Supporting Information

Enhanced electrophoretic separation of proteins by tethered SiO_2 nanoparticles in SDS-polyacrylamide gel network

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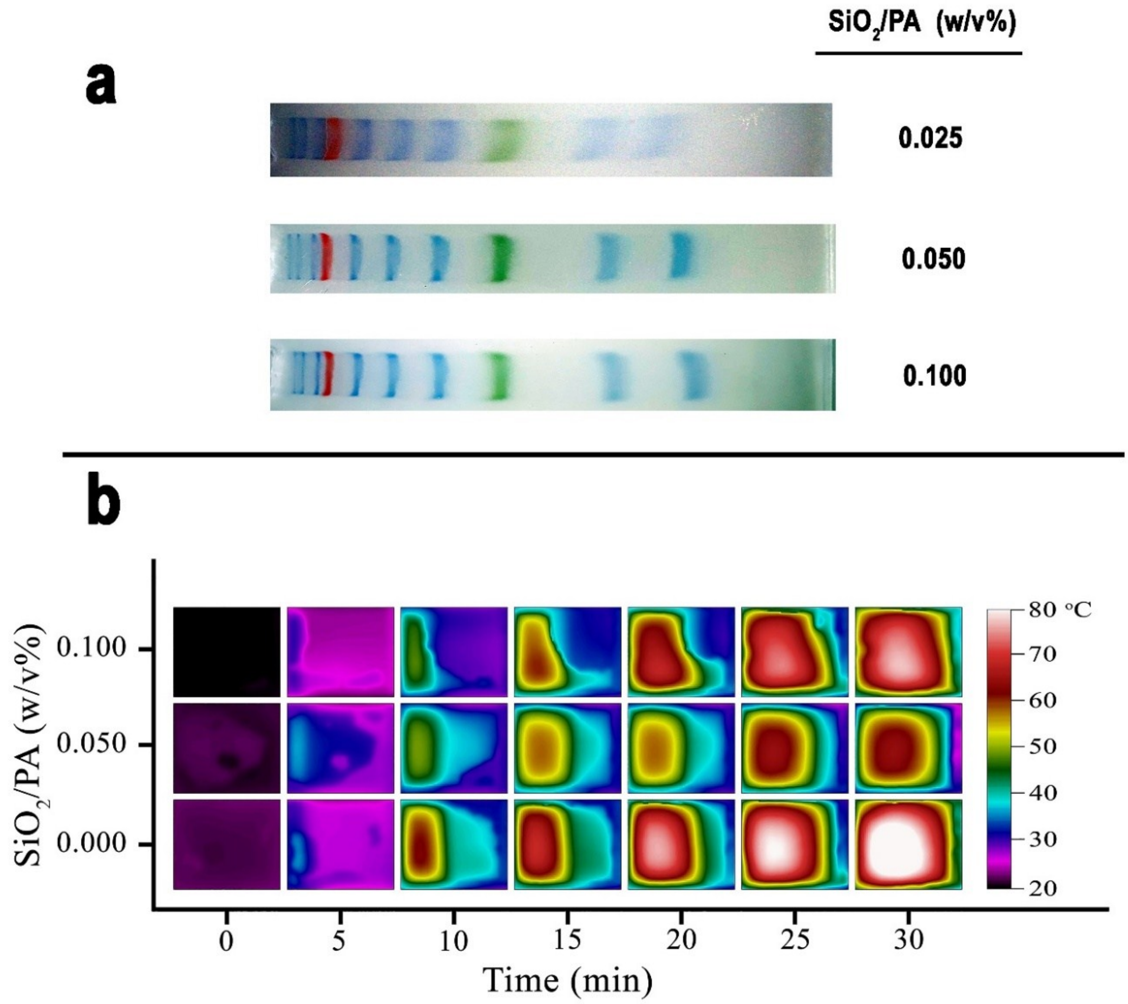

Fig. S1. SDS-PAGE profile of the standard protein mixture on SiO_2/PA composite gels. The pictures were obtained after 1 h electrophoresis at 160 V. b) Temperature profile of the composite gels during electrophoresis.

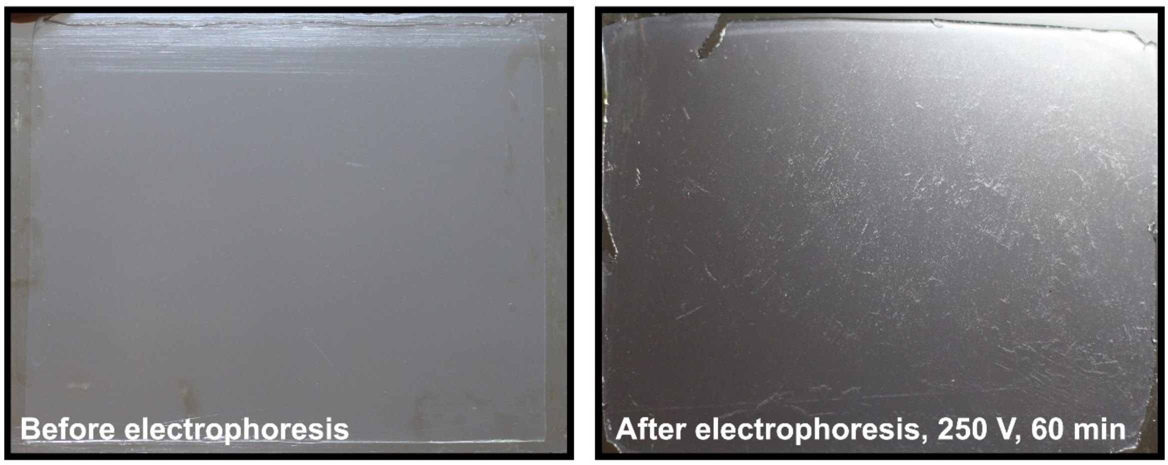

Fig S2. Photograph of SiO_2/PA (0.200 % w/v) composite gel before and after electrophoresis.

Table S1. Distance travelled by each protein, d, $FWHM$, and resolution for each protein peak in pure PA, SiO_2/PA, and M-SiO_2/PA gels at the applied voltages of 150 V.

Peak	d	$FWHM$	Rs
PA			
1	0.071	0.007	1.967
2	0.099	0.010	2.305
3	0.147	0.015	1.041
4	0.185	0.028	1.947
5	0.261	0.018	3.013
6	0.365	0.022	2.546
7	0.470	0.026	2.403
8	0.637	0.055	2.378
9	0.834	0.042	1.735
10	0.949	0.036	N/A
SiO_2/PA			
1	0.066	0.007	1.745
2	0.092	0.010	2.148
3	0.136	0.014	1.069
4	0.174	0.028	1.809
5	0.245	0.019	2.898
6	0.344	0.021	2.589
7	0.447	0.025	2.252
8	0.605	0.057	2.176
9	0.800	0.048	1.575
10	0.916	0.038	N/A
M-SiO_2/PA			
1	0.051	0.014	0.919
2	0.076	0.018	1.214
3	0.145	0.049	0.375
4	0.166	0.017	2.222
5	0.241	0.023	2.500
6	0.344	0.025	2.256
7	0.451	0.030	2.268
8	0.614	0.054	2.198
9	0.817	0.054	1.441
10	0.936	0.043	N/A

Table S2. Distance travelled by each protein, d, $FWHM$, and resolution for each protein peak in pure PA, SiO_2/PA, and M-SiO_2/PA gels at the applied voltages of 250 V.

Peak	d	$FWHM$	Rs
PA			
1	0.116	0.010	0.995
2	0.154	0.035	0.583
3	0.188	0.033	0.655
4	0.219	0.022	1.831
5	0.289	0.023	2.244
6	0.387	0.028	1.874
7	0.484	0.033	1.846
8	0.628	0.059	1.957
9	0.807	0.048	1.452
10	0.925	0.047	N/A
SiO_2/PA			
1	0.066	0.010	0.987
2	0.092	0.021	0.739
3	0.132	0.042	0.582
4	0.163	0.019	1.915
5	0.229	0.021	2.218
6	0.319	0.026	1.959
7	0.416	0.032	1.848
8	0.563	0.061	1.951
9	0.745	0.049	1.536
10	0.864	0.042	N/A
M-SiO_2/PA			
1	0.072	0.010	1.345
2	0.101	0.015	1.337
3	0.159	0.035	0.610
4	0.189	0.023	2.244
5	0.270	0.019	2.982
6	0.373	0.022	2.278
7	0.475	0.030	2.224
8	0.636	0.055	2.293
9	0.828	0.043	1.801
10	0.942	0.031	N/A

Table S3. Distance travelled by each protein, d, $FWHM$, and resolution for each protein peak in 10% pure PA and M-SiO_2/PA gels at the applied voltages of 300 V.

Peak	d	$FWHM$	Rs
PA			
1	0.094	0.017	1.193
2	0.128	0.017	1.876
3	0.183	0.018	1.312
4	0.234	0.027	1.741
5	0.305	0.021	3.048
6	0.415	0.022	2.184
7	0.506	0.027	2.314
8	0.645	0.044	1.916
9	0.792	0.046	0.624
10	0.819	0.006	N/A
M-SiO_2/PA			
1	0.083	0.015	1.473
2	0.119	0.014	2.071
3	0.175	0.019	1.090
4	0.217	0.026	2.194
5	0.304	0.021	3.150
6	0.416	0.021	2.762
7	0.529	0.027	2.822
8	0.693	0.041	2.606
9	0.871	0.039	1.808
10	0.948	0.011	N/A

Table S4. Average (Avg) and standard deviation (StD) Distance (normalized to the gel length) travelled by the each protein, d, $FWHM$, resolution, Rs, and number of theoretical plates, N, for some of E.Coli protein peaks in pure PA, SiO_2/PA, and M-SiO_2/PA at the applied voltages of 200 V.

Peak	$d \times 100$		$FWHM \times 100$		$Rs \times 100$		$N/100$	
	Avg	**StD**	**Avg**	**StD**	**Avg**	**StD**	**Avg**	**StD**
PA								
g	67.695	0.218	2.786	0.415	41.964	8.735	32.708	0.726
h	69.115	0.228	1.132	0.090	96.723	8.139	206.398	1.297
i	71.125	0.245	1.255	0.234	67.181	11.055	178.032	6.211
j	72.933	0.261	1.908	0.318	66.057	7.694	80.975	2.257
k	74.947	0.288	1.616	0.067	96.108	3.611	119.210	0.206
l	77.919	0.278	1.919	0.075	97.000	2.415	91.338	0.142
SiO_2/PA								
g	70.973	0.615	5.033	4.570	47.219	22.160	11.015	9.081
h	72.891	0.480	1.674	0.223	80.008	6.187	105.037	1.865
i	74.942	0.472	1.271	0.098	70.397	4.599	192.707	1.150
j	76.902	0.462	1.922	0.143	65.003	5.532	88.661	0.497
k	79.012	0.418	1.814	0.254	92.089	11.345	105.105	2.063
l	82.238	0.429	2.248	0.269	84.657	9.795	74.142	1.067
M-SiO_2/PA								
g	71.508	0.223	1.562	0.586	67.294	6.785	116.156	16.363
h	73.376	0.268	1.658	0.205	89.186	7.538	108.506	1.653
i	75.532	0.232	1.118	0.014	72.955	6.015	252.714	0.041
j	77.539	0.261	2.050	0.332	67.139	6.393	79.284	2.084
k	79.669	0.305	1.606	0.065	105.742	3.393	136.274	0.222
l	83.088	0.394	2.088	0.110	92.154	5.654	87.698	0.247

Table S5. Summary of previous reports on the use of NPs for enhancing gel electrophoresis performance.

Nano filler	**Separation medium**	**Effect (changes compare to pure gel)**	**Cause**	**Ref.**
Multi-walled carbon nanotubes (MWCNTs)	Native polyacrylamide gel (PAG)	Significant improvement of the relative selectivity in the separation between apolipoprotein A-I and complement C3	Interactions between the proteins and the surface of the carbon nanotubes	1
TiO_2 NPs Al_2O_3 NPs	Native-PAG	Change of the observed mobility of proteins; no significant improvement of relative selectivities	Higher electrical conductivity of the PAM in the presence of NPs	1
MWCNTs Single-walled carbon nanotubes (SWCNTs)	SDS-PAG	Reduction in standard deviation in the molecular weight calibration plots compared	More uniform pore size distribution of PAM in the presence of CNT	2
MWCNTs	Native-PAG	No need for catalyst (TEMED); Improvement of pore size distribution of the gel matrix and linearity of molecular weight calibration plots	Using MWCNTs as a mild catalyst for polymerization	3
SWCNTs	Pore-gradient Native-PAG	Significant improvements in separation of complement C3 protein and haptoglobin (Hp) in human serum	Modification of SWCNTs by Triton X-100 and carboxylation	4
CeO_2 NPs	SDS-PAG	Reduction in Joule heating; Improving the resolution and speed of protein separation	Higher thermal conductivity of NPs than that of pure gel	5
Graphitic carbon nitride (GCN)	SDS-PAG	Improving the resolution and efficiency of protein separation; No need for polymerization catalyst	Higher thermal conductivity (TC) of GCN than that of pure gel; GCN acts as catalyst	6
MWCNTs SWCNTs	Native-PAG	Improving separation of proteins		7
Au NPs	Native-PAG	Changing the effective electrophoretic mobility of a model protein, ovum serum albumin (OSA)	Reduction in protein mobility by increasing aspect ratio of the NPs	8
ZrO_2 NPs	Agarose gel	Reducing Joule heating. increasing separation efficiency and resolution	Higher TC of NPs than that of pure agarose gel	9
TiO_2 NPs	SDS-PAG	Better heat dissipation leading to a cooler gel during electrophoresis; Increasing the efficiency of electrophoretic separation of proteins	Using NPs as heat sink in the gel	10
M-SiO_2	SDS-PAG	Increasing the efficiency of electrophoretic separation of proteins	Tethering NPs inside the PAM network	Current work

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