGTTA</b>
F_to_G-20+21_Ex_Link_R-5nt's	r9t20f	<b>CTACA</b> AATCAATATCTGGTCACAAATATCAAACCTC <b>CAACGA</b>
F_to_G-22+23_Ex_Link_R-5nt's	r9t22f	<b>GTATG</b> ACCAGTAATAAAAGGGATTACCAGTCACACG <b>GTGCA</b>
<b>Origami-G 5-nt Sticky-End Bridging Strands <sup>(2)</sup></b>		
G_to_F-0+1_Ex_Link_L-5nt's	r-9t2i	<b>ATCTG</b> AACTTTCAACAGTTTCTGGGATTTTGCTAAAC <b>ACTGT</b>
G_to_F-2+3_Ex_Link_L-5nt's	r-9t4e	<b>GGAGA</b> CACAGCATCGGAACGAACCTCAGCAGCGAAA <b>GTGTG</b>
G_to_F-4+5_Ex_Link_L-5nt's	r-9t6e	<b>TACGGT</b> CATAAGGGAACCGAAAGCGCGCAGACGGTCA <b>TTCTT</b>
G_to_F-6+7_Ex_Link_L-5nt's	r-9t8e	<b>TCTTG</b> GGAAGAAAAATCTACGACCAAGTCAAGGACGTTG <b>CGTAC</b>
G_to_F-8+9_Ex_Link_L-5nt's	r-9t10e	<b>AATGG</b> CATTGAATCCCCTCAAATCGTCATAAATATT <b>CAGGT</b>
G_to_F-10+11_Ex_Link_L-5nt's	r-9t12e	<b>TCATG</b> CTGTAGCTCAACATGTATTGCTGAATATAATG <b>GTACC</b>
G_to_F-12+13_Ex_Link_L-5nt's	r-9t14e	<b>CTCTA</b> GGTTGTACCAAAAACAAGCATAAAGCTAAAT <b>CACAGT</b>
G_to_F-14+15_Ex_Link_L-5nt's	r-9t16e	<b>TGCTG</b> TATGAACGGTAATCGTAGCAAAACAAGAGAAT <b>CCACAC</b>
G_to_F-16+17_Ex_Link_L-5nt's	r-9t18e	<b>CCTAA</b> GTAATGGGATAGGTCAAACGGCGGATTGAC <b>TTTCGT</b>
G_to_F-18+19_Ex_Link_L-5nt's	r-9t20e	<b>TGTAG</b> TGTAACGACGGCCATTCCAGTCACGACG <b>TAAACC</b>
G_to_F-20+21_Ex_Link_L-5nt's	r-9t22e	<b>CATAC</b> CGGTTTGCATTTGGGAACGCGCGGGGAGAGG <b>TCGTT</b>

G_to_F-22_Ex_Link_L-5nt's	r-9t24e	TTTTTCGATGGCCCACTACGTAACCGTCTATCAGGG <u>TGCAC</u>
<sup>(2)</sup> Colors indicate sticky-end segments, and matching colors and underline indicate complimentary sequences		
<b>Origami-F 8-nt Sticky-End Bridging Strands <sup>(3)</sup></b>		
F_to_G-1_Ex_Link_R-8nt's	r9t0f	TTTTTTATAAGTATAGCCCGCCGTCGAGAGGGTTGAT <u>TGCTTGC</u>
F_to_G-2+3_Ex_Link_R-8nt's	r9t2f	<u>AGTGTCTG</u> ATAAATCCTCATTAAATGATATTCACAAACAA <u>GAGACTTC</u>
F_to_G-4+5_Ex_Link_R-8nt's	r9t4f	<u>TGCTACACA</u> AATCAGTAGCGACAGATCGATAGCAGCACCGT <u>GAAACTTG</u>
F_to_G-6+7_Ex_Link_R-8nt's	r9t6f	<u>GAAACGTTT</u> AAAGGTGGCAACATAGTAGAAAATACATACAT <u>CTCTGCAA</u>
F_to_G-8+9_Ex_Link_R-8nt's	r9t8f	<u>GCTAGACG</u> GACGGGAGAATTAACACAGGGAAGCGCATTAAATGGAA <u>C</u>
F_to_G-10+11_Ex_Link_R-8nt's	r9t10f	<u>AGCTCACAG</u> CTTATCCGGTATTCTAAATCAGATATAGAAG <u>CTTGGCAT</u>
F_to_G-12+13_Ex_Link_R-8nt's	r9t12f	<u>ACCTGGTGC</u> GACAAAAGGTAAAGTAGAGAATATAAAGTACT <u>TCACATAG</u>
F_to_G-14+15_Ex_Link_R-8nt's	r9t14f	<u>CTCTGTAC</u> CGCGAGAAAACTTTTATCGCAAGACAAAGAA <u>TTCACTGC</u>
F_to_G-16+17_Ex_Link_R-8nt's	r9t16f	<u>TAGCACGA</u> ATTAATTACATTTAACACATCAAGAAAACAA <u>AATCTGTC</u>
F_to_G-18+19_Ex_Link_R-8nt's	r9t18f	<u>TGAATTCG</u> TTTCATCAATATAATCCTATCAGATGATGGCAAT <u>TGCAGGAT</u>
F_to_G-20+21_Ex_Link_R-8nt's	r9t20f	<u>AAAGGCGT</u> AATCAATATCTGGTCACAAATATCAAACCTCT <u>TAAGCGC</u>
F_to_G-22+23_Ex_Link_R-8nt's	r9t22f	<u>CGTTGTCC</u> ACCAGTAATAAAAGGGATTACCAGTCACACG <u>TCCGTCCT</u>
<b>Origami-G 8-nt Sticky-End Bridging Strands <sup>(3)</sup></b>		
G_to_F-0+1_Ex_Link_L-8nt's	r-9t2i	<u>CAGACACT</u> AACTTTCAACAGTTTCTGGGATTTTGCTAAAC <u>GCAAGCAA</u>
G_to_F-2+3_Ex_Link_L-8nt's	r-9t4e	<u>GTGTAGCA</u> GACAGCATCGGAACGAACCTCAGCAGCGAAA <u>GAAGTCTC</u>
G_to_F-4+5_Ex_Link_L-8nt's	r-9t6e	<u>AACGTTTCT</u> CATAAGGGAACCGAAAGGCGCAGACGGTCAA <u>CAAGTTTC</u>
G_to_F-6+7_Ex_Link_L-8nt's	r-9t8e	<u>CGTCTAGC</u> GGAAGAAAATCTACGACAGTCAGGACGTTGTT <u>GCAGGA</u>
G_to_F-8+9_Ex_Link_L-8nt's	r-9t10e	<u>TGTGAGCT</u> CATTGAATCCCCCTCAAATCGTCATAAATATTGTTCCAAT
G_to_F-10+11_Ex_Link_L-8nt's	r-9t12e	<u>CACCAGGT</u> CTGTAGCTCAACATGTATTGCTGAATATAATGAT <u>TCGCAAG</u>
G_to_F-12+13_Ex_Link_L-8nt's	r-9t14e	<u>GTACAGAG</u> GGTTGTACAAAAACAAGCATAAAGCTAAATC <u>CTATGTGA</u>
G_to_F-14+15_Ex_Link_L-8nt's	r-9t16e	<u>TCGTGCTA</u> GATGAACGGTAATCGTAGCAAACAAGAGAATC <u>GCAGTGAA</u>
G_to_F-16+17_Ex_Link_L-8nt's	r-9t18e	<u>CGAATTCAG</u> TAAATGGGATAGGTCAAACGGCGGATTGACC <u>GACAGATT</u>
G_to_F-18+19_Ex_Link_L-8nt's	r-9t20e	<u>ACGGCTTT</u> TGTAACGACGGCCATTCCAGTCAGCAGCT <u>ATCCTGCA</u>
G_to_F-20+21_Ex_Link_L-8nt's	r-9t22e	<u>GGACAACG</u> CGGTTTGCATTTGGGAACGCGGGGAGAGGG <u>CGCTTAG</u>
G_to_F-22_Ex_Link_L-8nt's	r-9t24e	TTTTTCGATGGCCCACTACGTAACCGTCTATCAGGG <u>AGGACGGA</u>
<sup>(3)</sup> Colors indicate sticky-end segments, and matching colors and underline indicate complimentary sequences		
<b>Origami-F 11-nt Sticky-End Bridging Strands <sup>(4)</sup></b>		
F_to_G-1_Ex_Link_R-11nt's	r9t0f	TTTTTTATAAGTATAGCCCGCCGTCGAGAGGGTTGAT <u>GTCGGTATGAA</u>
F_to_G-2+3_Ex_Link_R-11nt's	r9t2f	<u>ATCATTAGAC</u> ATAAATCCTCATTAAATGATATTCACAAACAA <u>CGTTAGTCCAC</u>
F_to_G-4+5_Ex_Link_R-11nt's	r9t4f	<u>TGTGGAGTTT</u> CAATCAGTAGCGACAGATCGATAGCAGCACCGT <u>CTTGATACAGG</u>
F_to_G-6+7_Ex_Link_R-11nt's	r9t6f	<u>CCAAAAGAGT</u> CTAAAGGTGGCAACATAGTAGAAAATACATACAAAGT <u>GCCTGT</u>
F_to_G-8+9_Ex_Link_R-11nt's	r9t8f	<u>AAACTGTAGG</u> CACGGGAGAATTAACACAGGGAAGCGCATTATTTCCGCTCTA
F_to_G-10+11_Ex_Link_R-11nt's	r9t10f	<u>ACAAGCACGCT</u> GCTTATCCGGTATTCTAAATCAGATATAGAAG <u>GGACATTTGC</u>
F_to_G-12+13_Ex_Link_R-11nt's	r9t12f	<u>TACACAACGCT</u> CGACAAAAGGTAAAGTAGAGAATATAAAGTAC <u>GCCAATCAGTC</u>
F_to_G-14+15_Ex_Link_R-11nt's	r9t14f	<u>CTAGGTTAAAC</u> CGCGAGAAAACTTTTATCGCAAGACAAAGAA <u>CTGGACGAAC</u>
F_to_G-16+17_Ex_Link_R-11nt's	r9t16f	<u>CTTTGCTCTG</u> ATTAATTACATTTAACACATCAAGAAAACAA <u>GAGATAAACCC</u>
F_to_G-18+19_Ex_Link_R-11nt's	r9t18f	<u>TATAAAGCCGT</u> TTTCATCAATATAATCCTATCAGATGATGGCAAT <u>TAGTAGTAGT</u>
F_to_G-20+21_Ex_Link_R-11nt's	r9t20f	<u>TTATACCCACA</u> ATCAATATCTGGTCACAAATATCAAACCTCTATTATG <u>GCGG</u>
F_to_G-22+23_Ex_Link_R-11nt's	r9t22f	<u>TATGTAAGT</u> AGACCAGTAATAAAAGGGATTACCAGTCACACG <u>GATACCGCTGC</u>
<b>Origami-G 11-nt Sticky-End Bridging Strands <sup>(4)</sup></b>		
G_to_F-0+1_Ex_Link_L-11nt's	r-9t2i	<u>GTCTGAATGAT</u> AACTTTCAACAGTTTCTGGGATTTTGCTAAAC <u>TTCATACGGAC</u>
G_to_F-2+3_Ex_Link_L-11nt's	r-9t4e	<u>GAAACTCCACA</u> GACAGCATCGGAACGAACCTCAGCAGCGAAA <u>GTGGACTAACG</u>
G_to_F-4+5_Ex_Link_L-11nt's	r-9t6e	<u>GACTCTTTTGG</u> TCATAAGGGAACCGAAAGGCGCAGACGGTCAA <u>CCTGTATCAAG</u>
G_to_F-6+7_Ex_Link_L-11nt's	r-9t8e	<u>GCCTACAGTTT</u> GGAAGAAAATCTACGACAGTCAGGACGTTG <u>ACAGGGCACTT</u>
G_to_F-8+9_Ex_Link_L-11nt's	r-9t10e	<u>AGCGTGCTGT</u> CATTGAATCCCCCTCAAATCGTCATAAATATT <u>AGGAGCGGAA</u>
G_to_F-10+11_Ex_Link_L-11nt's	r-9t12e	<u>AGCGTTGTGT</u> ACTGTAGCTCAACATGTATTGCTGAATATAATG <u>GCAAAATGTCC</u>
G_to_F-12+13_Ex_Link_L-11nt's	r-9t14e	<u>GTTTACCCTAG</u> GGTTGTACAAAAACAAGCATAAAGCTAAATC <u>GACTGATGGC</u>
G_to_F-14+15_Ex_Link_L-11nt's	r-9t16e	<u>CAAGGACAAAG</u> ATGAACGGTAATCGTAGCAACAAGAGAATC <u>AGTTCTCCAG</u>
G_to_F-16+17_Ex_Link_L-11nt's	r-9t18e	<u>ACGGCTTTATA</u> AGTAATGGGATAGGTCAAACGCGGATTGACC <u>GGGTTTATCTC</u>
G_to_F-18+19_Ex_Link_L-11nt's	r-9t20e	<u>GGTGGGTATA</u> TGTAACGACGGCCATTCCAGTCAGCAGCT <u>ACTACCTACTA</u>
G_to_F-20+21_Ex_Link_L-11nt's	r-9t22e	<u>CTAGTACATA</u> CGGTTTGCATTTGGGAACGCGGGGAGAGG <u>CCGCATAATA</u>
G_to_F-22_Ex_Link_L-11nt's	r-9t24e	TTTTTCGATGGCCCACTACGTAACCGTCTATCAGGG <u>GCAGCGGTATC</u>
<sup>(4)</sup> Colors indicate sticky-end segments, and matching colors and underline indicate complimentary sequences		

**Table S1.** Sequences of the DNA strands for origami-F and origami-G.

#### 4. References

1. Rothmund, P. W. K., Folding DNA to Create Nanoscale Shapes and Patterns. *Nature* **2006**, *440*, 297-302.