Journal Name

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Cite this: DOI: 10.1039/c0xx00000x

www.rsc.org/xxxxxx

ARTICLE TYPE

Electronic Supplementary Information

Growth of Gold Nanowires on Flexible Substrate for Highly Sensitive Biosensing: Detection of Thrombin as an Example

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Received (in XXX, XXX) Xth XXXXXXXXX 20XX, Accepted Xth XXXXXXXXX 20XX
DOI: 10.1039/b000000x

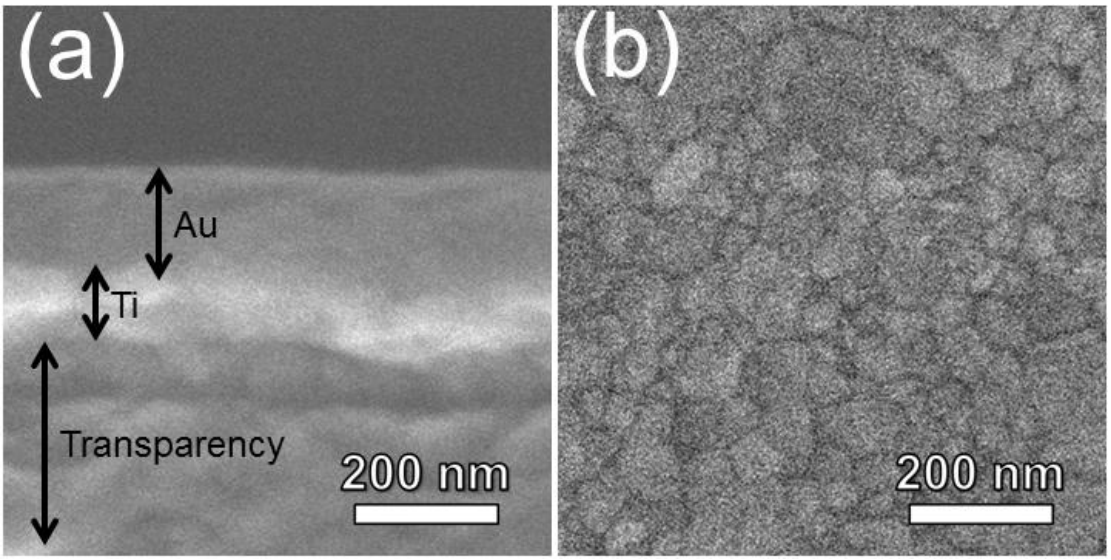

Figure S1. SEM images of a flexible Au/Ti/PET substrate. (a) Cross-sectional and (b) top views.

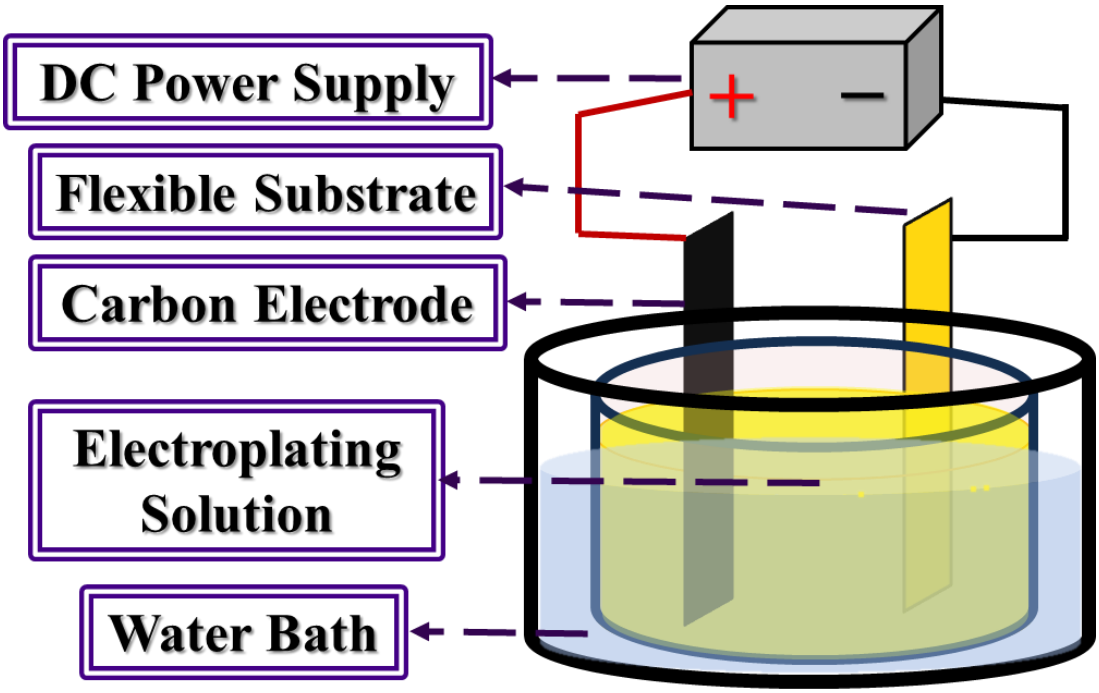

Figure S2. Two-electrode electrochemical deposition system.

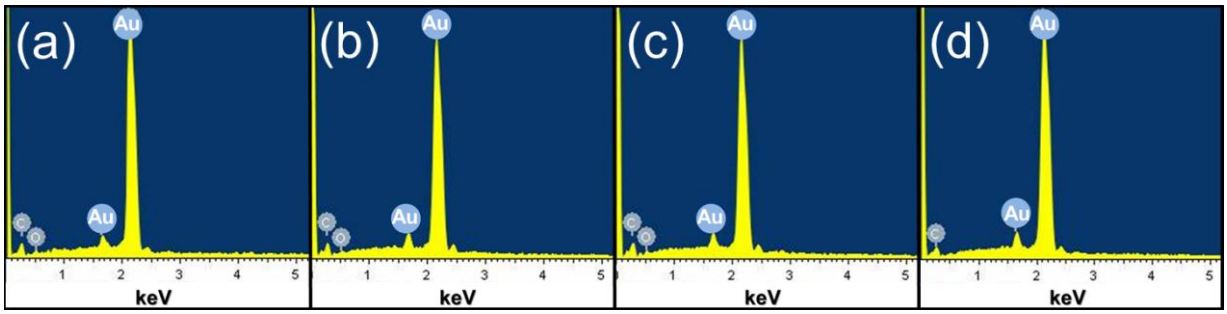

Figure S3. EDS of Au nanostructures on flexible substrates. (a) NTs, (b) NCs, (c) NSs, and (d) NWs.

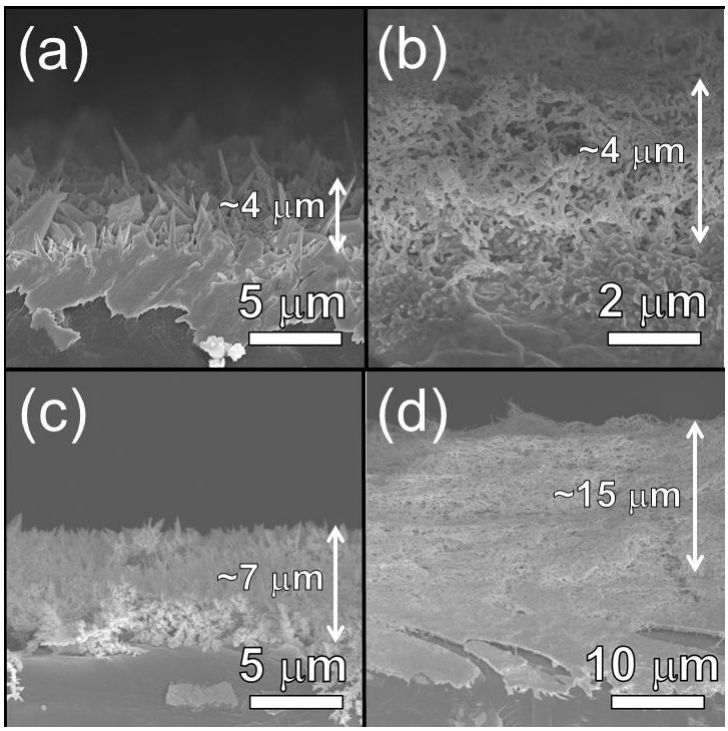

Figure S4. Side-view SEM images of Au nanostructures on flexible PET substrates. (a) NTs, (b) NCs, (c) NSs, and (d) NWs. Layer thicknesses are marked and estimated.

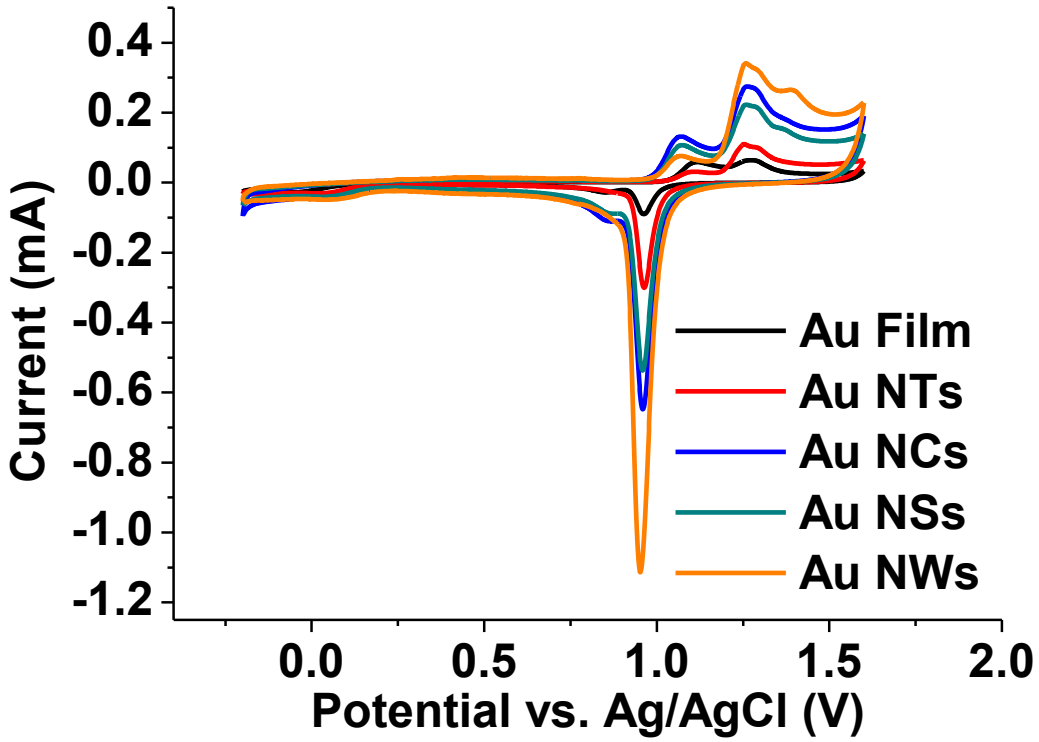

Figure S5. Cyclic voltammograms of Au nanostructures (in $H_2SO_{4(aq)}$, 0.5 M) for RSA estimations. Black: bare film, red: NTs, blue: NCs, green: NSs, and orange: NWs.

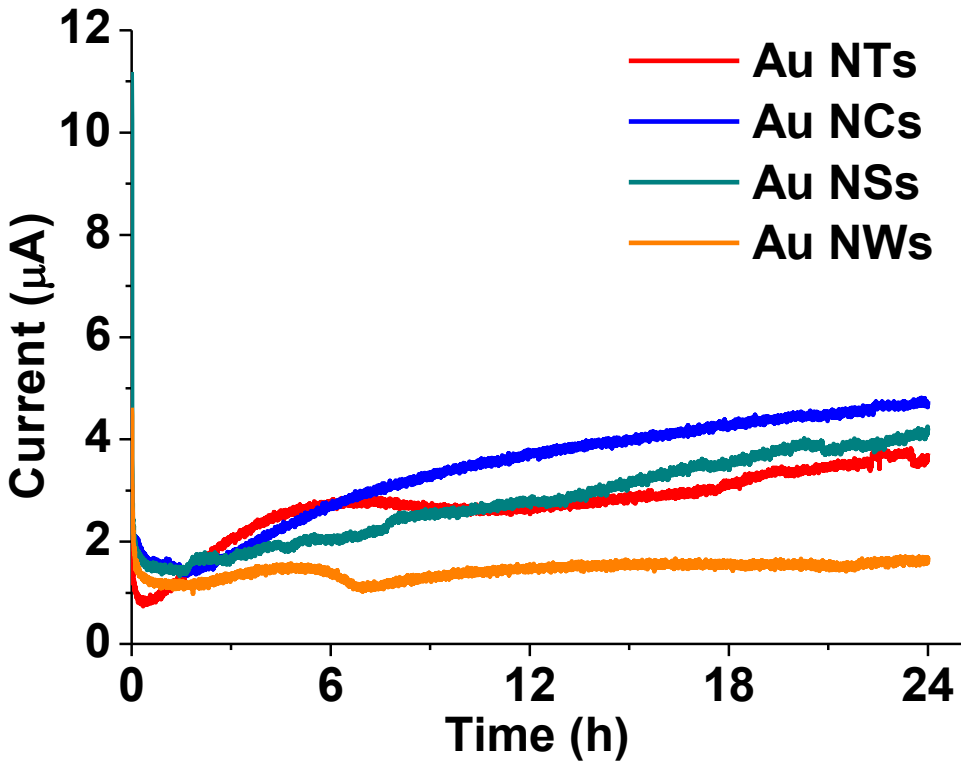

Figure S6. Supplied reduction currents during electrochemical depositions of Au nanostructures on flexible substrates. Red: NTs, blue: NCs, green: NSs, and orange: NWs.

The weight of Au deposited on the substrate was calculated by using Faraday's law of electrolysis. The equation is m = (Q/F) × (M/z). Here, m is the weight of Au in g, F is the Faraday constant 96500 $Cmol^{-1}$, M is the molar mass of Au 196.97 $gmol^{-1}$, and z is the valence number of the Au ion in the electrolyte. Q is the total electric charge (C) supplied and it can be calculated by the integration $Q = \int_0^t Idt$, using the data in this figure. The equation of the reaction is $Au^{3+}_{(aq)} + 3e^- \rightarrow Au_{(s)}$ while 100% current efficiency is assumed.

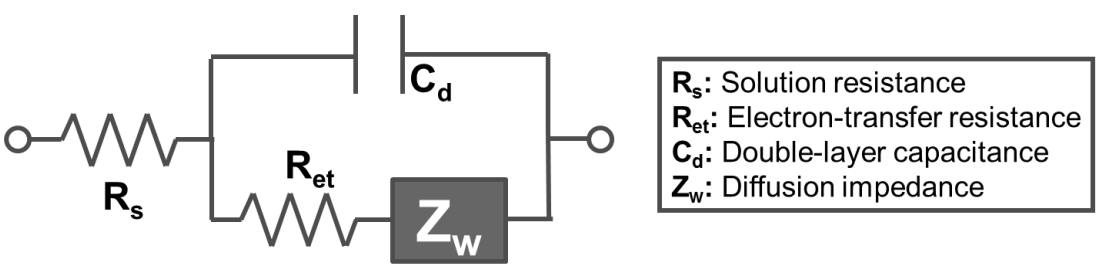

Figure S7. Randle modified equivalent circuit model for the EIS diagrams.

Table S1. Fitted elementary parameters of modified Au film surfaces and responses to various proteins using the equivalent circuit in Figure S6.

Au Film				
Surface	**R_{et} (kΩ)**	**R_s (kΩ)**	**C_d (μF)**	**Z_w (mΩ$S^{1/2}$)**
Bare	0.064 ± 0.007	0.26 ± 0.01	31.57 ± 1.17	2.46 ± 0.04
TBAI	1.37 ± 0.27	0.22 ± 0.03	34.53 ± 2.64	4.16 ± 3.94
TBAI/MCH	2.31 ± 0.22	0.25 ± 0.01	26.34 ± 0.52	2.51 ± 1.52
Thrombin				
Concentration	**R_{et} (kΩ)**	**R_s (kΩ)**	**C_d (μF)**	**Z_w (mΩ$S^{1/2}$)**
0 pM	2.39 ± 0.24	0.26 ± 0.02	25.58 ± 1.82	2.13 ± 0.82
1 pM	2.51 ± 0.20	0.26 ± 0.02	25.05 ± 1.79	1.92 ± 0.45
10 pM	2.62 ± 0.28	0.24 ± 0.01	25.14 ± 1.18	1.94 ± 0.83
20 pM	2.78 ± 0.27	0.26 ± 0.02	25.79 ± 1.13	1.94 ± 0.85
30 pM	3.03 ± 0.26	0.25 ± 0.03	24.84 ± 0.74	2.02 ± 0.92
40 pM	3.27 ± 0.28	0.25 ± 0.02	24.21 ± 1.11	1.89 ± 0.75
50 pM	3.43 ± 0.29	0.25 ± 0.03	28.71 ± 1.00	1.59 ± 0.61
BSA				
1 μM	2.49 ± 0.17	0.25 ± 0.02	25.91 ± 1.02	2.8 ± 1.87
Avidin				
1 μM	2.50 ± 0.13	0.25 ± 0.02	25.43 ± 1.75	1.99 ± 0.55

Table S2. Fitted elementary parameters of modified Au NTs surfaces and responses to various proteins using the equivalent circuit in Figure S6.

Au NTs				
Surface	**R_{et} (kΩ)**	**R_s (kΩ)**	**C_d (μF)**	**Z_w (mΩS$^{1/2}$)**
Bare	0.053 ± 0.003	0.26 ± 0.04	3.01 ± 0.75	2.66 ± 0.32
TBAI	3.92 ± 0.25	0.27 ± 0.03	22.86 ± 0.76	0.97 ± 0.19
TBAI/MCH	5.26 ± 0.19	0.25 ± 0.01	22.03 ± 3.43	0.80 ± 0.08
Thrombin				
Concentration	**R_{et} (kΩ)**	**R_s (kΩ)**	**C_d (μF)**	**Z_w (mΩS$^{1/2}$)**
0 pM	5.42 ± 0.17	0.25 ± 0.03	20.66 ± 0.64	0.82 ± 0.09
1 pM	5.79 ± 0.21	0.24 ± 0.02	21.10 ± 0.69	0.68 ± 0.07
10 pM	6.18 ± 0.18	0.25 ± 0.03	21.54 ± 0.78	0.61 ± 0.05
20 pM	6.90 ± 0.16	0.27 ± 0.02	20.79 ± 0.59	0.60 ± 0.04
30 pM	7.51 ± 0.08	0.23 ± 0.03	21.78 ± 0.66	0.53 ± 0.02
40 pM	8.83 ± 0.21	0.25 ± 0.03	20.62 ± 0.45	0.44 ± 0.17
50 pM	9.91 ± 0.28	0.24 ± 0.04	20.62 ± 0.45	0.36 ± 0.09
BSA				
1 μM	5.62 ± 0.20	0.26 ± 0.02	22.60 ± 3.79	0.72 ± 0.07
Avidin				
1 μM	5.43 ± 0.17	0.25 ± 0.02	20.21 ± 0.91	0.78 ± 0.05

Table S3. Fitted elementary parameters of modified Au NCs surfaces and responses to various proteins using the equivalent circuit in Figure S6.

Au NCs				
Surface	**R_{et} (kΩ)**	**R_s (kΩ)**	**C_d (μF)**	**Z_w (mΩS$^{1/2}$)**
Bare	0.043 ± 0.009	0.22 ± 0.04	11.88 ± 1.49	3.04 ± 0.13
TBAI	4.59 ± 0.54	0.24 ± 0.02	36.87 ± 2.01	0.86 ± 0.19
TBAI/MCH	8.93 ± 1.25	0.22 ± 0.05	11.34 ± 0.26	0.82 ± 0.03
Thrombin				
Concentration	**R_{et} (kΩ)**	**R_s (kΩ)**	**C_d (μF)**	**Z_w (mΩS$^{1/2}$)**
0 pM	9.24 ± 1.25	0.25 ± 0.02	13.62 ± 0.09	1.00 ± 0.21
1 pM	11.87 ± 1.58	0.27 ± 0.02	11.19 ±0.07	0.80 ± 0.07
10 pM	12.83 ± 1.58	0.22 ± 0.05	11.01 ± 0.12	0.61 ± 0.05
20 pM	14.34 ± 1.45	0.24 ± 0.03	10.77 ± 0.11	0.64 ± 0.05
30 pM	15.28 ± 1.35	0.24 ± 0.02	11.01 ± 0.07	0.70 ± 0.05
40 pM	15.99 ± 1.32	0.25 ± 0.03	10.99 ± 0.08	0.74 ± 0.05
50 pM	17.7 ± 0.91	0.23 ± 0.02	11.42 ± 0.08	0.58 ± 0.12
BSA				
1 μM	9.73 ± 1.06	0.22 ± 0.04	11.22 ± 0.20	0.80 ± 0.03
Avidin				
1 μM	9.52 ± 1.02	0.23 ± 0.04	11.19 ± 0.11	0.74 ± 0.09

Table S4. Fitted elementary parameters of modified Au NSs surfaces and responses to various proteins using the equivalent circuit in Figure S6.

Au NSs				
Surface	**R_{et} (kΩ)**	**R_s (kΩ)**	**C_d (μF)**	**Z_w (mΩS$^{1/2}$)**
Bare	0.051 ± 0.002	0.25 ± 0.04	7.85 ± 0.68	3.14 ± 0.06
TBAI	6.11 ± 1.45	0.25 ± 0.01	36.44 ± 1.10	0.87 ± 0.11
TBAI/MCH	13.57 ± 0.98	0.24 ± 0.04	11.10 ± 0.23	0.65 ±0.14
Thrombin				
Concentration	**R_{et} (kΩ)**	**R_s (kΩ)**	**C_d (μF)**	**Z_w (mΩS$^{1/2}$)**
0 pM	13.64 ± 0.95	0.23 ± 0.03	11.14 ± 0.19	0.57 ± 0.05
1 pM	16.55 ± 1.00	0.27 ± 0.01	10.86 ± 0.19	0.68 ± 0.06
10 pM	18.24 ± 1.02	0.25 ± 0.02	11.03 ± 0.11	0.60 ± 0.08
20 pM	19.61 ± 1.08	0.24 ± 0.03	11.42 ± 0.17	0.58 ± 0.11
30 pM	20.94 ± 1.10	0.25 ± 0.03	11.12 ± 0.13	0.52 ± 0.09
40 pM	22.24 ± 1.25	0.23 ± 0.04	11.14 ± 0.16	0.47 ± 0.09
50 pM	24.31 ± 1.2	0.22 ± 0.04	11.12 ± 0.14	0.44 ± 0.11
BSA				
1 μM	13.91 ± 0.81	0.21 ± 0.05	11.03 ± 0.19	0.57 ± 0.07
Avidin				
1 μM	13.92 ± 0.77	0.27 ± 0.02	11.08 ± 0.22	0.67 ± 0.11

Table S5. Fitted elementary parameters of modified Au NWs surfaces and responses to various proteins using the equivalent circuit in Figure S6.

Au NWs				
Surface	**R_{et} (kΩ)**	**R_s (kΩ)**	**C_d (μF)**	**Z_w (mΩ$S^{1/2}$)**
Bare	0.012 ± 0.006	0.22 ± 0.01	12.23 ± 5.31	2.94 ± 0.73
TBAI	14.58 ± 1.41	0.24 ± 0.04	17.54 ± 0.29	0.35 ± 0.03
TBAI/MCH	21.80 ± 2.41	0.27 ± 0.01	7.44 ± 0.11	0.80 ± 0.04
Thrombin				
Concentration	**R_{et} (kΩ)**	**R_s (kΩ)**	**C_d (μF)**	**Z_w (mΩ$S^{1/2}$)**
0 pM	22.24 ± 2.23	0.24 ± 0.03	6.27 ± 0.09	0.65 ± 0.05
1 pM	29.36 ± 2.72	0.24 ± 0.03	6.01 ± 0.09	0.58 ± 0.14
10 pM	31.05 ± 2.74	0.27 ± 0.02	6.03 ± 0.11	0.63 ± 0.07
20 pM	33.88 ± 2.06	0.25 ± 0.01	6.37 ± 0.11	0.45 ± 0.09
30 pM	36.96 ± 2.01	0.23 ± 0.03	6.19 ± 0.11	0.40 ± 0.07
40 pM	39.62 ± 2.87	0.23 ± 0.03	6.17 ± 0.10	0.39 ± 0.05
50 pM	42.99 ± 2.85	0.23 ± 0.03	6.17 ± 0.10	0.36 ± 0.06
BSA				
1 μM	22.67 ± 2.14	0.26 ± 0.01	7.37 ± 0.10	0.74 ± 0.07
Avidin				
1 μM	22.60 ± 2.30	0.25 ± 0.01	7.41 ± 0.11	0.78 ± 0.05