SUPPORTING INFORMATION

Molecular Engineering of the Peptoid Nanosheet Hydrophobic Core

Ellen J. Robertson, Caroline Proulx, Jessica K. Su, Rita Garcia, Stan Yoo, Eric M. Nehls, Michael D. Connolly, Laudann Taravati, and Ronald N. Zuckermann*

The Molecular Foundry, Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley, California, 94720, United States.

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Table S1. Characterization data for peptoids 1-18.

Compound		Formula	Calc. m/z $[M+H]^+$	Obs. m/z $[M+H]^+$ $[M+2H]^+$	Retention time (min)	Crude Purity (%)	Purity (%)	Yield (%)	SP_{900} Value (mN/m)
1	$(Nae\text{-}Npe)_3$-$(Nce\text{-}Npe)_3$[a]	$C_{87}H_{114}N_{16}O_{18}$	1672.0	837.3	9.69[c]	66.5	>99		14.8 ± 3.2
2	Nae-Nbpe-Nae-Npe-Nae-Nbpe-Nce-Npe-Nce-Nbpe-Nce-Npe	$C_{105}H_{126}N_{16}O_{18}$	1900.3	951.4	13.23[c]	88	91	39	26.2 ± 1.9
3	Nae-Nfpe-Nae-Npe-Nae-Nfpe-Nce-Npe-Nce-Nfpe-Nce-Npe	$C_{90}H_{111}F_9N_{16}O_{18}$	1876.0	940.7	12.32[c]	93	96	35	32.9 ± 2.4
4	$(Nce\text{-}Neph)_4$-$(Nae\text{-}Neph)_4$	$C_{116}H_{151}N_{21}O_{24}$	2223.6	2224.2	12.39[c]	22.5	90	1.6	24.2 ± 1.7
5	$(Nae\text{-}Npe)_4$-$(Nce\text{-}Npe)_4$[a]	$C_{116}H_{151}N_{21}O_{24}$	2223.6	1113.0	10.12[c]	83.6	98		21.8 ± 3.3
6	$(Nae\text{-}Nmb)_4$ $(Nce\text{-}Nmb)_4$	$C_{116}H_{151}N_{21}O_{24}$	2223.6	2224.2	11.08[c]	75.7	>99	9.2	36.3 ± 3.6
7	$(Nae\text{-}N25dmpe)_4$-$(Nce\text{-}N25dmpe)_4$	$C_{132}H_{183}N_{21}O_{24}$	2449.0	2446.5	19.60[d]	79.9	97	13	32.1 ± 2.0
8	$(Nae\text{-}N24dmpe)_4$-$(Nce\text{-}N24dmpe)_4$	$C_{132}H_{183}N_{21}O_{24}$	2449.0	2447.1	20.13[d]	38.3	87	17	32.4 ± 2.6
9	$(Nae\text{-}N34dmpe)_4$-$(Nce\text{-}N34dmpe)_4$	$C_{132}H_{183}N_{21}O_{24}$	2449.0	2469.3	18.77[d]	55.8	97	23	37.4 ± 1.4
10	$(Nae\text{-}N2mpe)_4$-$(Nce\text{-}N2mpe)_4$	$C_{124}H_{167}N_{21}O_{24}$	2336.8	2334.8	17.21[d]	42.5	93	27	28.1 ± 1.3
11	$(Nae\text{-}N3mpe)_4$-$(Nce\text{-}N3mpe)_4$	$C_{124}H_{167}N_{21}O_{24}$	2336.8	2336.1	17.79[d]	37.5	83	33	32.1 ± 2.5
12	$(Nae\text{-}N4mpe)_4$-$(Nce\text{-}N4mpe)_4$	$C_{124}H_{167}N_{21}O_{24}$	2336.8	2334.8	17.81[d]	35.0	89	26	34.6 ± 1.0
13	$(Nae\text{-}Nclpe\text{-}Nae\text{-}Npe)_3$-Nae-Nclpe-$(Nce\text{-}Npe\text{-}Nce\text{-}Nclpe)_3$-Nce-Npe[b]	$C_{203}H_{255}Cl_7N_{36}O_{42}$	4120.6	4119.6	13.57		79	6.3	25.0 ± 2.6
14	$(Nae\text{-}Npe)_7$-$(Nce\text{-}Npe)_7$[a]	$C_{203}H_{262}N_{36}O_{42}$	3878.5	3873.4	11.67[c]	30.5	>99		22.5 ± 2.2
15	$(Nae\text{-}Ncp)_7$-$(Nce\text{-}Ncp)_7$	$C_{161}H_{262}N_{36}O_{42}$	3374.1	3376.5	8.77[c]	21.6	70	6	13.2 ± 4.6
16	$(Nae\text{-}Nch)_7$-$(Nce\text{-}Nch)_7$	$C_{175}H_{290}N_{36}O_{42}$	3570.5	3571.9	11.65[c]	18.0	87	4.5	23.8 ± 3.1
17	$(Nae\text{-}Nibu)_7$-$(Nce\text{-}Nibu)_7$	$C_{147}H_{262}N_{36}O_{42}$	3205.9	3207.9	8.68[c]	12.8	>99	18.3	22.8 ± 0.6
18	$(Nae\text{-}Nmbu)_7$-$(Nce\text{-}Nmbu)_7$	$C_{161}H_{290}N_{36}O_{42}$	3402.3	3404.1	12.60[c]	19.8	79	3.6	36.9 ± 1.4

[a] Previously published.[1]
[b] Previously published.[2]
[c] Analytical HPLC analyses were performed on a Vydac column (4.6 mm x 150 mm, 5 μm, C18) at 60 °C with a flow rate of 1.0 mL/min using a 20–80% gradient of CH_3CN (0.1% TFA) in water (0.1% TFA) over 20 min. HPLC traces were monitored at 214 nm.
[d] Analytical HPLC analyses were performed as above, using a 5–95% gradient of CH_3CN (0.1% TFA) in water (0.1% TFA) over 30 min.

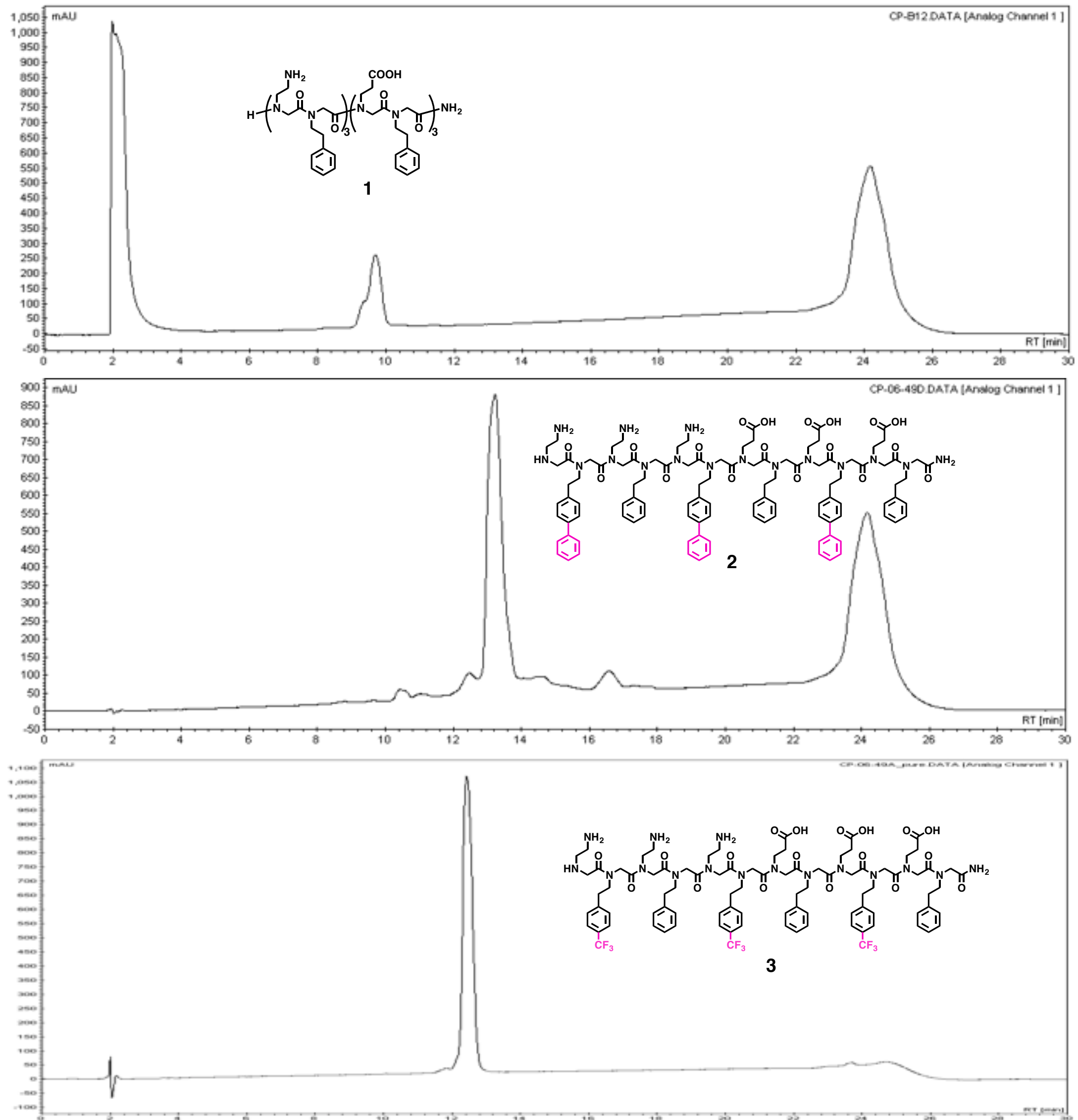


Figure S1. HPLC traces for peptoids **1-3.**

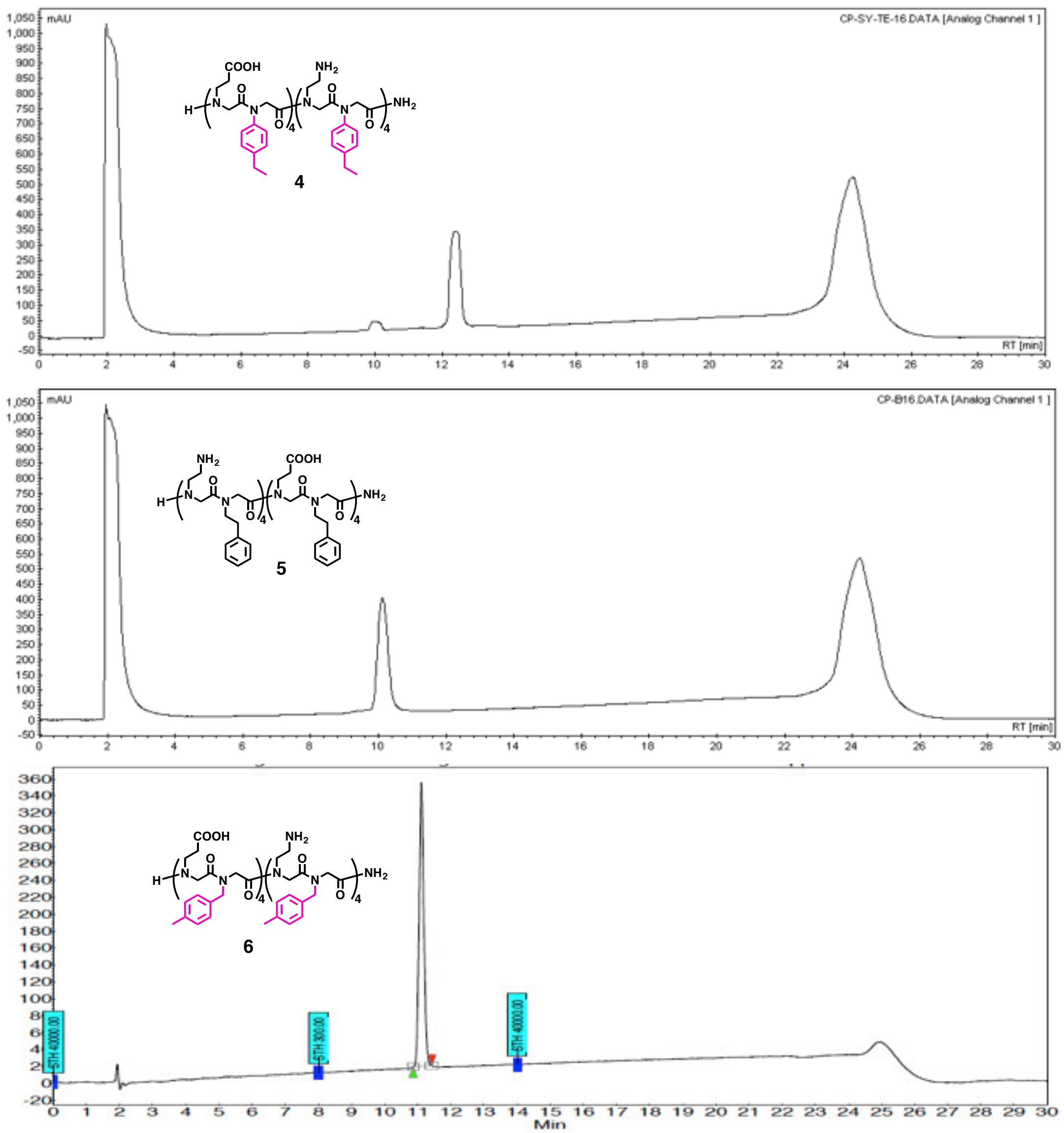


Figure S2. HPLC traces for peptoids **4-6.**

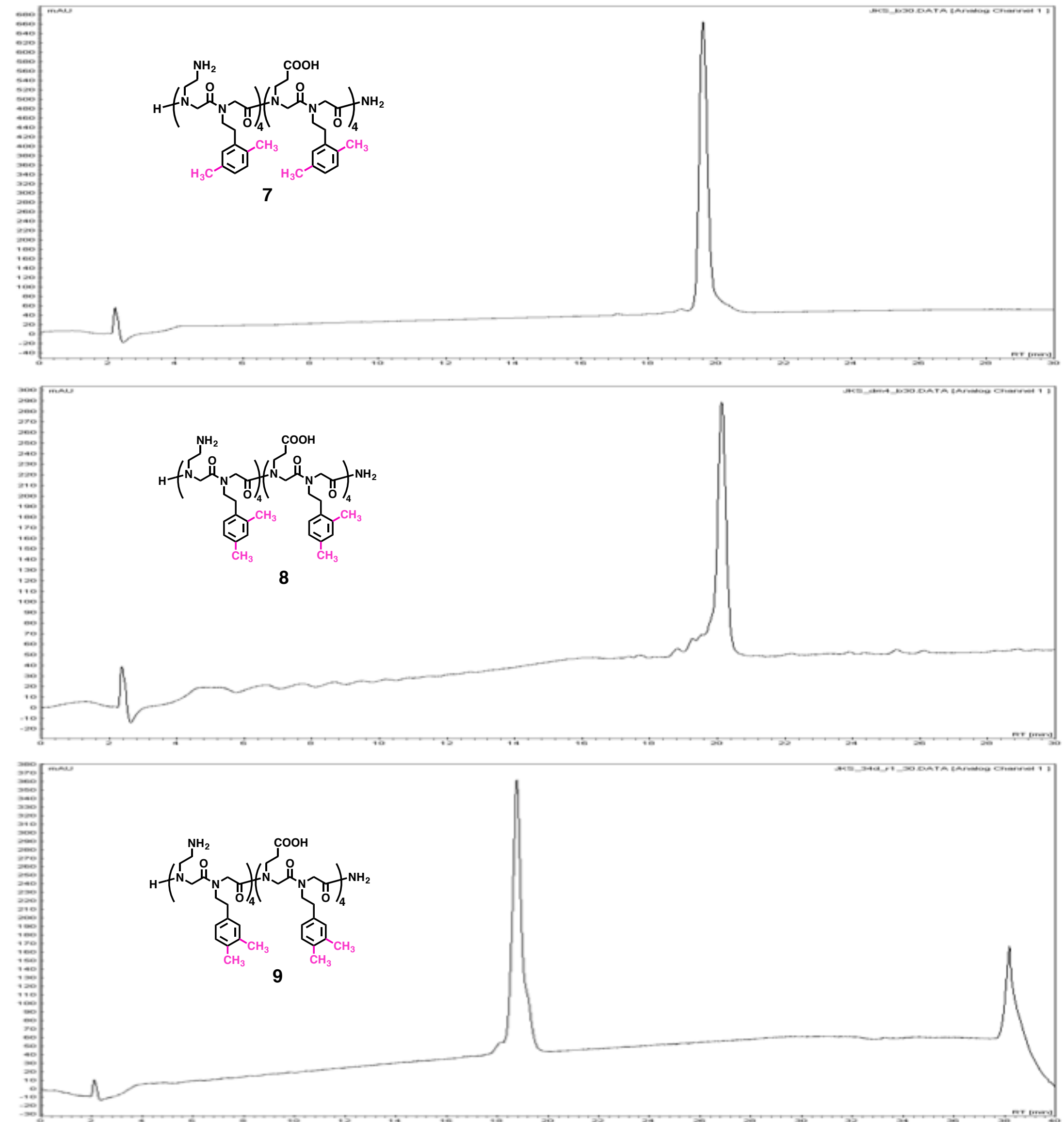


Figure S3. HPLC traces for peptoids **7-9.**

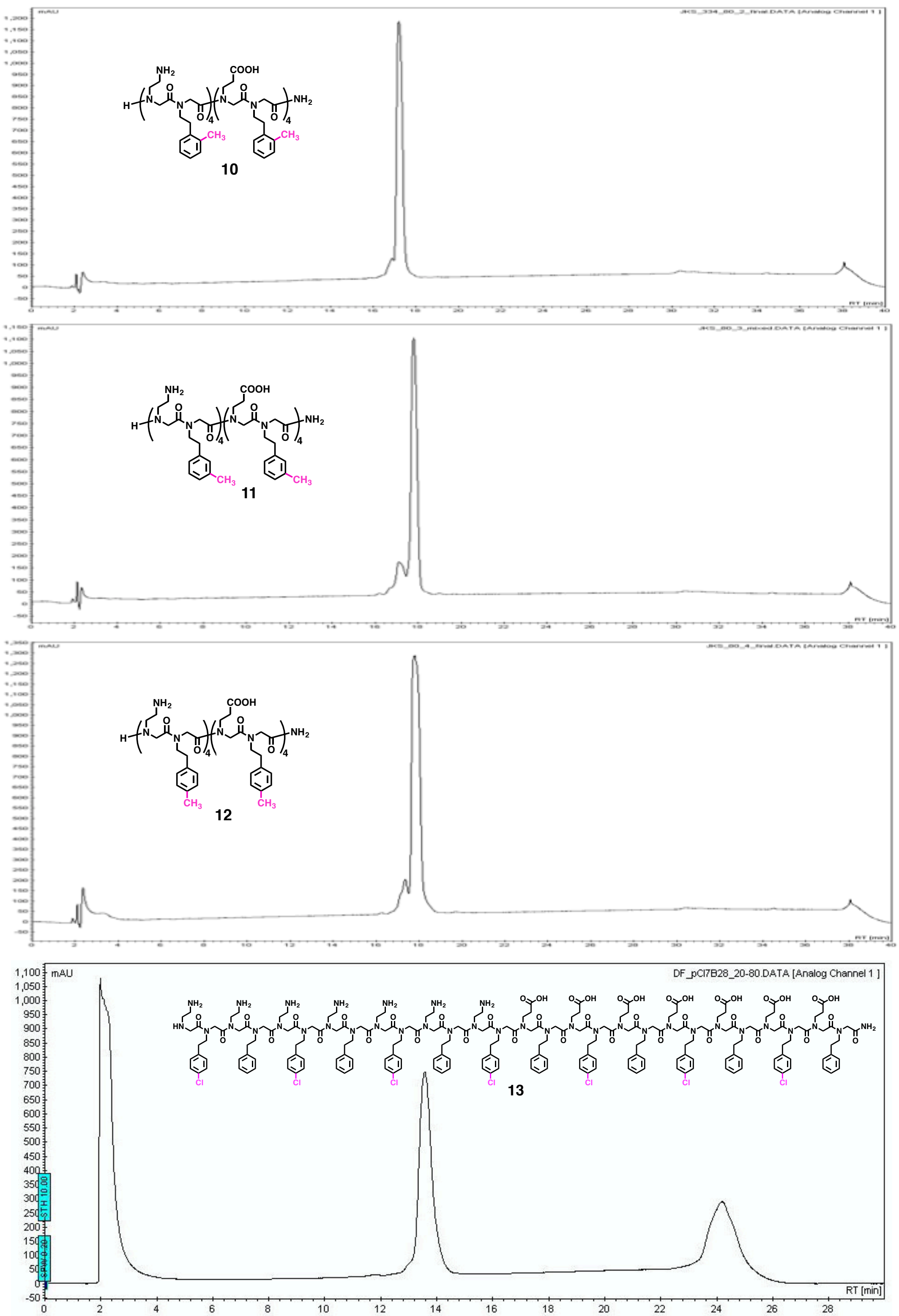


Figure S4. HPLC traces for peptoids **10-13.**

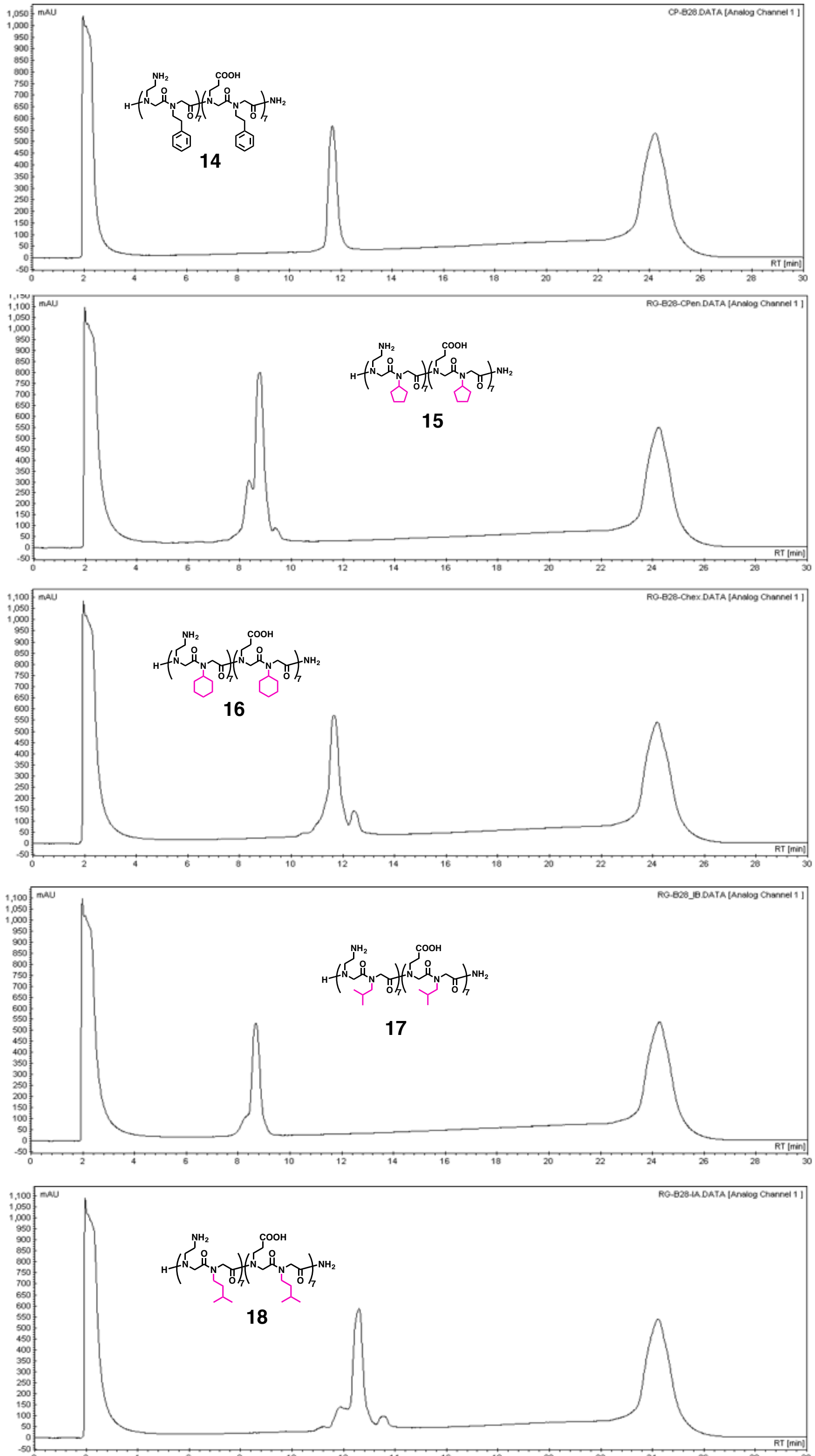


Figure S5. HPLC traces for peptoids **14-18.**

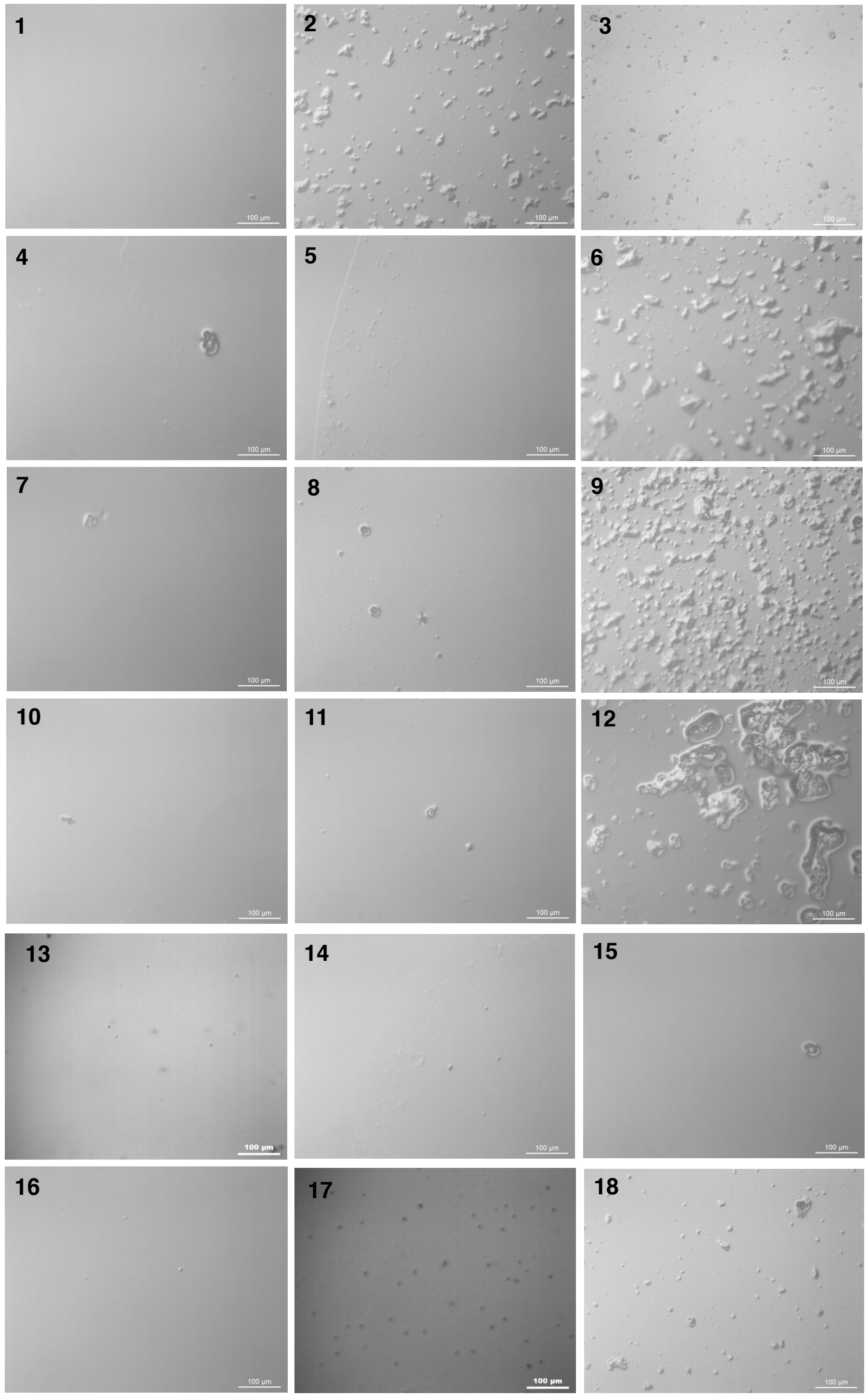
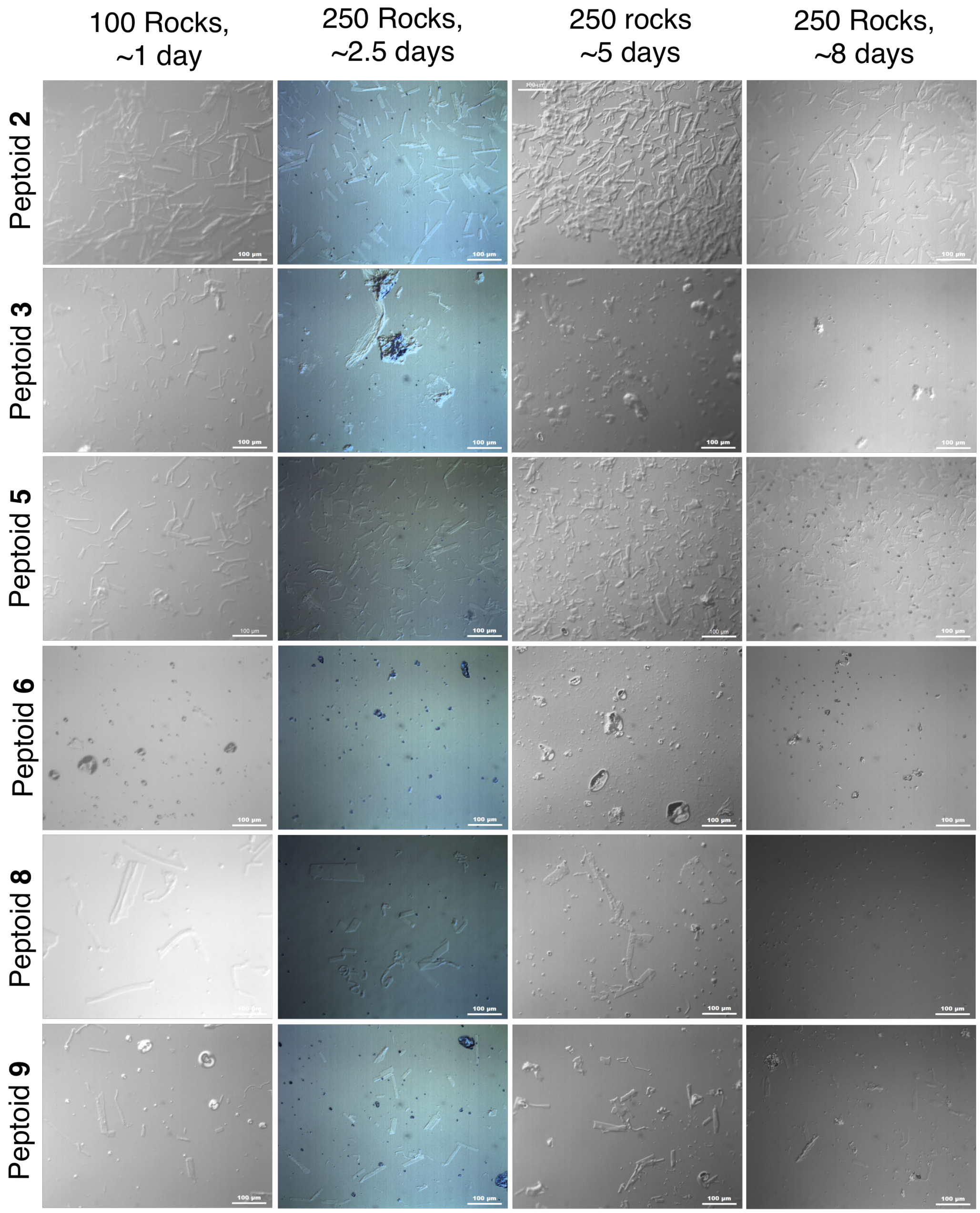


Figure S6. Optical microscopy images of unrocked solutions of peptoids **1-18** under the standard nanosheet forming conditions (20 μM peptoid in 10 mM Tris, pH 8) that had been left for ~2.5 days undisturbed. Images were taken in the differential interference contrast (DIC) mode.


100 Rocks, ~1 day
250 Rocks, ~2.5 days
250 rocks ~5 days
250 Rocks, ~8 days
Peptoid 2
Peptoid 3
Peptoid 5
Peptoid 6
Peptoid 8
Peptoid 9

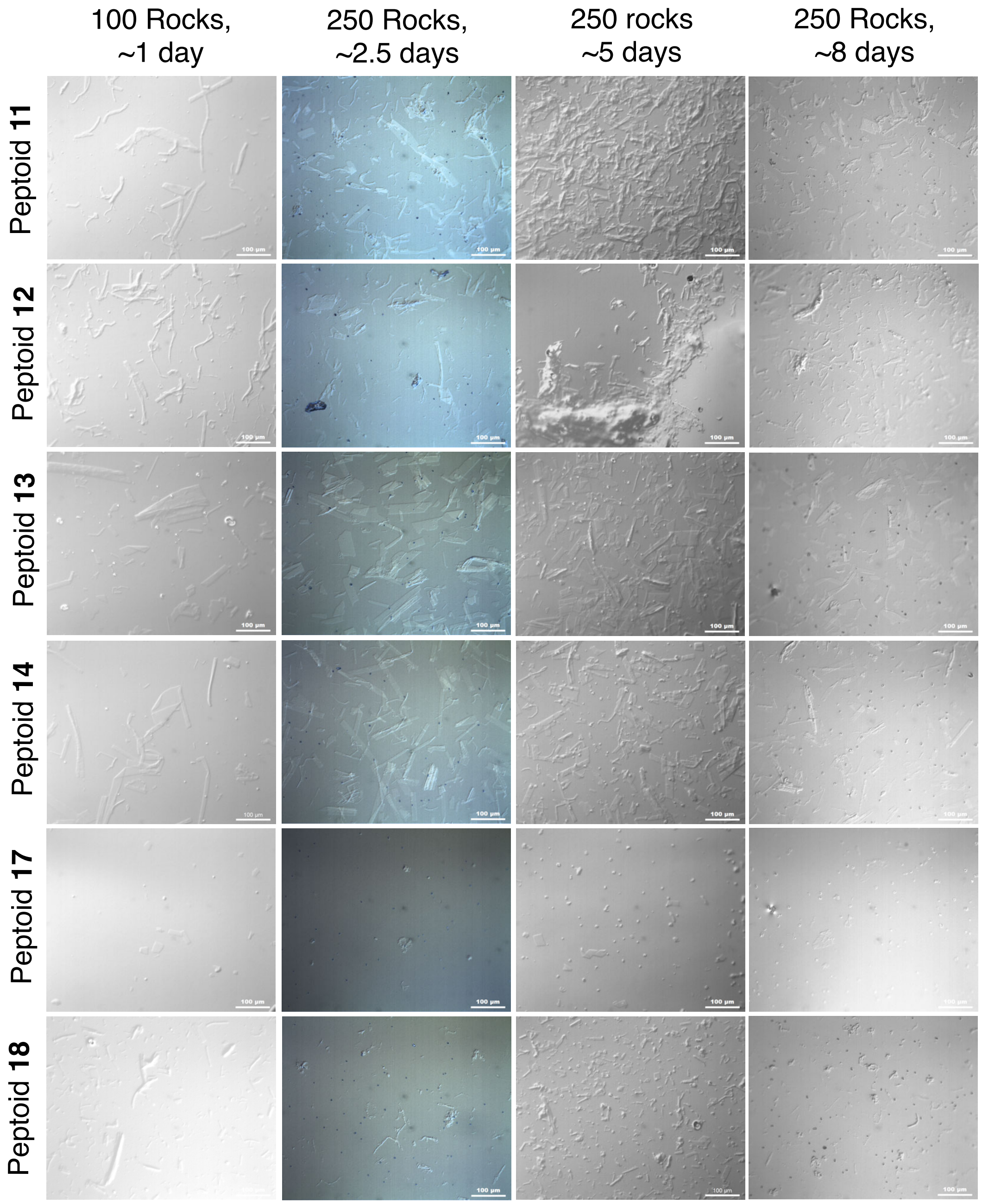


Figure S7. Stability studies of nanosheets composed of peptoids **2**, **3**, **5**, **6**, **8**, **9, 11-14, 17, and 18** as observed from optical microscopy images of nanosheets deposited on 1% agar gel. Peptoid solutions under the standard nanosheet forming conditions were rocked for 100 cycles and then imaged (~1 day after solutions started rocking). The solutions were returned to the sheet rocker for ~2.5 more days and then imaged after a total of 250 cycles. These same solutions were allowed to sit undisturbed and imaged after a total of 5 days and 8 days after the solutions were initially put on the sheet rocker.

Calculating degree of monomer packing from crystalized substituted aromatic *N,N'*-disubstituted diketopiperazines.

The degree of monomer packing was calculated from the crystal structures of substituted aromatic *N,N'*-disubstituted diketopiperazines (DKP) in which the aromatic rings are packed within a plane, as they would be in the nanosheet core. Figure S8 shows the planar packing of the aromatic rings within the crystal structure of all DKPs studied except for *cyclo*-[N4mpe-N4mpe] (Fig. S8d) and *cyclo*-[N24dmpe-N24dmpe] (Fig. S8h). For *cyclo*-[Npe-Npe] (Fig. S8a), *cyclo*-[N2mpe-N2mpe] (Fig. S8b), *cyclo*-[N3mpe-N3mpe] (Fig. S8c), *cyclo*-[Npe-Nclpe] (Fig. S8e), *cyclo*-[N25dmpe-N25dmpe] (Fig. S8f), and *cyclo*-[N34dmpe-N34dmpe] (Fig. S8g), the degree of monomer packing (as given by the area per DKP molecule) was calculated in Mercury by measuring the area occupied by five planar nitrogen atoms, as depicted by the green lines in Figure 6, and then dividing this area by 2. The area per *cyclo*-[N4mpe-N4mpe] DKP molecule was estimated by dividing the area occupied by five planar nitrogen atoms by 4, as the aromatic groups in this crystal structure are interdigitated. The crystal structure of *cyclo*-[N24dmpe-N24dmpe] did not allow for calculating the area per DKP molecule.

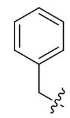
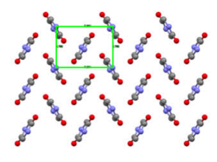
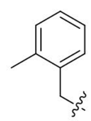
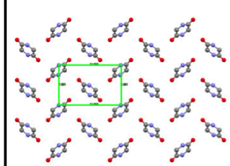
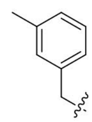
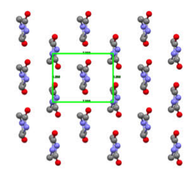
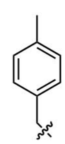
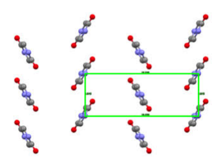
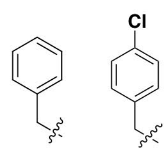
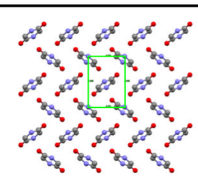
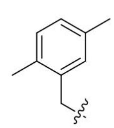
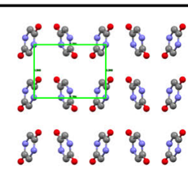
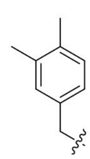
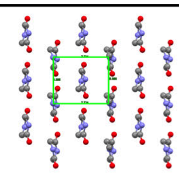
Submonomer(s)	Crystal Structure	Monomer Packing
		23.0 Å^2/ monomer
		41.5 Å^2/ monomer
		24.3 Å^2/ monomer
		24.0 Å^2/ monomer
		23.2 Å^2/ monomer
		27.8 Å^2/ monomer
		24.8 Å^2/ monomer

Figure S8. Lateral packing configurations for various substituted aromatic *N,N'*-disubstituted diketopiperazines obtained by analysis of the crystal structures. The aromatic packing regions here are oriented to show the plane in which all of the aromatic groups lay. For clarity, the sidechains have been removed.

Characterization of Peptoid Nanosheets with an Aliphatic Hydrophobic Core

Peptoid nanosheets composed of $(Nae\text{-}Nmbu)_7$-$(Mce\text{-}Nmbu)_7$ (peptoid **18**) were characterized using scanning electron microscopy (SEM, Fig. S9), atomic force microscopy (AFM, Fig. S10), and X-ray diffraction (XRD, Fig. S11). The SEM images were obtained using a Zeiss Gemini Supra 55 VP-SEM with an in-lens detector.[3] The AFM data were obtained using an Asylum MFP-3D AFM in tapping mode. The XRD data were collected at beamline 8.3.1 at the Advanced Light Source located at Lawrence Berkeley National Laboratory, as previously described.[4]

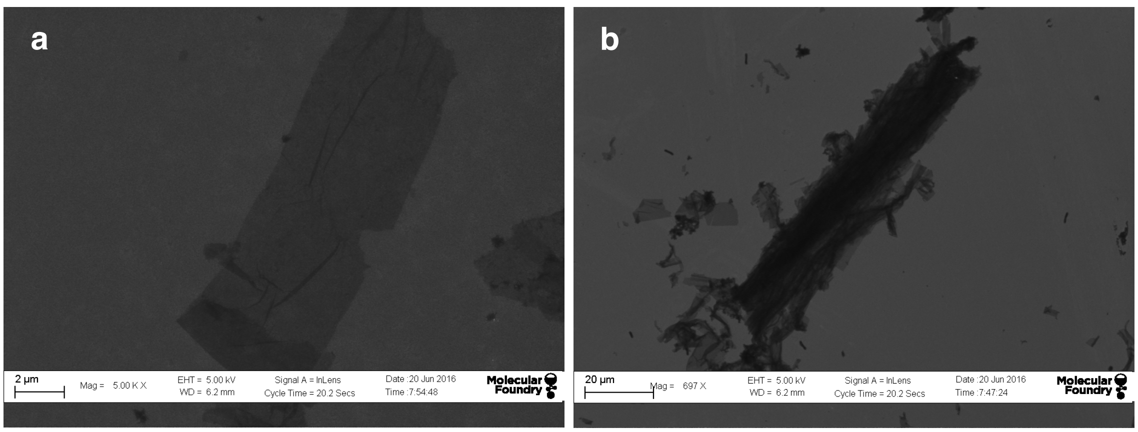


Figure S9. Scanning electron microscopy images of nanosheets composed of $(Nae\text{-}Nmbu)_7$-$(Nce\text{-}Nmbu)_7$ that had been deposited onto plasma etched silicon wafers. (a) SEM image revealing a morphology similar to nanosheets composed of $(Nae\text{-}Npe)_7$-$(Nae\text{-}Npe)_7$[3], which have an aryl rather than an aliphatic hydrophobic core. (b) SEM showing that the nanosheets composed of **18** have a tendency to stack and aggregate.

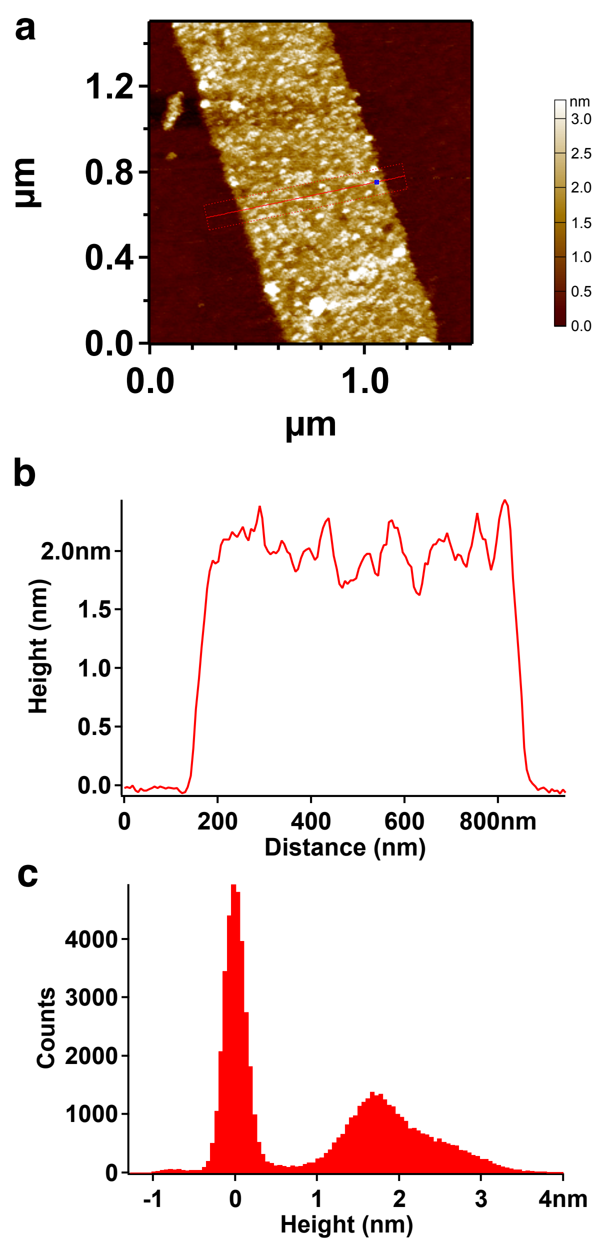


Figure S10. AFM data for peptoid nanosheets composed of peptoid **18** obtained by depositing the nanosheets from solution onto freshly cleaved mica, drying, and washing with Milli-Q water. (a) Height mode AFM image of a nanosheet obtained in ambient air. (b) Height profile of the nanosheet taken across the width of the nanosheet shown by the red line in (a). The height across this section of the nanosheet is on average 2.0 ± 1.7 nm. (c) Histrogram representing the distribution of heights within the nanosheet, in which the mica surface height distribution is centered at 0 nm. The peak of the nanosheet height distribution is centered at 1.7 nm, yet a broad distribution of heights are observed between 2 and 3 nm.

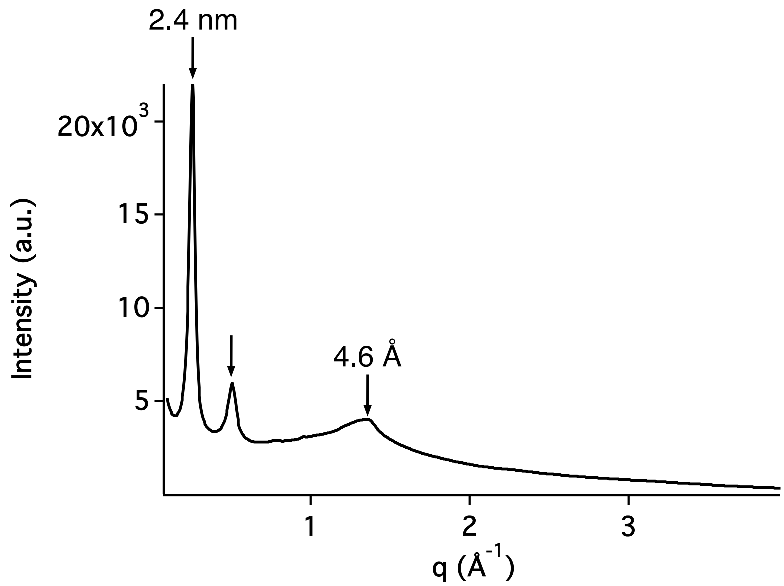


Figure S11. Powder XRD spectrum of nanosheets composed of peptoid **18** showing a nanosheet thickness of 2.4 nm and an interchain spacing of 4.6 Å.

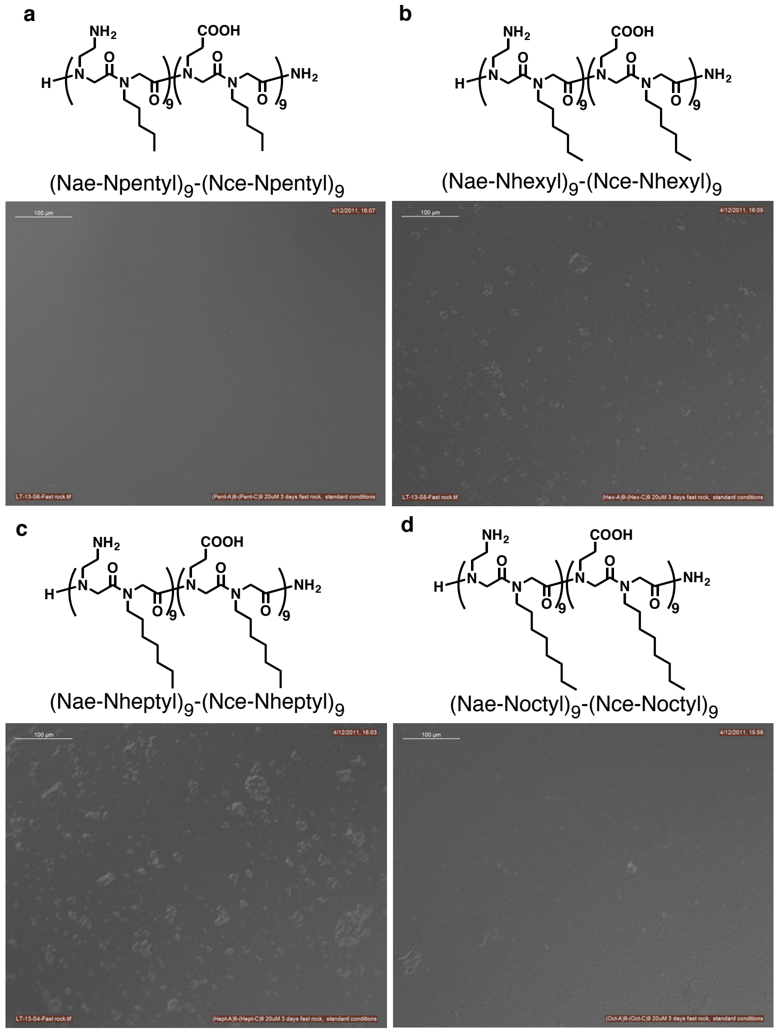
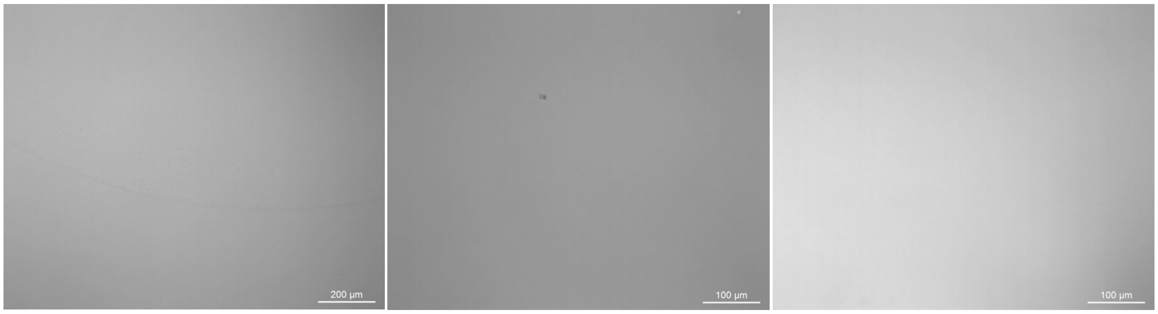


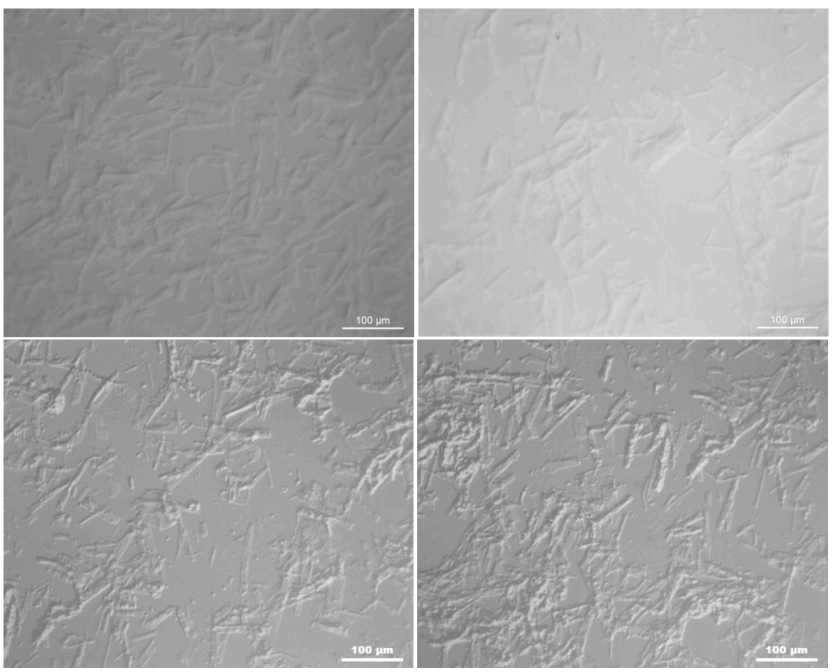
Figure S12. Optical microscopy images of peptoids rocked under the standard nanosheet forming conditions that had been synthesized with (a) N-pentyl monomers, (b) N-hexyl monomers, (c) N-heptyl monomers, and (d) N-octyl monomers. No nanosheets are observed in these images.

Nanosheet Image Gallery

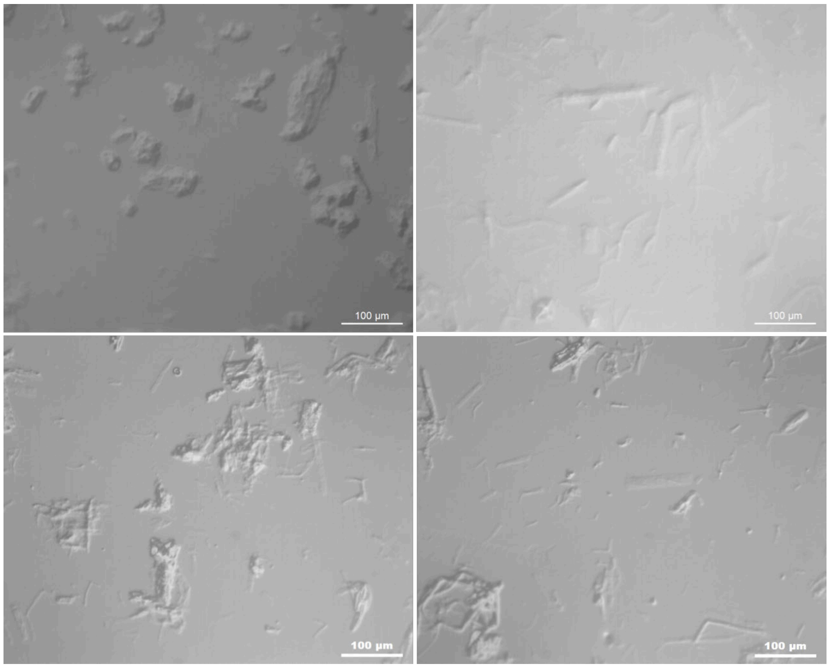
Below are shown images of nanosheet deposited on 1% agar gel from peptoid solutions (**1-18**) under the standard nanosheet forming conditions.



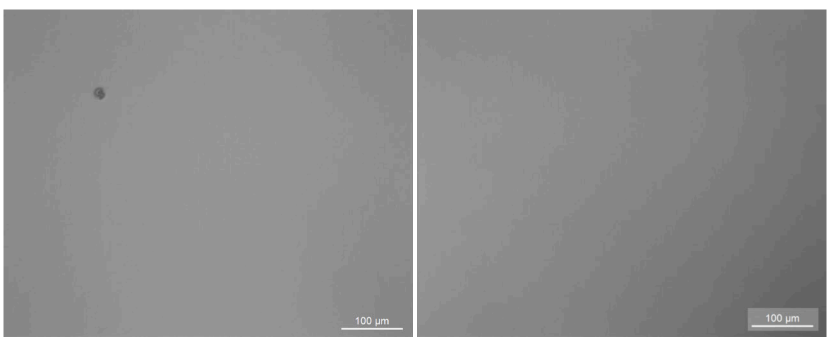
Peptoid 1



Peptoid 2



Peptoid 3



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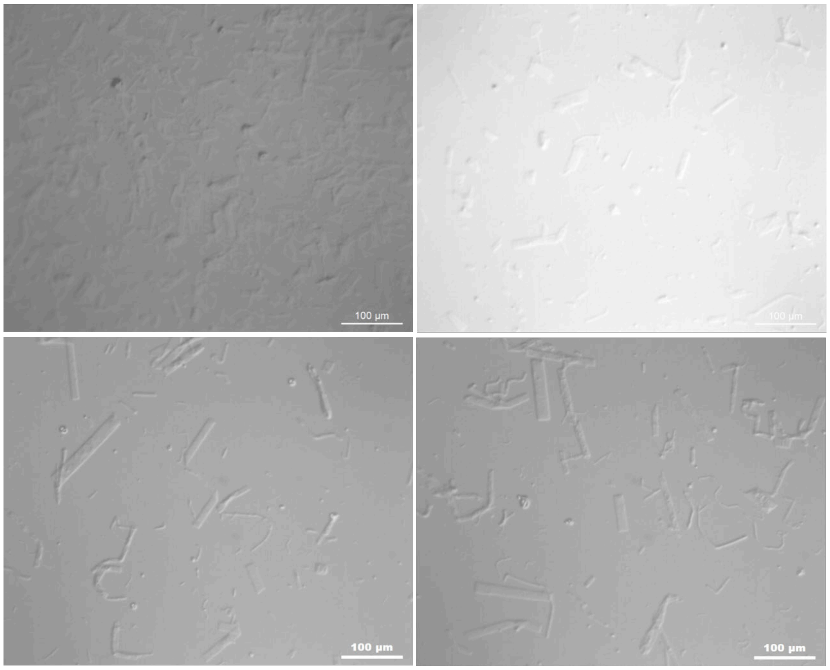

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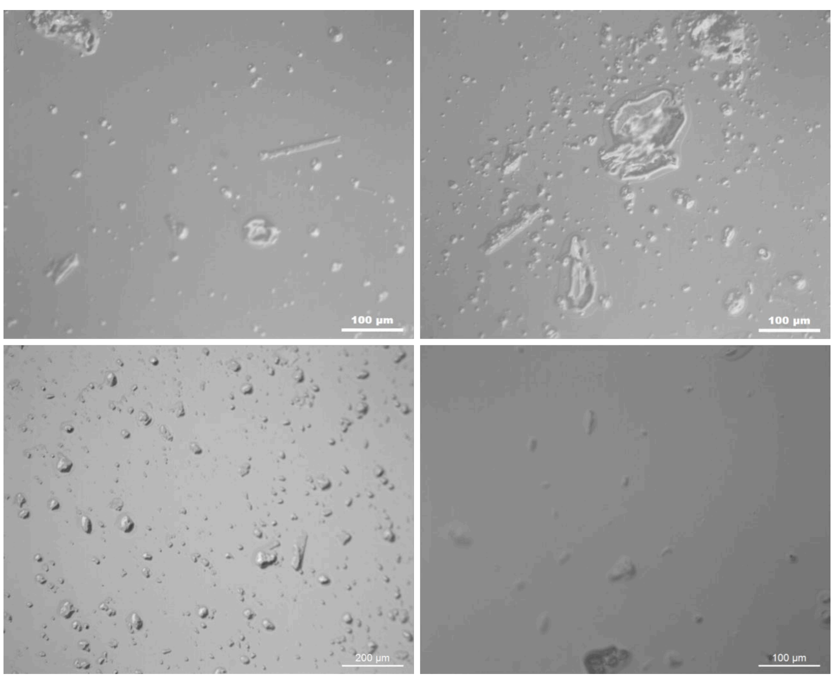

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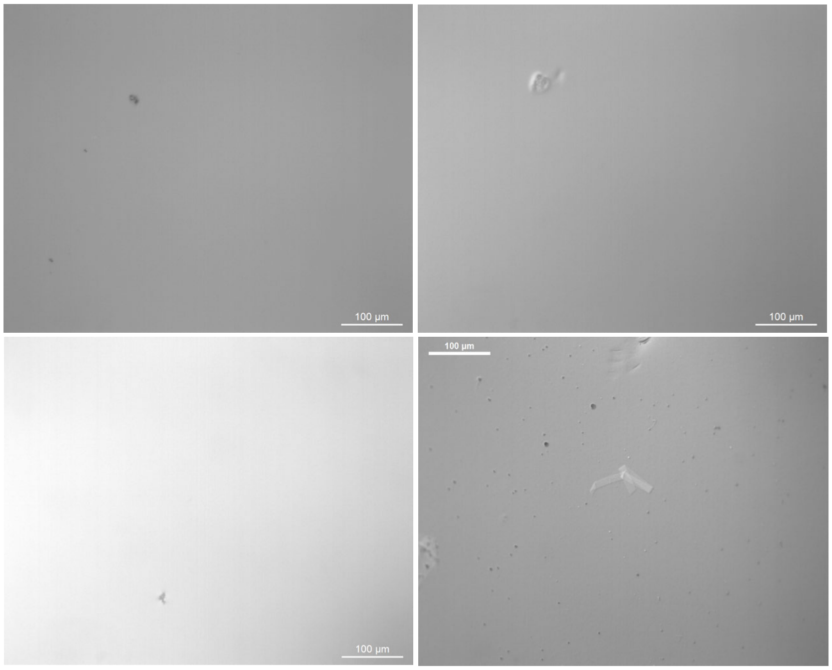

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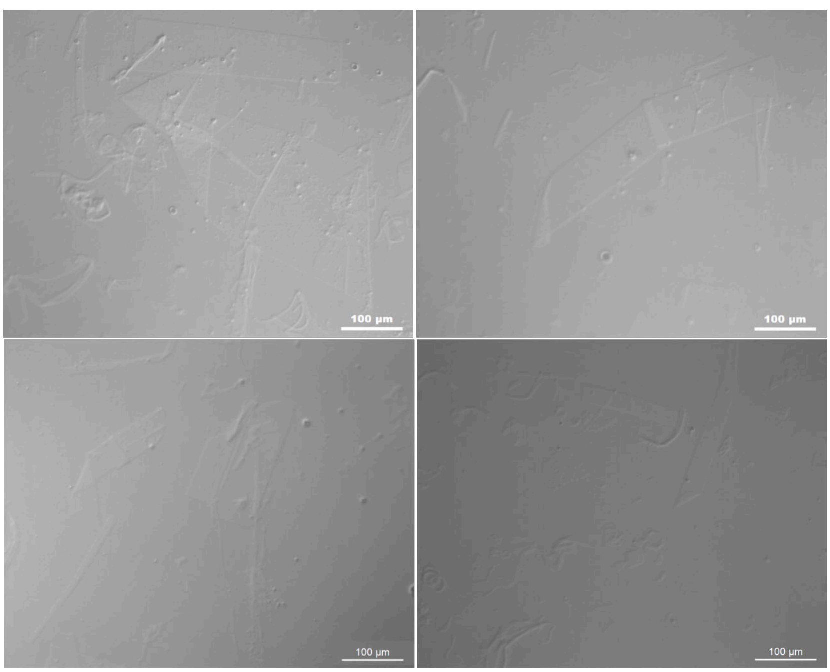

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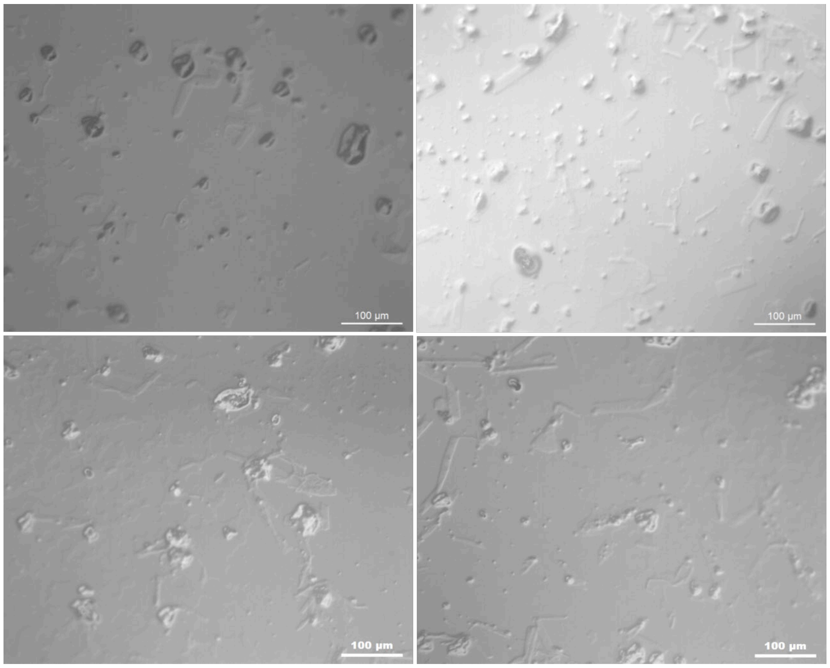

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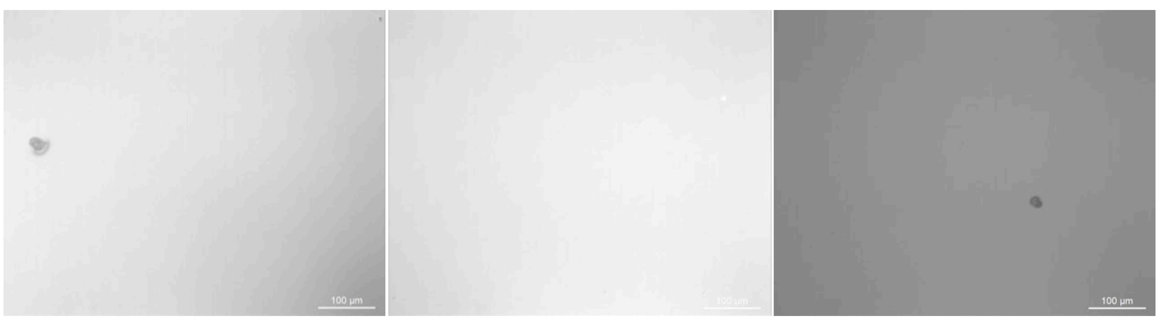

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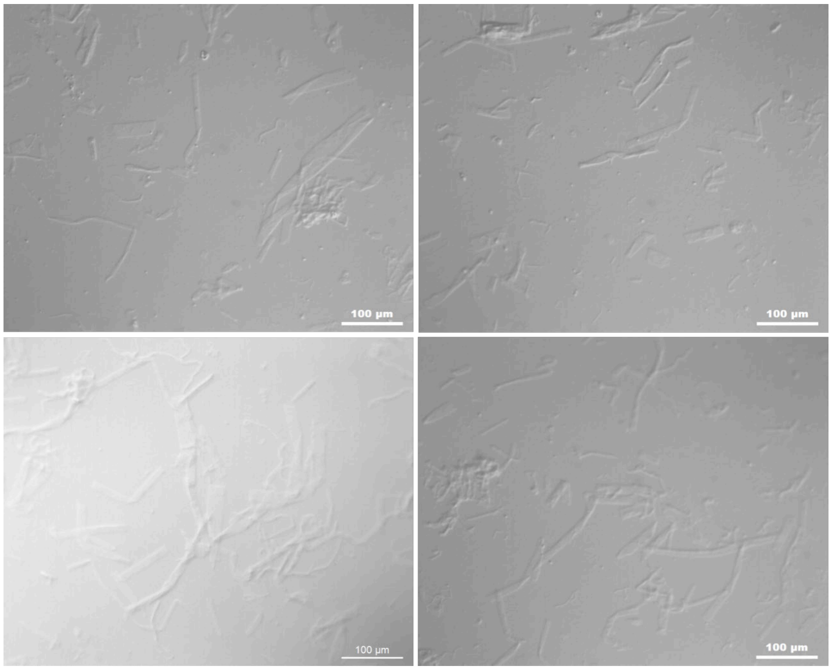

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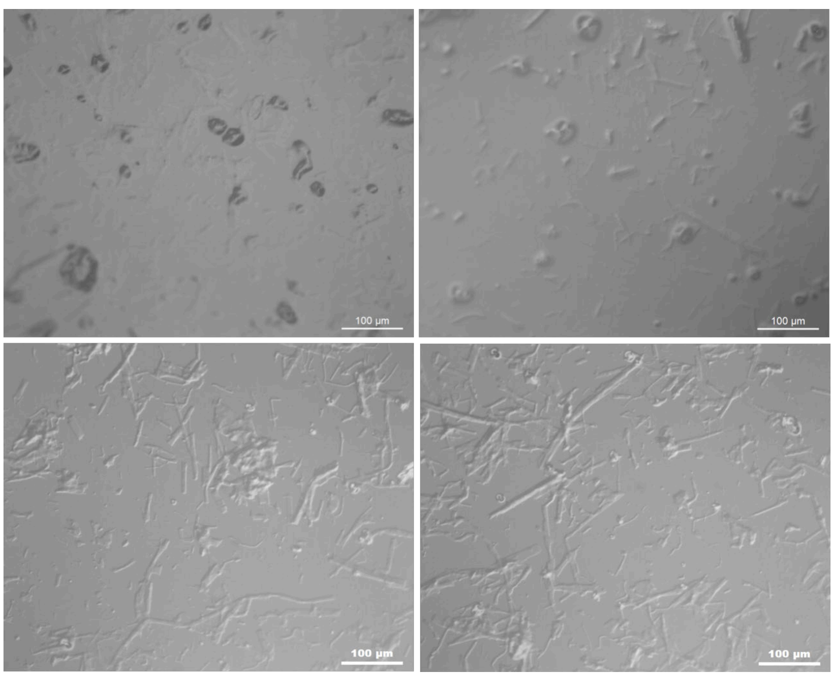

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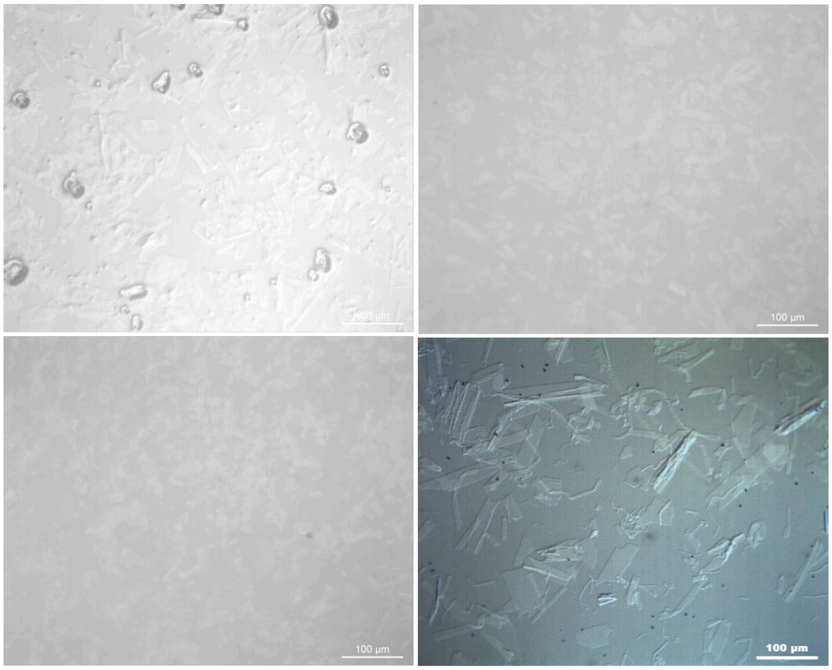

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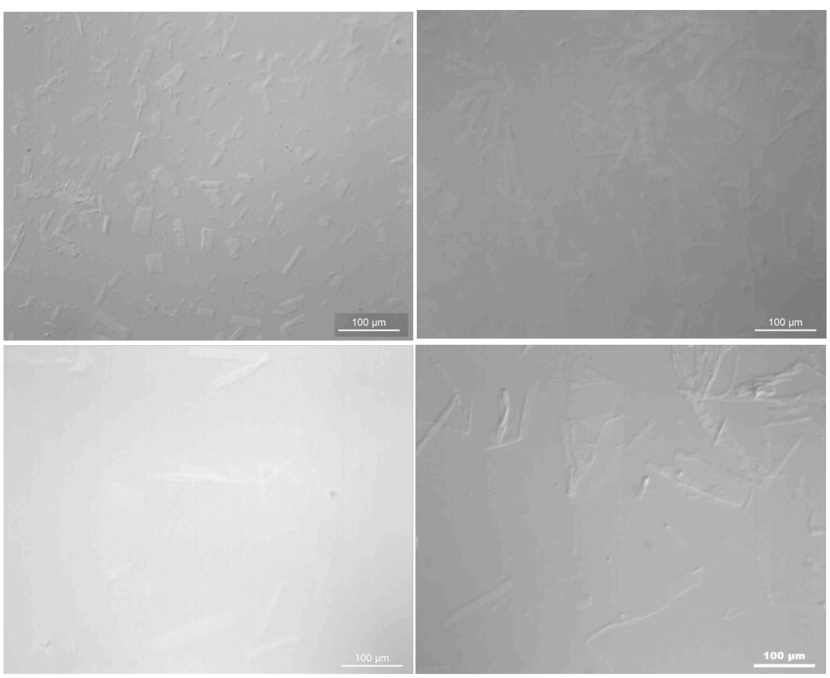

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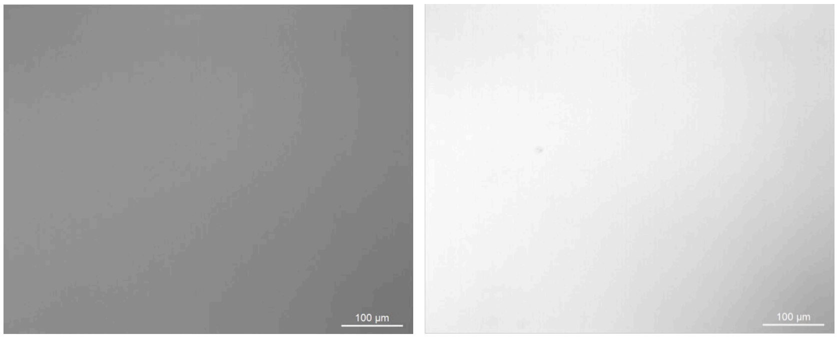

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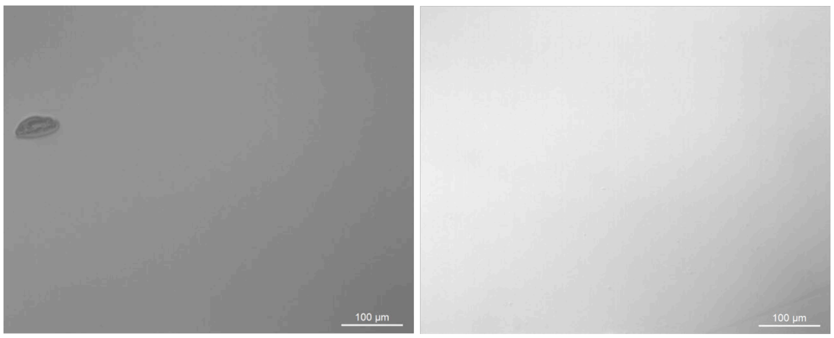

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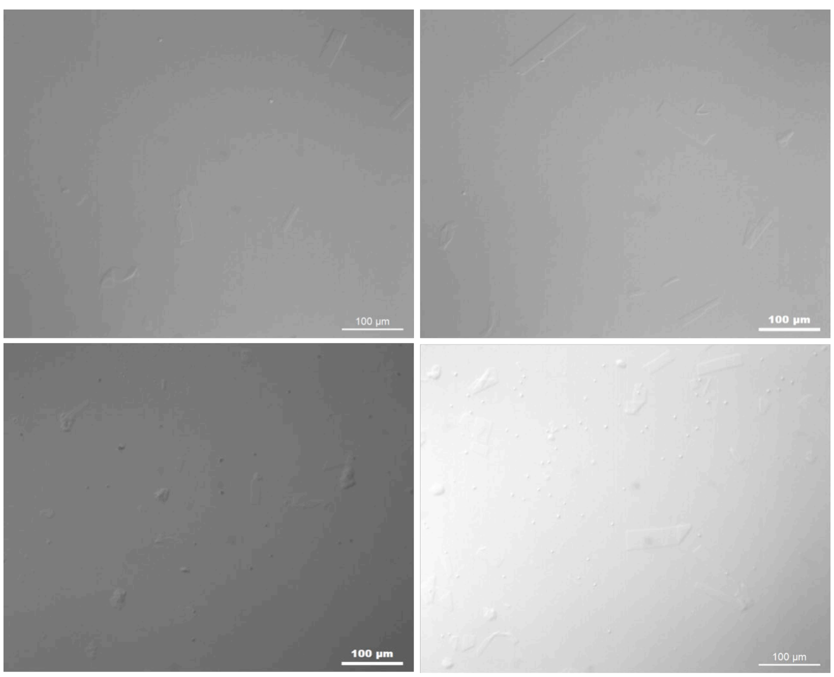

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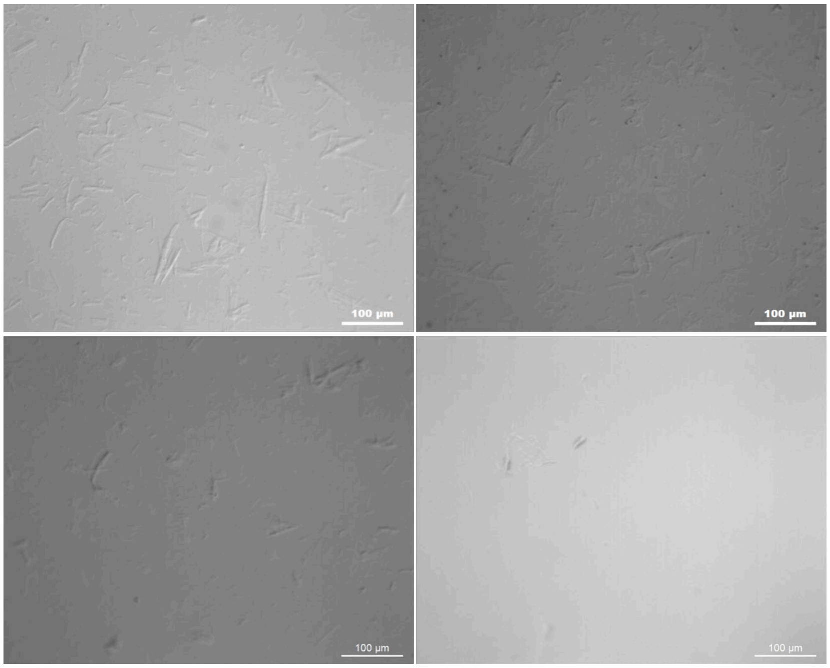

Peptoid 18

References

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