Electronic Supplementary Information† (ESI†)

Development and investigation of multi-layered homo- and hetero-type DNA thin films†

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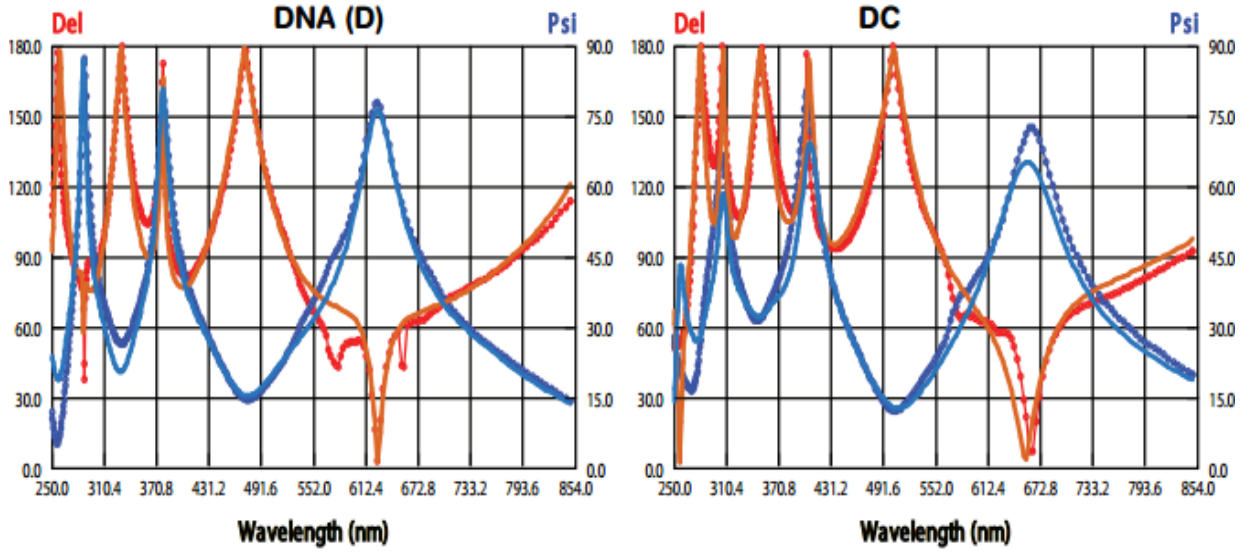
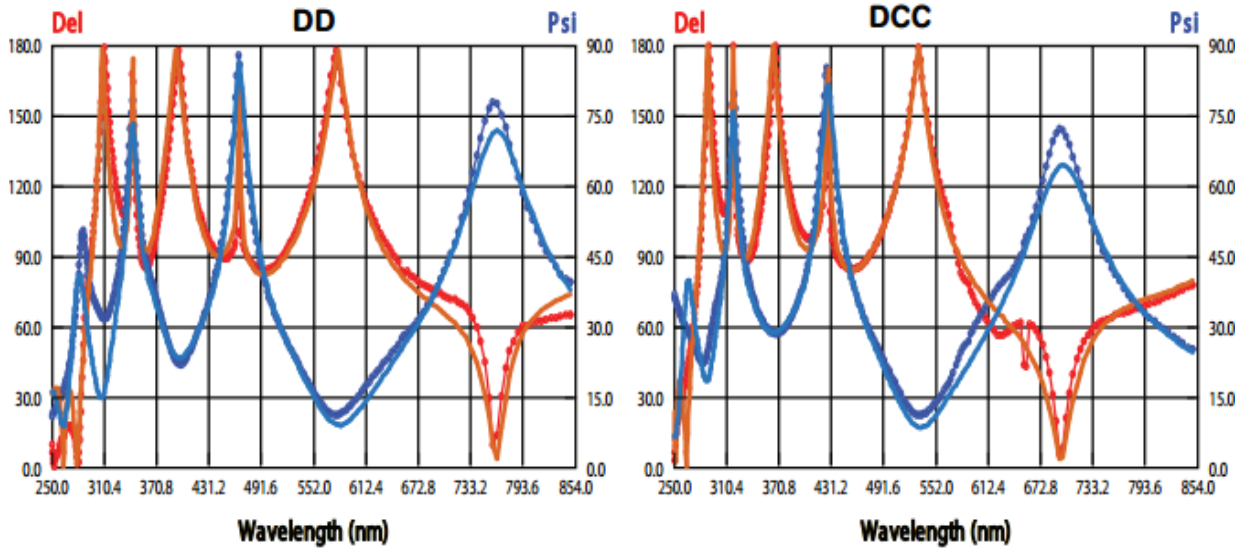

DNA (D)
Del
Psi
180.0
150.0
120.0
90.0
60.0
30.0
0.0
90.0
75.0
60.0
45.0
30.0
15.0
0.0
250.0 310.4 370.8 431.2 491.6 552.0 612.4 672.8 733.2 793.6 854.0
Wavelength (nm)

DC
Del
Psi
180.0
150.0
120.0
90.0
60.0
30.0
0.0
90.0
75.0
60.0
45.0
30.0
15.0
0.0
250.0 310.4 370.8 431.2 491.6 552.0 612.4 672.8 733.2 793.6 854.0
Wavelength (nm)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Del
Psi
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90.0
60.0
30.0
0.0
90.0
75.0
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45.0
30.0
15.0
0.0
250.0 310.4 370.8 431.2 491.6 552.0 612.4 672.8 733.2 793.6 854.0
Wavelength (nm)

DCC
Del
Psi
180.0
150.0
120.0
90.0
60.0
30.0
0.0
90.0
75.0
60.0
45.0
30.0
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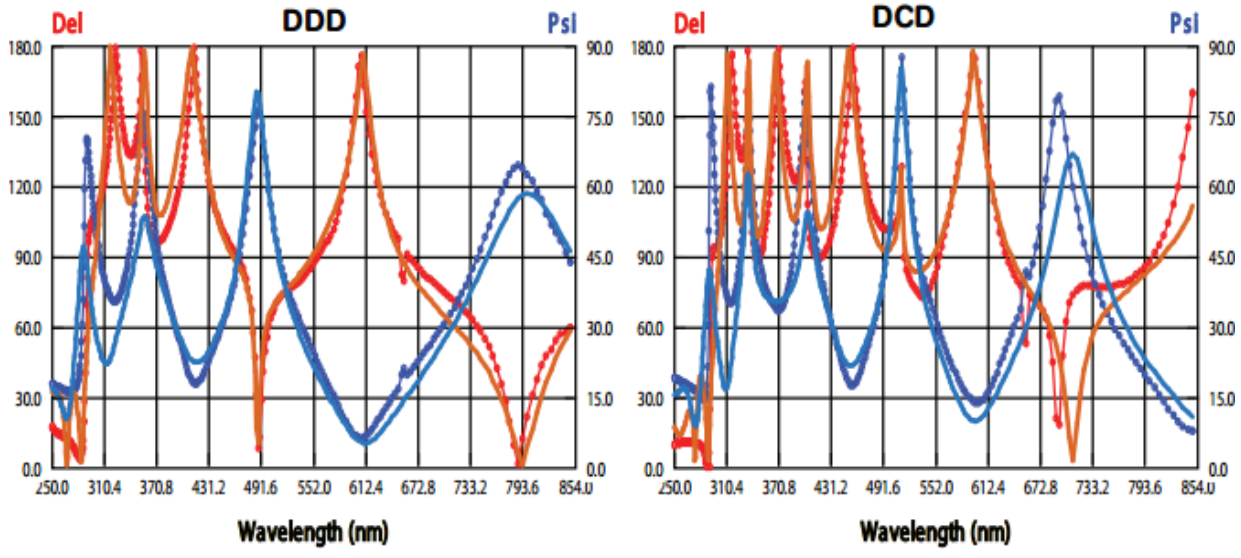
Wavelength (nm)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Del
Psi
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60.0
30.0
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75.0
60.0
45.0
30.0
15.0
0.0
250.0 310.4 370.8 431.2 491.6 552.0 612.4 672.8 733.2 793.6 854.0
Wavelength (nm)

DCD
Del
Psi
180.0
150.0
120.0
90.0
60.0
30.0
0.0
90.0
75.0
60.0
45.0
30.0
15.0
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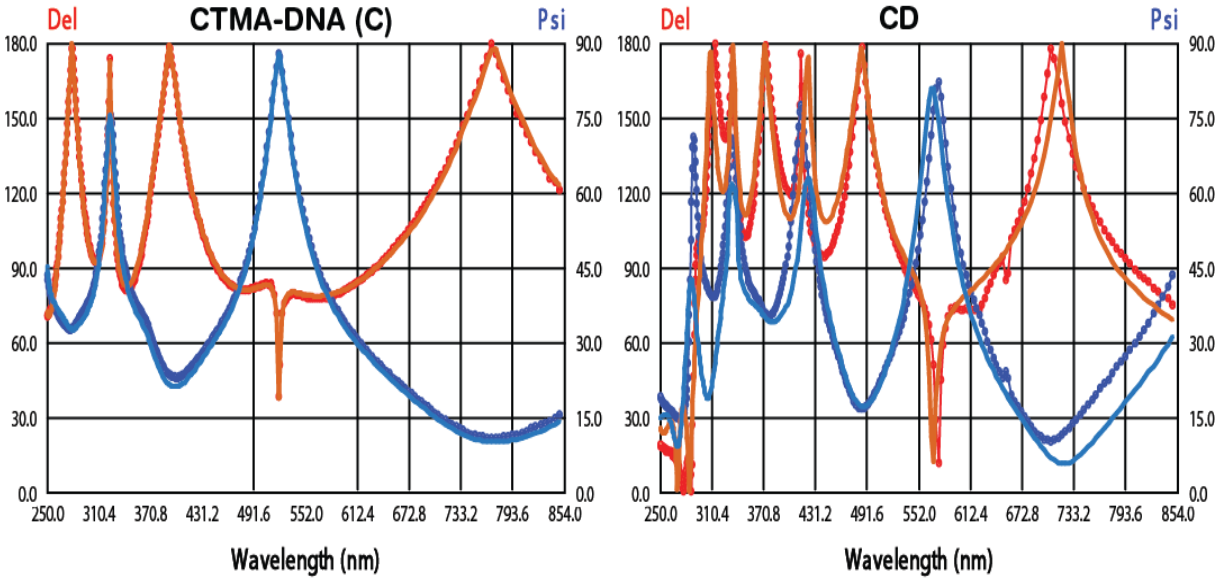
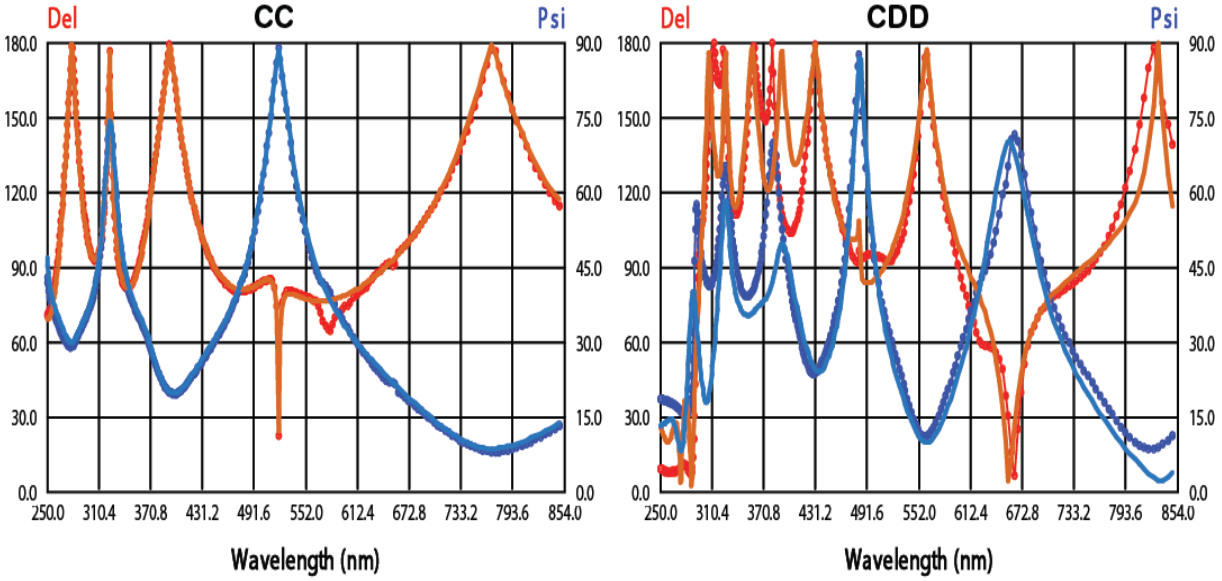
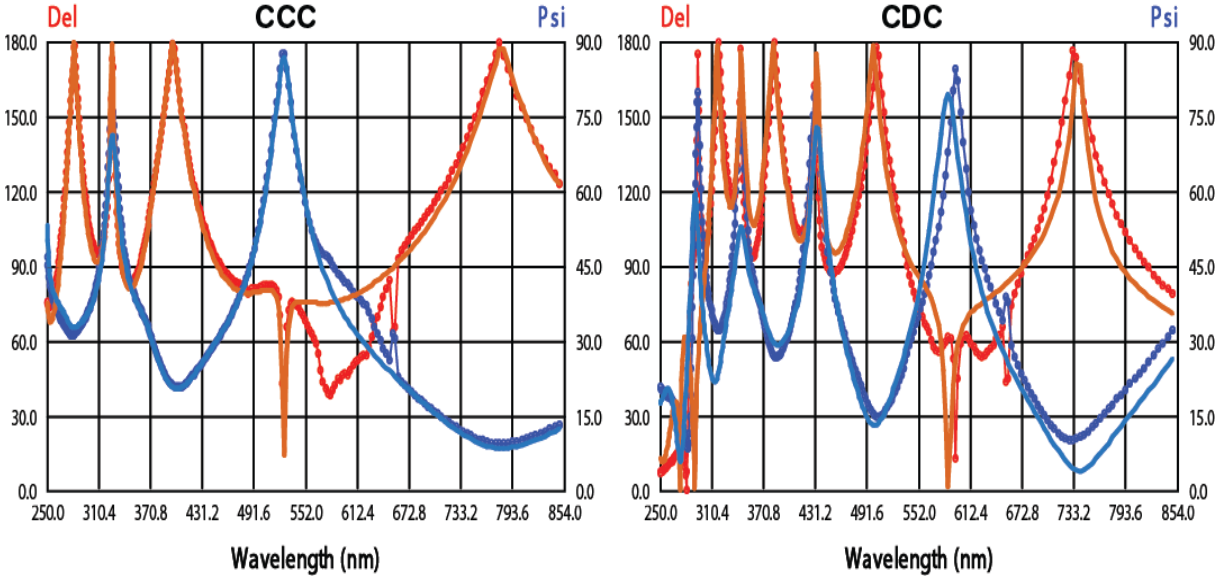
250.0 310.4 370.8 431.2 491.6 552.0 612.4 672.8 733.2 793.6 854.0
Wavelength (nm)


Del
CTMA-DNA (C)
Psi
180.0
150.0
120.0
90.0
60.0
30.0
0.0
90.0
75.0
60.0
45.0
30.0
15.0
0.0
250.0 310.4 370.8 431.2 491.6 552.0 612.4 672.8 733.2 793.6 854.0
Wavelength (nm)

Del
CD
Psi
180.0
150.0
120.0
90.0
60.0
30.0
0.0
90.0
75.0
60.0
45.0
30.0
15.0
0.0
250.0 310.4 370.8 431.2 491.6 552.0 612.4 672.8 733.2 793.6 854.0
Wavelength (nm)

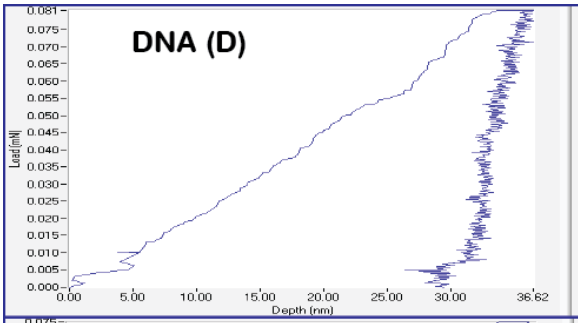

Del
CC
Psi
180.0
150.0
120.0
90.0
60.0
30.0
0.0
90.0
75.0
60.0
45.0
30.0
15.0
0.0
250.0 310.4 370.8 431.2 491.6 552.0 612.4 672.8 733.2 793.6 854.0
Wavelength (nm)

Del
CDD
Psi
180.0
150.0
120.0
90.0
60.0
30.0
0.0
90.0
75.0
60.0
45.0
30.0
15.0
0.0
250.0 310.4 370.8 431.2 491.6 552.0 612.4 672.8 733.2 793.6 854.0
Wavelength (nm)


Del
CCC
Psi
180.0
150.0
120.0
90.0
60.0
30.0
0.0
90.0
75.0
60.0
45.0
30.0
15.0
0.0
250.0 310.4 370.8 431.2 491.6 552.0 612.4 672.8 733.2 793.6 854.0
Wavelength (nm)

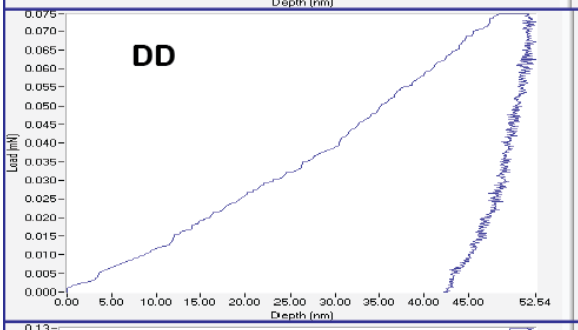
Del
CDC
Psi
180.0
150.0
120.0
90.0
60.0
30.0
0.0
90.0
75.0
60.0
45.0
30.0
15.0
0.0
250.0 310.4 370.8 431.2 491.6 552.0 612.4 672.8 733.2 793.6 854.0
Wavelength (nm)

Fig. S1. Representative data of optical constants (indicated by dotted lines) of single-, double-, and triple-layered DNA thin films (D) and CTMA-modified DNA thin films (C) obtained from a spectroscopic ellipsometry and corresponding curve fittings (marked with solid lines) by Cauchy dispersion relation. The ellipsometry raw data curves obtained as Del (Δ indicated as red) and Psi (ψ as blue) are fitted by Cauchy dispersion relations of $n(\lambda) = A + B/\lambda^2 + C/\lambda^4$ and $k(\lambda) = D + E/\lambda^2 + F/\lambda^4$, respectively. Here, n, k are wavelength (λ)-dependent refractive index (orange-coloured solid line), and extinction coefficient (navy-blue solid line), and A, B, C, D, E and F are curve fitting constants obtained after fitting. While the curve fitting, the mean square errors are relatively lesser for thinner films than thicker films due to the absorption amount of UV light.



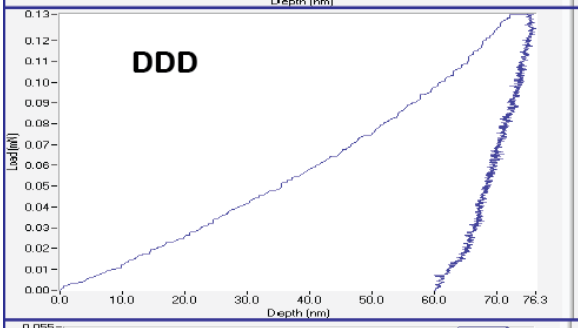
Analysis Results

Maximum Depth (nm)	36.62
Maximum Load (mN)	0.081
Contact Depth (nm)	31.40
Hardness (GPa)	3.33789
Reduced Modulus (GPa)	63.96933
Elastic Recovery Parameter	0.1660
Contact Compliance (nm/mN)	66.20
Plastic Work (nJ)	0.0000000
Elastic Work (nJ)	0.0000000
Fitting mean square error	0.0001



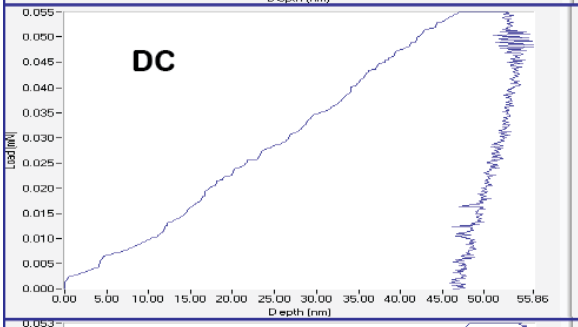
Analysis Results

Maximum Depth (nm)	52.54
Maximum Load (mN)	0.075
Contact Depth (nm)	48.33
Hardness (GPa)	1.30363
Reduced Modulus (GPa)	47.62655
Elastic Recovery Parameter	0.0871
Contact Compliance (nm/mN)	75.23
Plastic Work (nJ)	0.0000000
Elastic Work (nJ)	0.0000000
Fitting mean square error	0.0000



Analysis Results

Maximum Depth (nm)	76.25
Maximum Load (mN)	0.133
Contact Depth (nm)	67.90
Hardness (GPa)	1.17563
Reduced Modulus (GPa)	30.42163
Elastic Recovery Parameter	0.1230
Contact Compliance (nm/mN)	83.83
Plastic Work (nJ)	0.0000000
Elastic Work (nJ)	0.0000000
Fitting mean square error	0.0000



Analysis Results

Maximum Depth (nm)	55.86
Maximum Load (mN)	0.055
Contact Depth (nm)	48.86
Hardness (GPa)	0.93851
Reduced Modulus (GPa)	20.84723
Elastic Recovery Parameter	0.1432
Contact Compliance (nm/mN)	169.98
Plastic Work (nJ)	0.0000000
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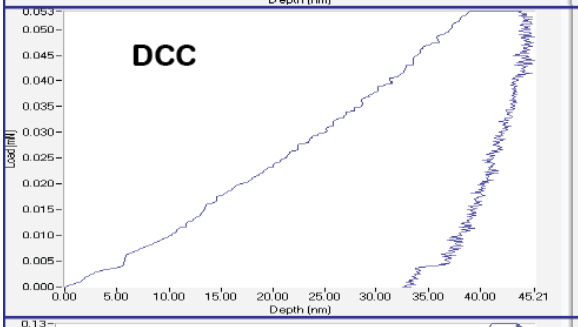
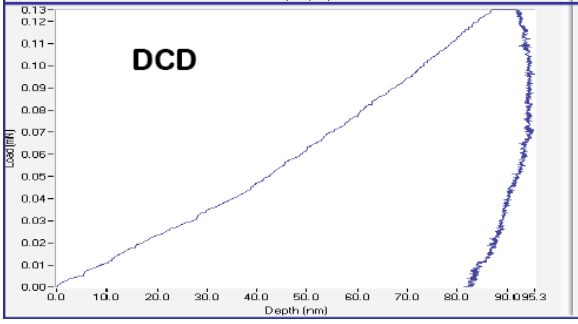
Fitting mean square error	0.0000



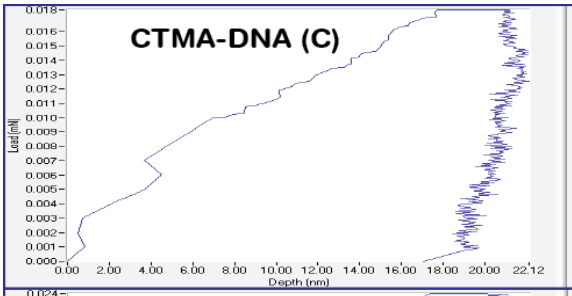
Analysis Results

Maximum Depth (nm)	45.21
Maximum Load (mN)	0.053
Contact Depth (nm)	40.35
Hardness (GPa)	1.34067
Reduced Modulus (GPa)	36.60330
Elastic Recovery Parameter	0.1205
Contact Compliance (nm/mN)	121.23
Plastic Work (nJ)	0.0000000
Elastic Work (nJ)	0.0000000
Fitting mean square error	0.0000



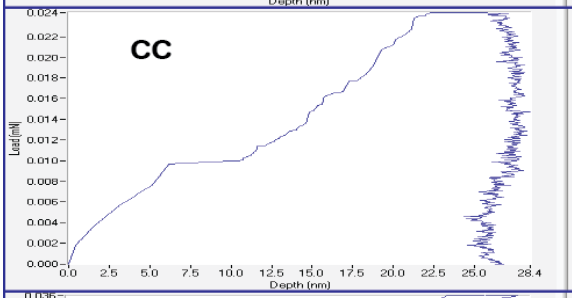
Analysis Results

Maximum Depth (nm)	95.32
Maximum Load (mN)	0.125
Contact Depth (nm)	84.01
Hardness (GPa)	0.72370
Reduced Modulus (GPa)	17.10776
Elastic Recovery Parameter	0.1346
Contact Compliance (nm/mN)	120.48
Plastic Work (nJ)	0.0000000
Elastic Work (nJ)	0.0000000
Fitting mean square error	0.0004



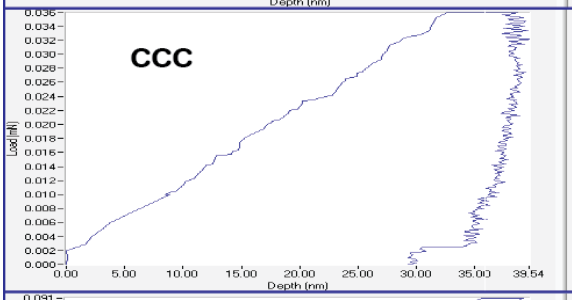
Analysis Results

Maximum Depth (nm)	22.12
Maximum Load (mN)	0.018
Contact Depth (nm)	18.67
Hardness (GPa)	2.05167
Reduced Modulus (GPa)	35.32527
Elastic Recovery Parameter	0.1848
Contact Compliance (nm/mN)	262.60
Plastic Work (nJ)	0.0000000
Elastic Work (nJ)	0.0000000
Fitting mean square error	0.0000



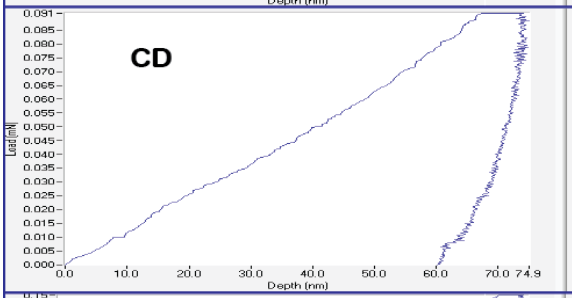
Analysis Results

Maximum Depth (nm)	28.43
Maximum Load (mN)	0.024
Contact Depth (nm)	19.51
Hardness (GPa)	2.60956
Reduced Modulus (GPa)	18.15811
Elastic Recovery Parameter	0.4573
Contact Compliance (nm/mN)	466.60
Plastic Work (nJ)	0.0000000
Elastic Work (nJ)	0.0000000
Fitting mean square error	0.0000



Analysis Results

Maximum Depth (nm)	39.54
Maximum Load (mN)	0.036
Contact Depth (nm)	35.98
Hardness (GPa)	1.13329
Reduced Modulus (GPa)	36.45553
Elastic Recovery Parameter	0.0989
Contact Compliance (nm/mN)	132.02
Plastic Work (nJ)	0.0000000
Elastic Work (nJ)	0.0000000
Fitting mean square error	0.0000



Analysis Results

Maximum Depth (nm)	74.86
Maximum Load (mN)	0.091
Contact Depth (nm)	69.32
Hardness (GPa)	0.77331
Reduced Modulus (GPa)	30.79761
Elastic Recovery Parameter	0.0799
Contact Compliance (nm/mN)	61.10
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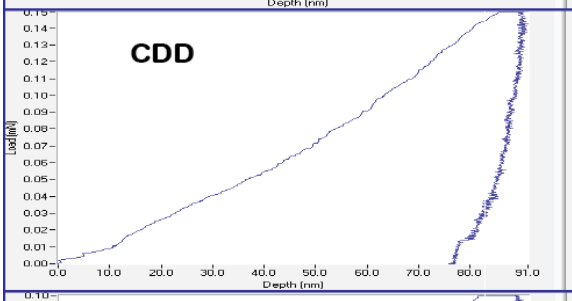
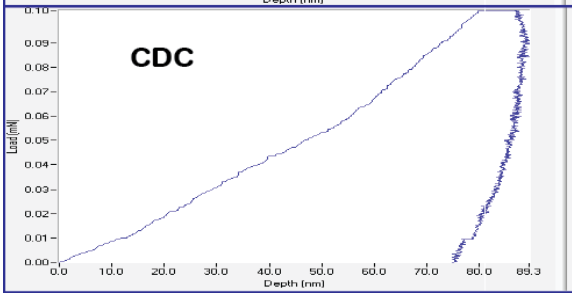
Elastic Work (nJ)	0.0000000
Fitting mean square error	0.0000



Analysis Results

Maximum Depth (nm)	90.96
Maximum Load (mN)	0.149
Contact Depth (nm)	86.33
Hardness (GPa)	0.81754
Reduced Modulus (GPa)	48.34062
Elastic Recovery Parameter	0.0538
Contact Compliance (nm/mN)	41.49
Plastic Work (nJ)	0.0000000
Elastic Work (nJ)	0.0000000
Fitting mean square error	0.0001



Analysis Results

Maximum Depth (nm)	89.26
Maximum Load (mN)	0.103
Contact Depth (nm)	84.45
Hardness (GPa)	0.59112
Reduced Modulus (GPa)	32.98049
Elastic Recovery Parameter	0.0570
Contact Compliance (nm/mN)	62.17
Plastic Work (nJ)	0.0000000
Elastic Work (nJ)	0.0000000
Fitting mean square error	0.0001

Fig. S2. Representative loading and unloading force curves as a function of thin film's depth (left) and corresponding analysis results of hardness, modulus, and elasticity (right) of single-, double-, and triple-layered DNA thin films (D) and CTMA-modified DNA thin films (C).

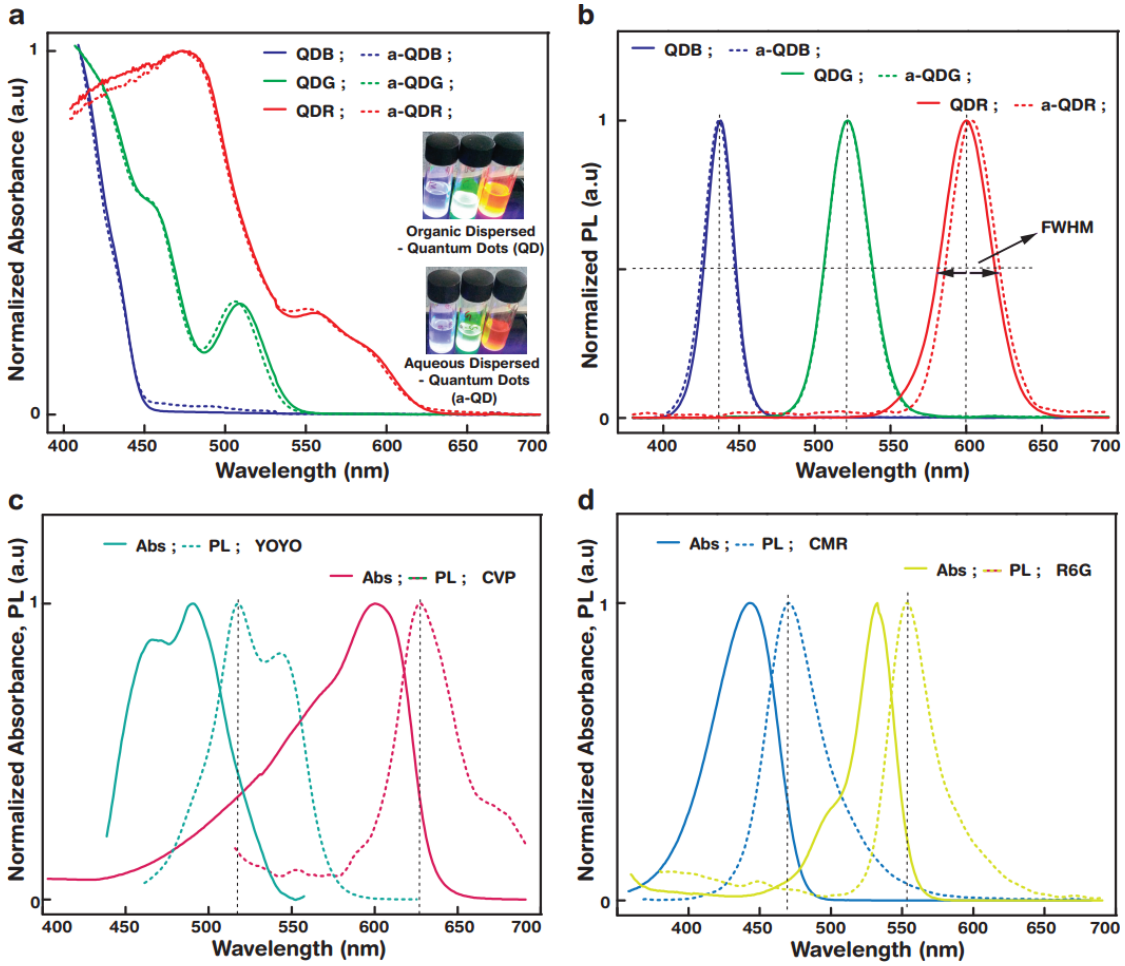


Fig. S3. Normalized absorbance and photoluminescence (PL) spectra of aqueous dispersed YOYO, a-QDB, a-QDG, a-QDR and organic dispersed CMR, R6G, CVP and QDB, QDG, QDR luminophore solutions. The PL emission spectra are measured at a fixed excitation wavelength of 365 nm and the characteristics PL emission peaks are indicated by the vertical dotted lines. (**a**) Normalized absorbance spectra of organic dispersed QDB, QDG, QDR (indicated by solid line) and aqueous dispersed a-QDB, a-QDG, a-QDR (dashed line) solutions. The peak shows the characteristics of QDs which is capable to continuously absorb the energy of shorter wavelength (*i.e.* presence of higher order excitation level). The inset shows the photographic images of PL emission while exciting the samples by an UV lamp with wavelength of 365 nm. (**b**) Normalized PL spectra of organic dispersed QDB, QDG, QDR (indicated by solid line) and aqueous dispersed a-QDB, a-QDG, a-QDR (dashed line) solutions. The PL peak represents the salient feature of QD's sharp and narrow full width at half maximum (FWHM) emission characteristics for first order and higher order excitations. The FWHM are 22, 32, 38, and 36 nm for QDB, QDG, QDR, and a-QDR, respectively at the fixed excitation of 365 nm. (**c**, **d**) Normalized absorbance (solid lines) and PL spectra (dotted lines) of aqueous dispersed YOYO, and organic dispersed CMR, R6G, CVP luminophores and the FWHM are 94, 45, 35, 41 nm, respectively at the fixed excitation of 365 nm.