Supporting Information

Structure-Function Relationships Affecting the Sensing Mechanism of Monolayer-Protected Cluster Doped Xerogel Amperometric Glucose Biosensors

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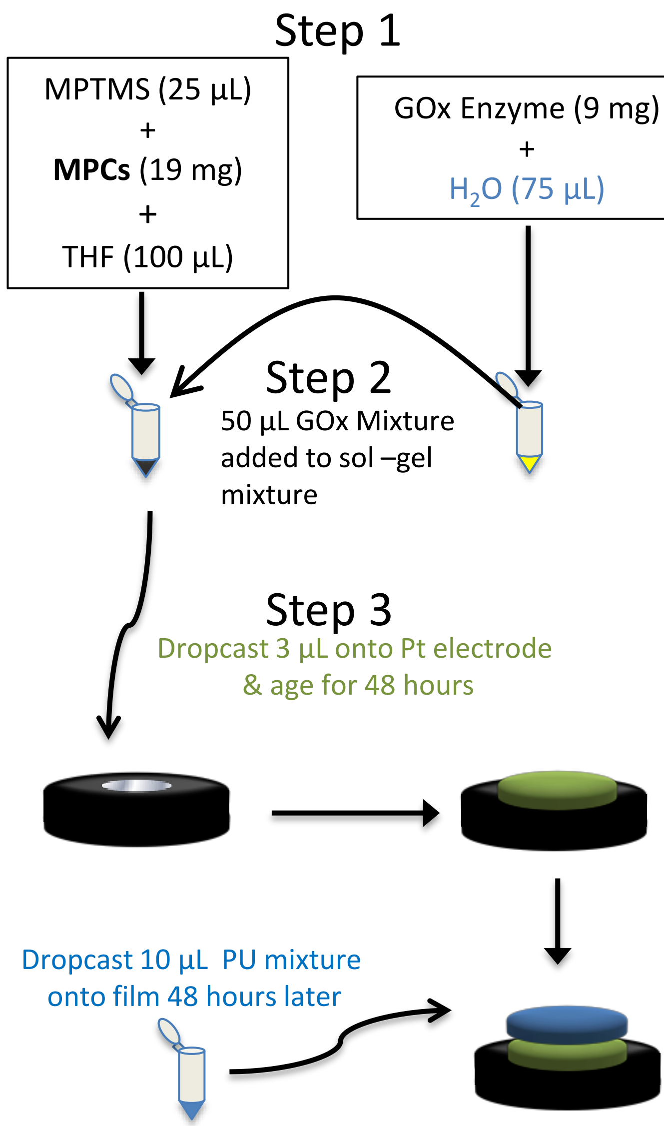


Figure SI-1. Schematic of film MPC-doped MPTMS xerogel preparation including estimates of mass percent composition for *typical* films (sample values are shown below).

	Glucose Oxidase Concentration	MPC Concentration	MPTMS Silane Concentration
Step 1	120 mg/mL	0.0029 M	1.08 M
Step 2	34.3 mg/mL	0.0020 M	0.769 M
Step 3	0.102 mg GOx in each film	0.32 mg MPC in each film	0.453 mg Silane in each film

Mass Percent Composition of Typical Xerogel Film

11.8% GOx	36.4% MPC	51.8% MPTMS

Notes: Estimations assume monodisperse gold nanoparticles; water and THF are eliminated via evaporation during the 48 hour aging process and do not factor into the final mass of the film. Similarly, the mass of the outer PU coating has not been considered in these estimations. It should also be noted that it cannot be assumed that all of the immobilized (encapsulated) GOx or MPCs are accessible by solvent and/or glucose/H2O2. Similarly, the deposited films extend past the geometric area of the platinum and may or may not be electrochemically active. Gravimetric analysis of the films revealed an experimental mass % of GOx within the films to be 8-10%.

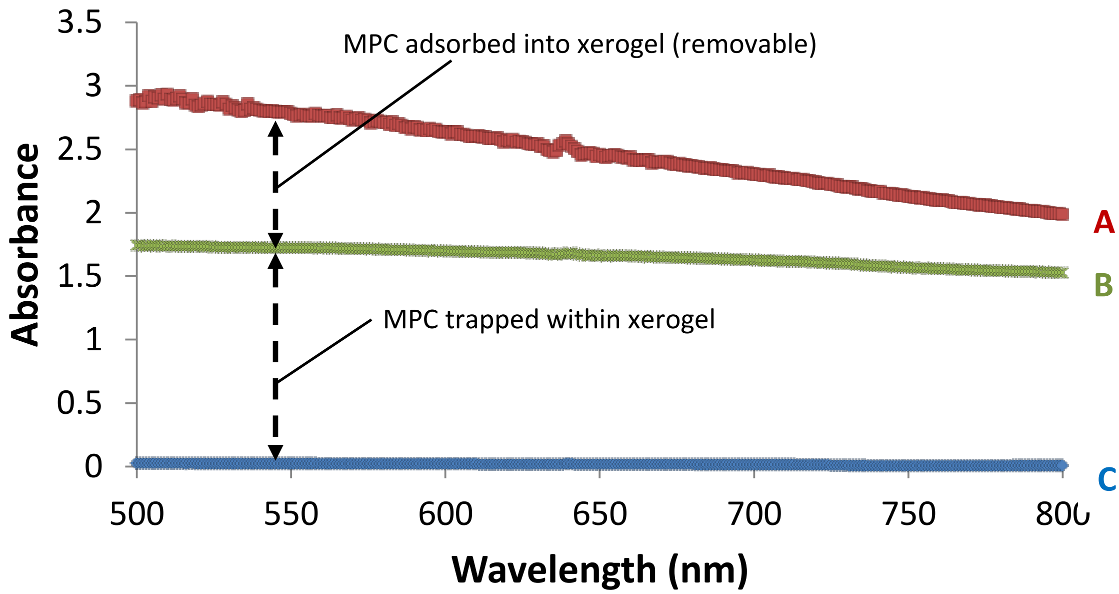


Figure SI-2. UV-Vis spectra of glass slides that are **(A)** MPTMS-modified, **(B)** MPTMS-modified and drop cast with a MPC-doped MPTMS xerogel, and **(C)** MPTMS-modified and drop cast with a MPC-doped MPTMS xerogel after soaking the slide in pure toluene for 15 minutes.

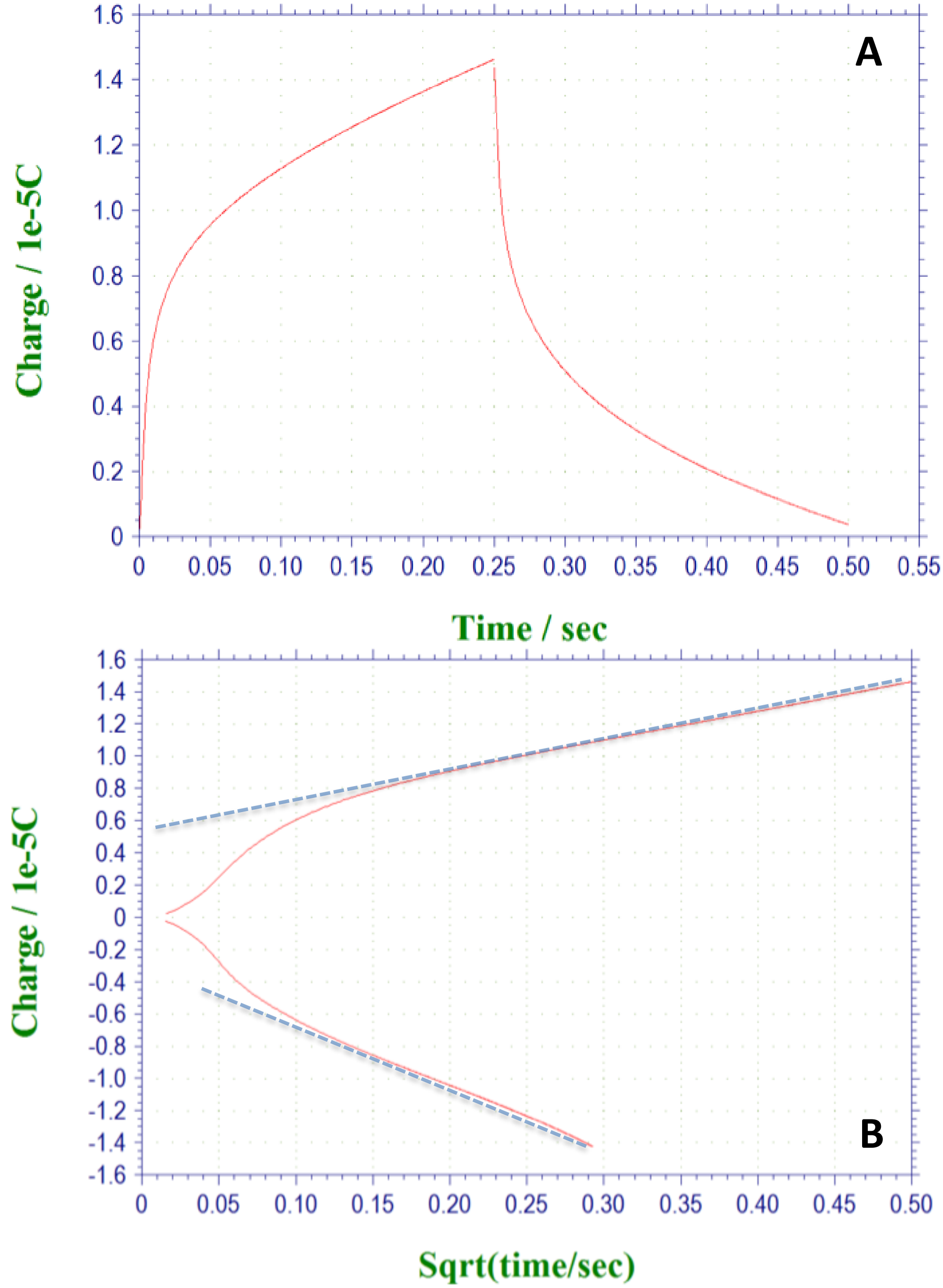


Figure SI-3. Examples of chronocoulometry analyses to determine electroactive surface area and diffusion coefficient (H_2O_2) according to Equation 1: (**A**) charge vs. time plot and (**B**) Anson plot for chronocoulometry experiments of 5 mM potassium ferricyanide (1 M KCl) where the potential is stepped from negligible Faradaic current to reductive potentials (-0.49V vs. Ag/AgCl) as determined from cyclic voltammetry (not shown) and the charge passed is monitored as a function of time. [Parameters: Initial E = 1.0V; Final E = -0.49V; Pulse Width = 0.25 s; Sample Interval 0.00025 s; Sensitivity = 1E-4.]

Notes: For **H_2O_2 diffusion coefficient** measurements the potential is stepped from -0.4 V to oxidative potentials (+0.65 V vs. Ag/AgCl) in a 27 mM H_2O_2 in phosphate buffer (pH = 7; 4.4 mM) solution. For **glucose diffusion coefficient** measurements, the potential is stepped to +1.0 V where some electroactivity (oxidation) of glucose has been observed previously (M.B. Jensen and D.C. Johnson, *Anal. Chem.* (1997), 69, 1776).

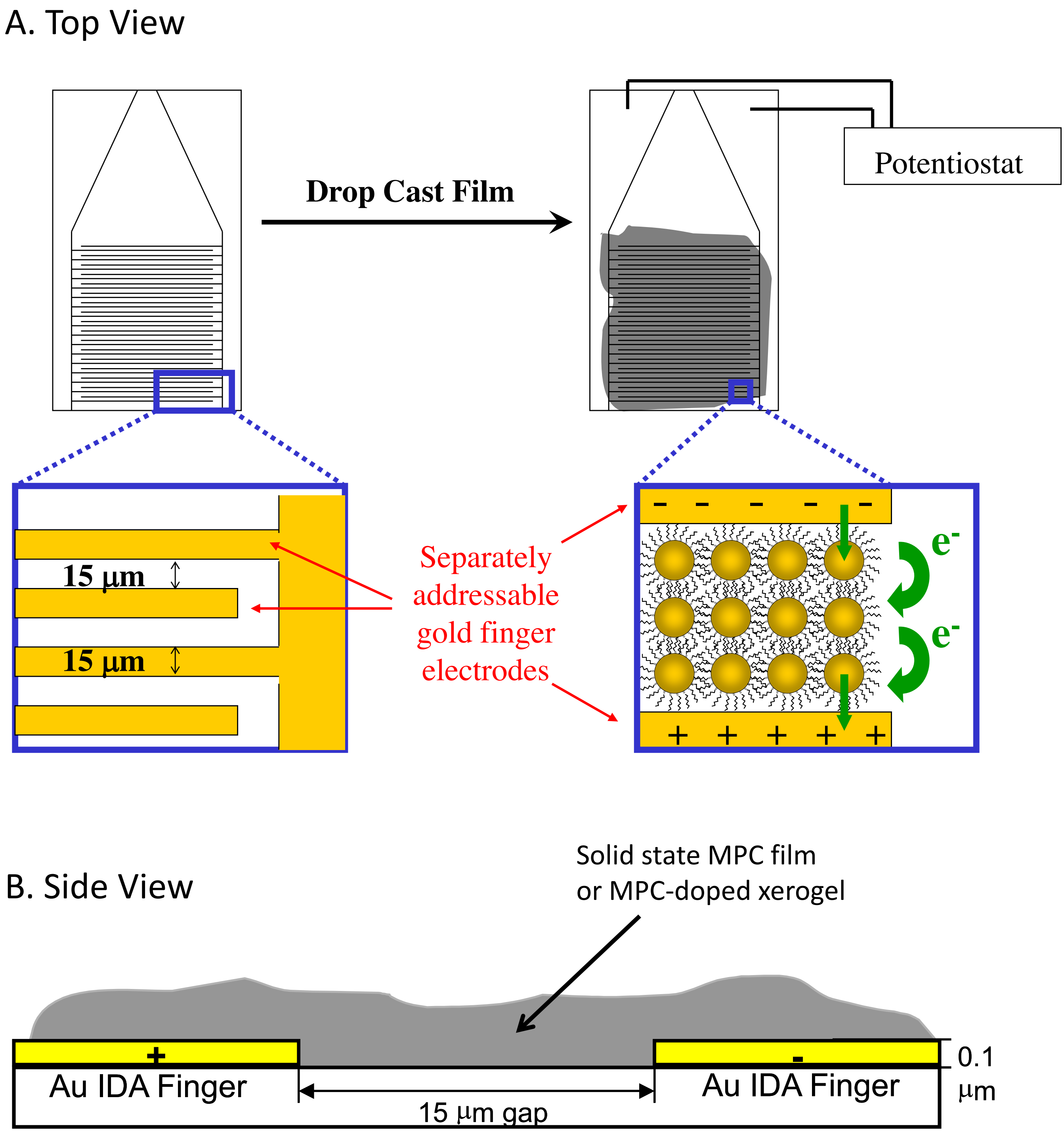


Figure SI-4. Interdigitated array electrode dimensions and set-up for electronic conductivity measurements of MPC drop-cast films and MPC-doped xerogels. Electronic conductivity was determined by σ_{EL} **=** d_{gap}/R·A where (1/R) is the slope (ΔI/ΔV) of the linear portion of the current-voltage (I-V) curve (between -0.2V and +0.2V), and d_{gap}/A is the IDA conductance cell constant.

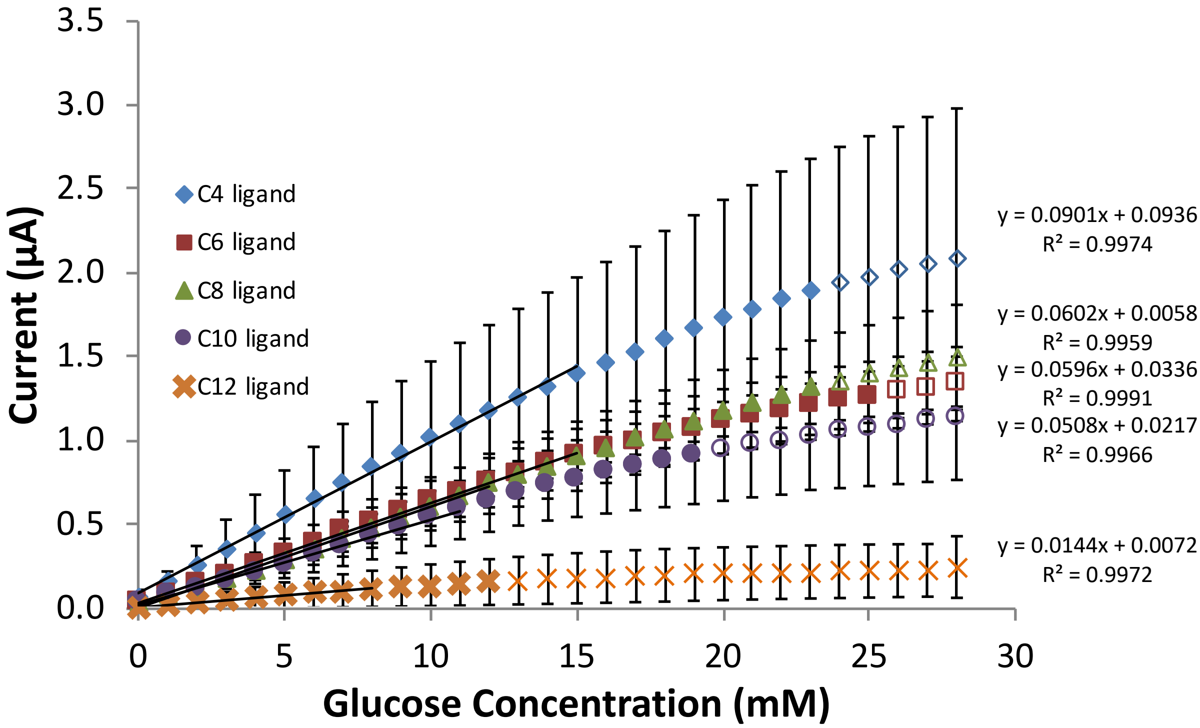


Figure SI-5. Calibration curves during successive 1 mM glucose injections at platinum electrodes modified with GOx embedded MPTMS xerogels doped with C4, C6, C8, C10, and C12 ligand coated MPCs and a PU outer layer. Solid or bolded symbols (,■,▲,●,**X**) indicate a step-like response to increases in glucose concentration whereas open or non-bolded symbols (◇,□,Δ,○,X) indicate a non-step response (dynamic range). Error bars represent standard deviation.

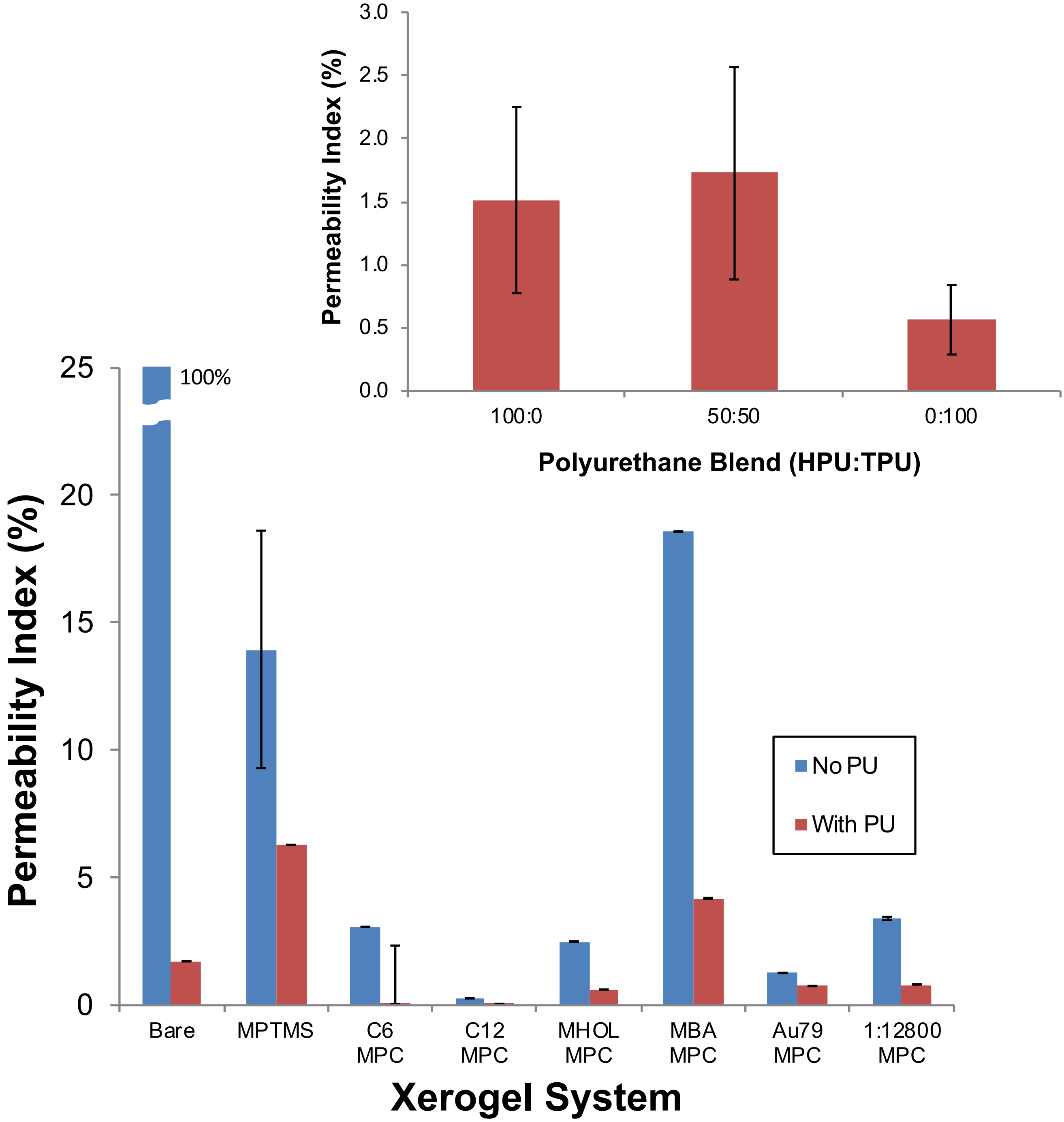


Figure SI-6. Permeability indices (PI) H_2O_2 at various MPC-doped xerogel systems with and without PU outer membranes. **Inset**: H_2O_2 permeability indices for different compositions of polyurethane (i.e., HPU:TPU ratios) coated platinum electrodes.

Notes: Bare = clean Pt electrode; MPTMS = undoped sol-gel; MHOL-MPC = $Au_{225}(C6)_{61}(MHOL)_{14}$; MBA MPC = $Au_{225}(C6)_{64}(MBA)_{11}$; Au79 MPC = $Au_{79}(C6)_{38}$; 1:12800 MPC = $Au_{225}(C6)_{75}$

Each injection of hydrogen peroxide resulted in a concentration of 100 μM in 25 mL of 4.4mM PBS (pH=7.00). Error bars representing standard deviation are sometimes too small to graphically visualize.

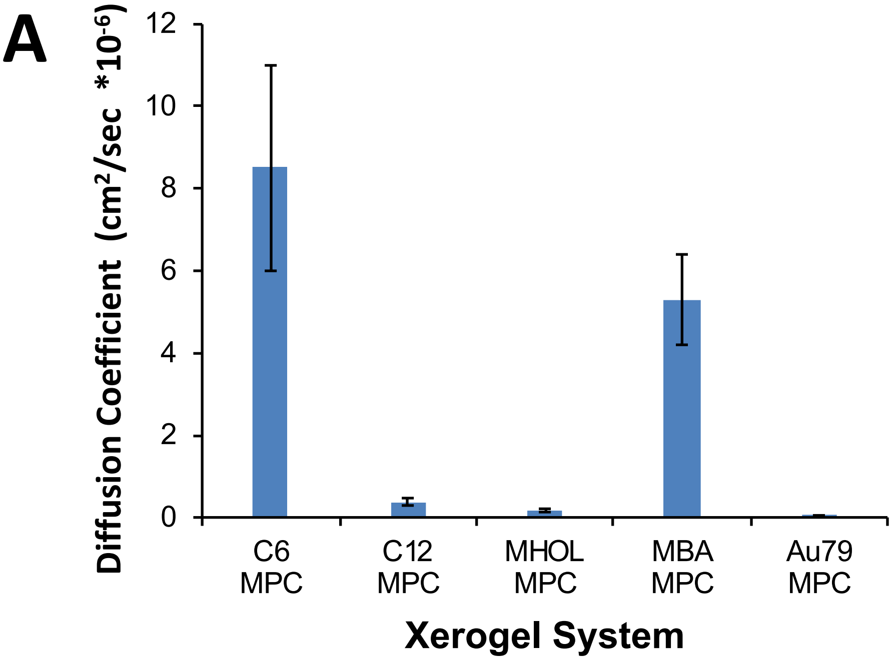
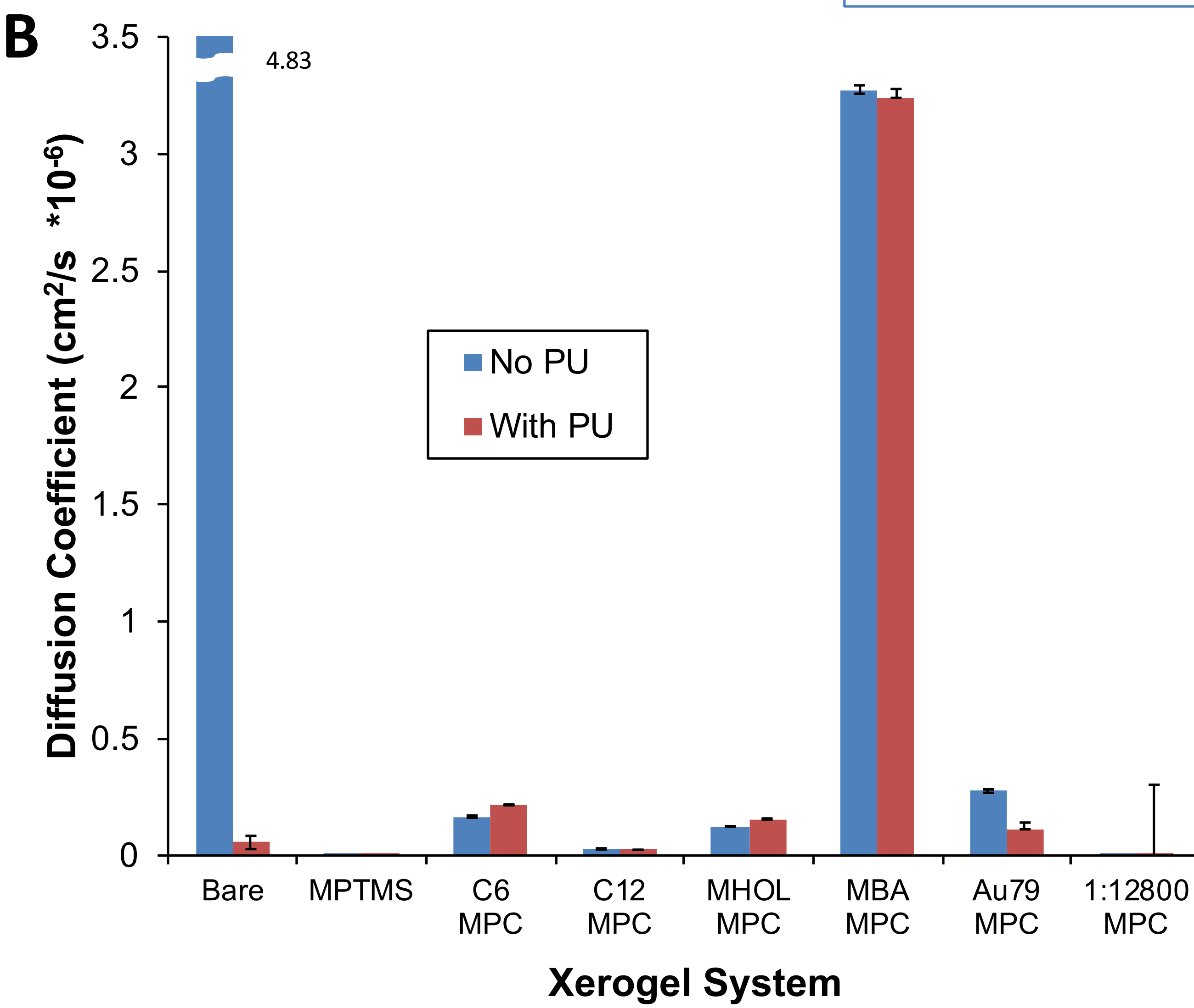


Figure SI-7. Diffusion coefficients measured for (A) H_2O_2 and (B) glucose for various MPC-doped xerogel systems both with and without PU outer membranes in the case of glucose.

Notes: Bare = clean Pt electrode; MPTMS = undoped sol-gel; MHOL-MPC = $Au_{225}(C6)_{61}(MHOL)_{14;}$ MBA MPC = $Au_{225}(C6)_{64}(MBA)_{11}$; Au79 MPC = $Au_{79}(C6)_{38}$; 1:12800 MPC = $Au_{225}(C6)_{75}$

Note: In some cases, MPTMS without MPC doping and 1:12800 MPC ratio doping into MPTMS xerogels (which should have similar compositions, are too small to be visible on scale used to display data.



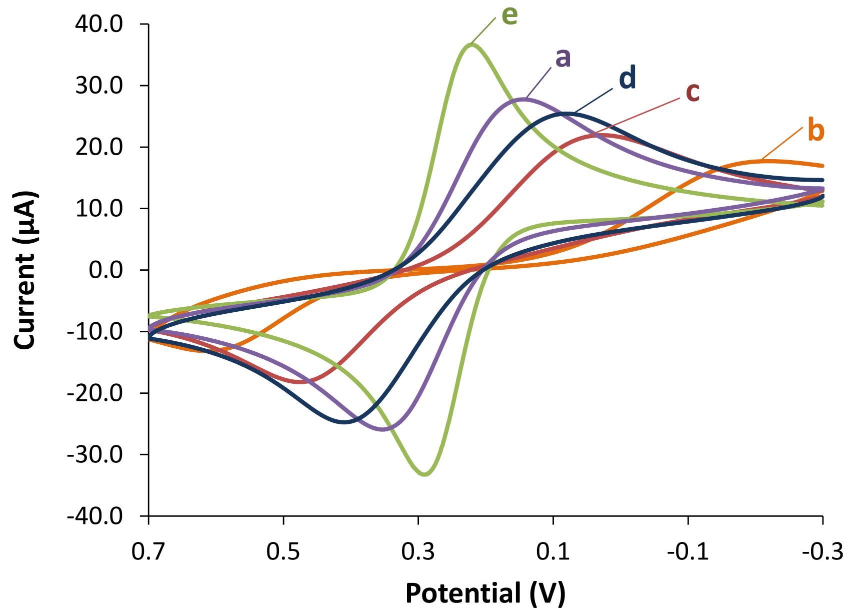


Figure SI-8. Cyclic voltammetry of 5 mM potassium ferricyanide at gold electrodes modified with SAMs comprised of (a) mercaptohexanol (MHOL), (b) hexanethiol, (c) thioctic acid (TA), (d) mercaptohexanoic acid (MHA), and (e) mercaptobenzoic acid (MBA). Voltammetry was recorded at 100 mV/s in 0.5 M KCl vs. Ag/AgCl (Satrd. KCl) reference electrode. Note: 6-mercaptophenol (MPOL) results excluded for presentation clarity – see Figure SI-9.

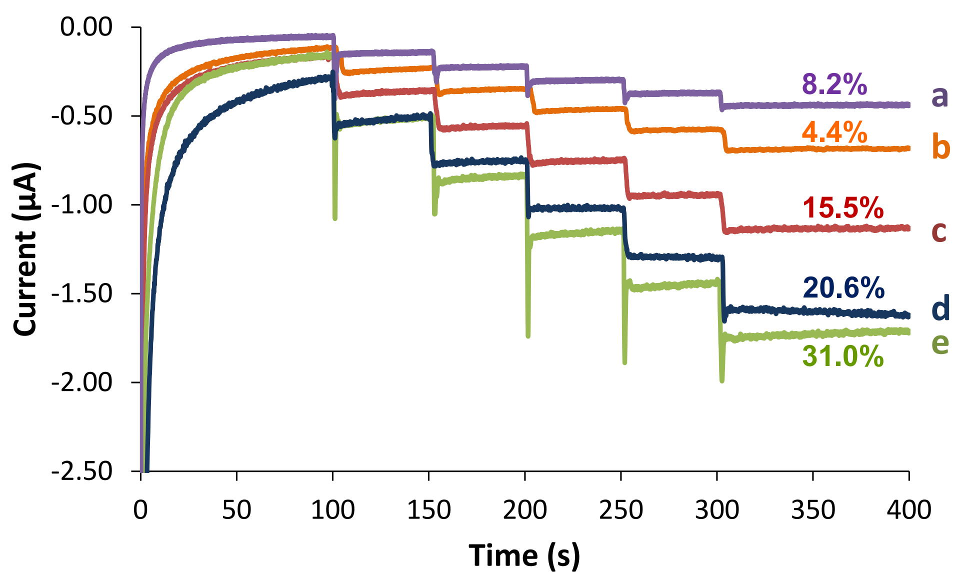


Figure SI-9. Amperometric I-t curves during successive injections of hydrogen peroxide at gold electrodes modified with SAMs comprised of (a) mercaptohexanol (MHOL), (b) hexanethiol, (c) thioctic acid (TA), (d) mercaptohexanoic acid (MHA), and (e) mercaptobenzoic acid (MBA) with the relative permeability indices shown for each trace. Each injection of hydrogen peroxide resulted in a concentration of 100 μM in 25 mL of 4.4mM PBS (pH=7.00). Note: 6-mercaptophenol (MPOL) results excluded for presentation clarity – see Figure SI-9.

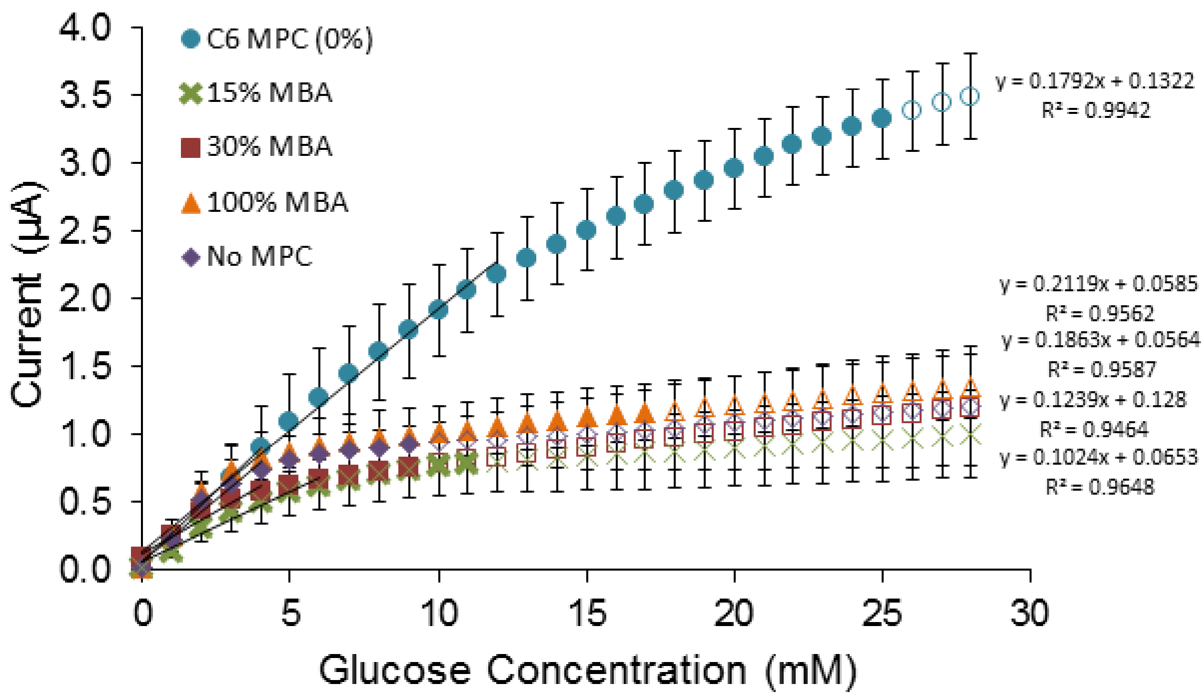


Figure SI-10. Calibration curves for glucose biosensors constructed at platinum electrodes modified with GOx embedded MPTMS xerogels undoped (♦) and doped with C6 MPCs (0%, ●), C6 MPCs exchanged with MBA (15%,**X**), C6 MPCs exchanged with MBA (30%, ■), and MBA MPCs (100%,▲). Solid symbols indicate a step-like response to increases in glucose concentration whereas open symbols indicate a nonstep response (dynamic range). All sensors were coated with a PU outer layer. Error bars represent standard deviation.

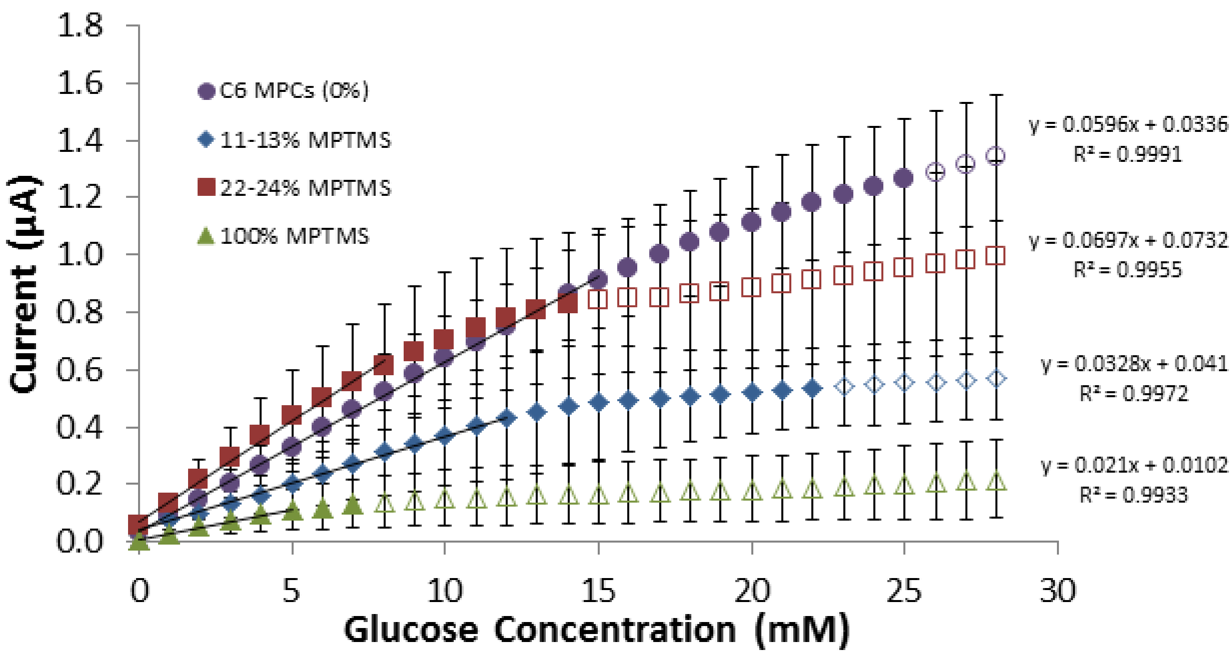


Figure SI-11. Calibration curves for glucose biosensors constructed at platinum electrodes modified with GOx embedded MPTMS xerogels doped with C6 MPCs (0%, ●), C6 MPCs exchanged with MPTMS (11-13%, ♦), C6 MPCs exchanged with MPTMS (22-24%, ■), MPTMS MPCs (100%, ▲). Solid symbols indicate a step-like response to increases in glucose concentration whereas open symbols indicate a nonstep response (dynamic range). All sensors were coated with a PU outer layer. Error bars represent standard deviation.

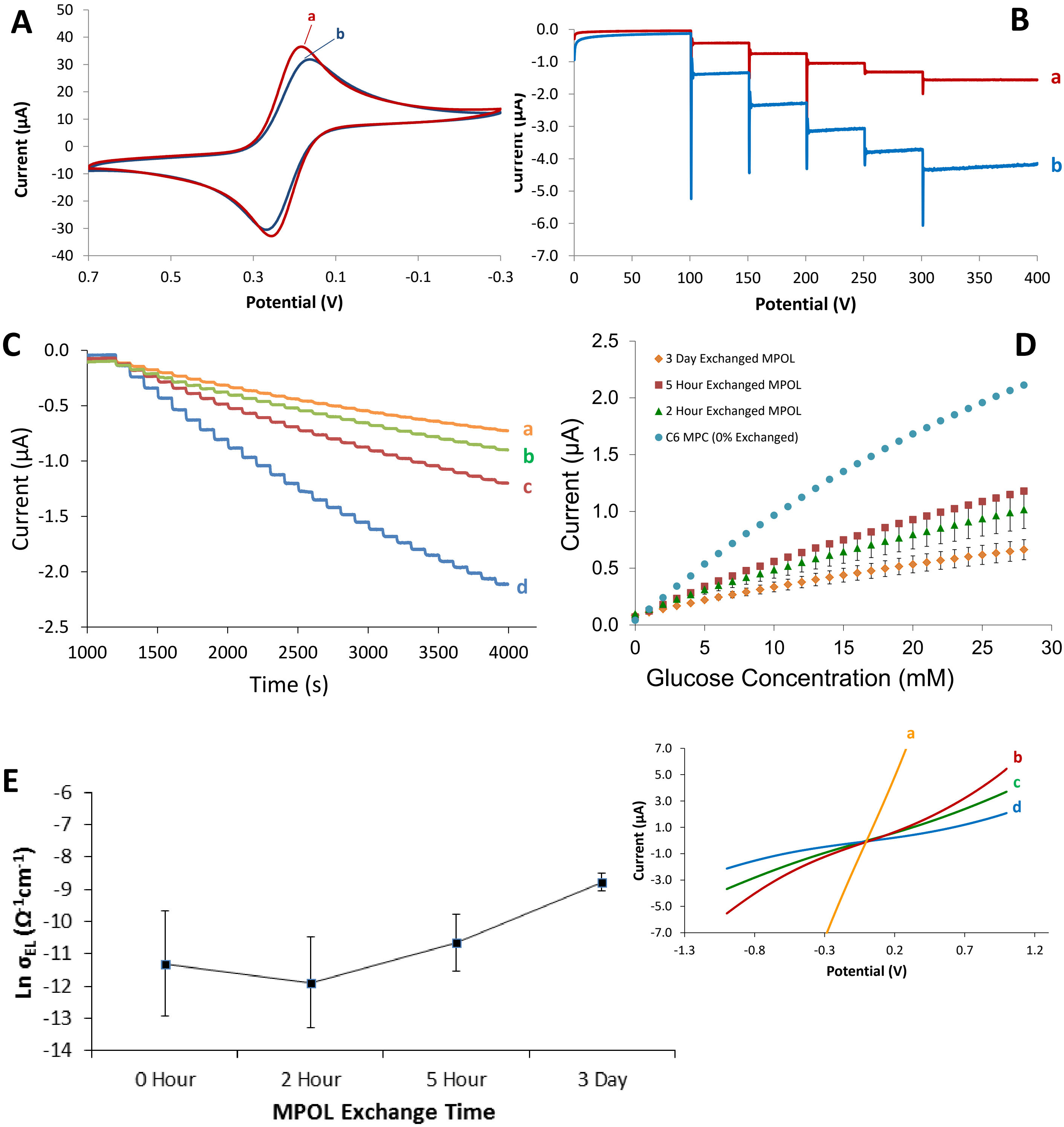


Figure SI-12. Various results related to MPOL-exchanged MPCs including **(A)** FeCN voltammetry and **(B)** amperometric response to H_2O_2 injections at MPOL SAM-modified electrodes held at +0.65V where response is either at **(a)** bare gold electrodes or **(b)** MPOL-SAM modified electrodes; **(C)** typical amperometric I-t curves of glucose sensing response at MPOL-MPC-doped xerogel electrodes with **(D)** corresponding calibration curve analysis of performance and **(E)** electronic conductivity (σ) measurements as a function of MPOL exchange time with corresponding (**inset**) examples of I-V curves obtained from measurements from an IDA electrode drop-cast with the materials: (**a**) 3 day, (**b**) 5 hour, (**c**) 2 hour, and (**d**) no MPOL-exchanged materials.

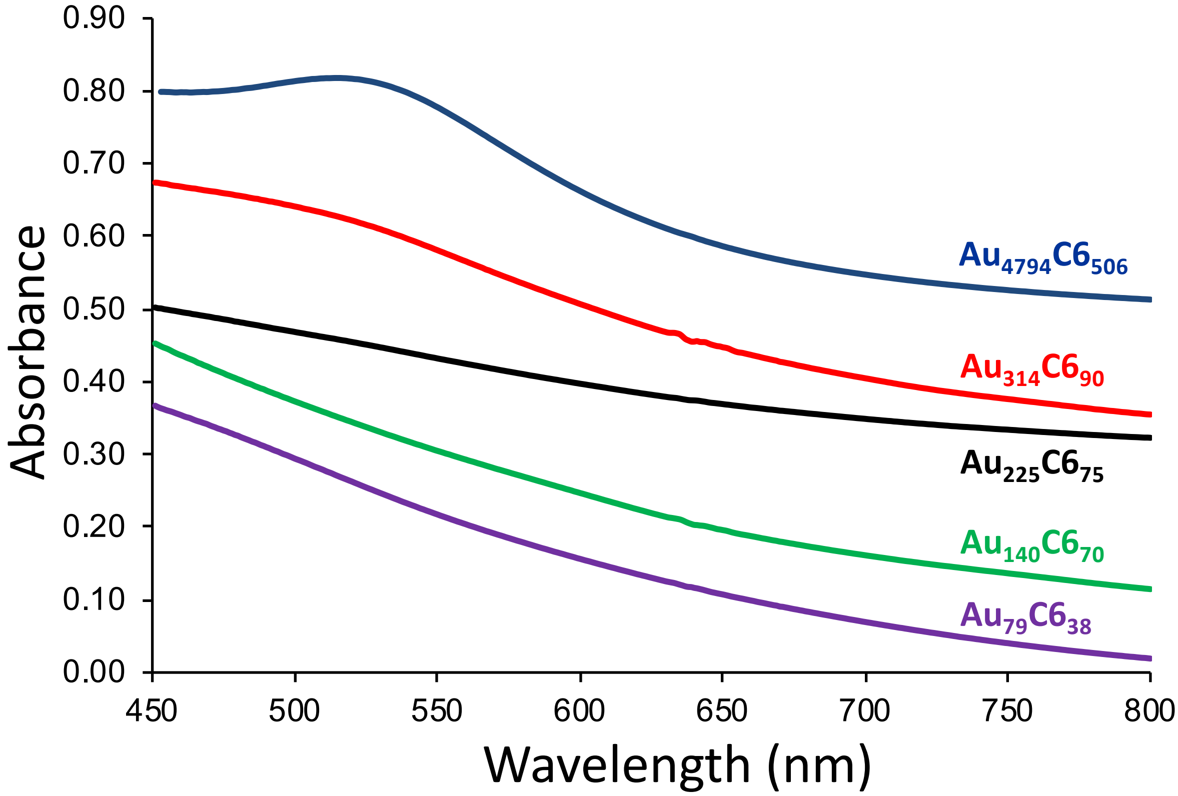


Figure SI-13. UV-Vis spectra of MPC solutions of various core sizes. The surface plasmon band at 520 nm is established to be more prominently defined with larger core sizes. Note: Spectra are offset (y axis) for more effective viewing of spectral features or lack there of.

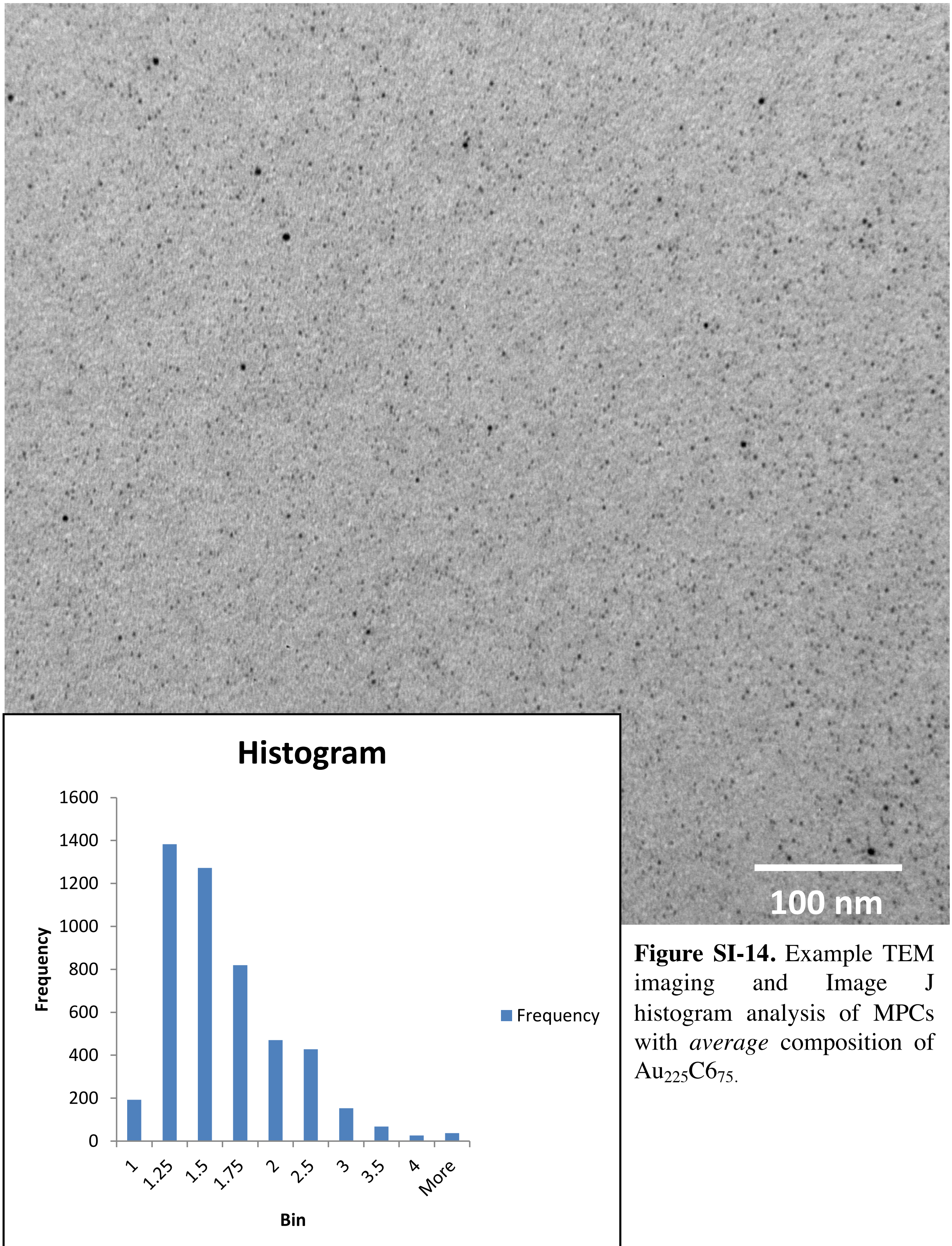
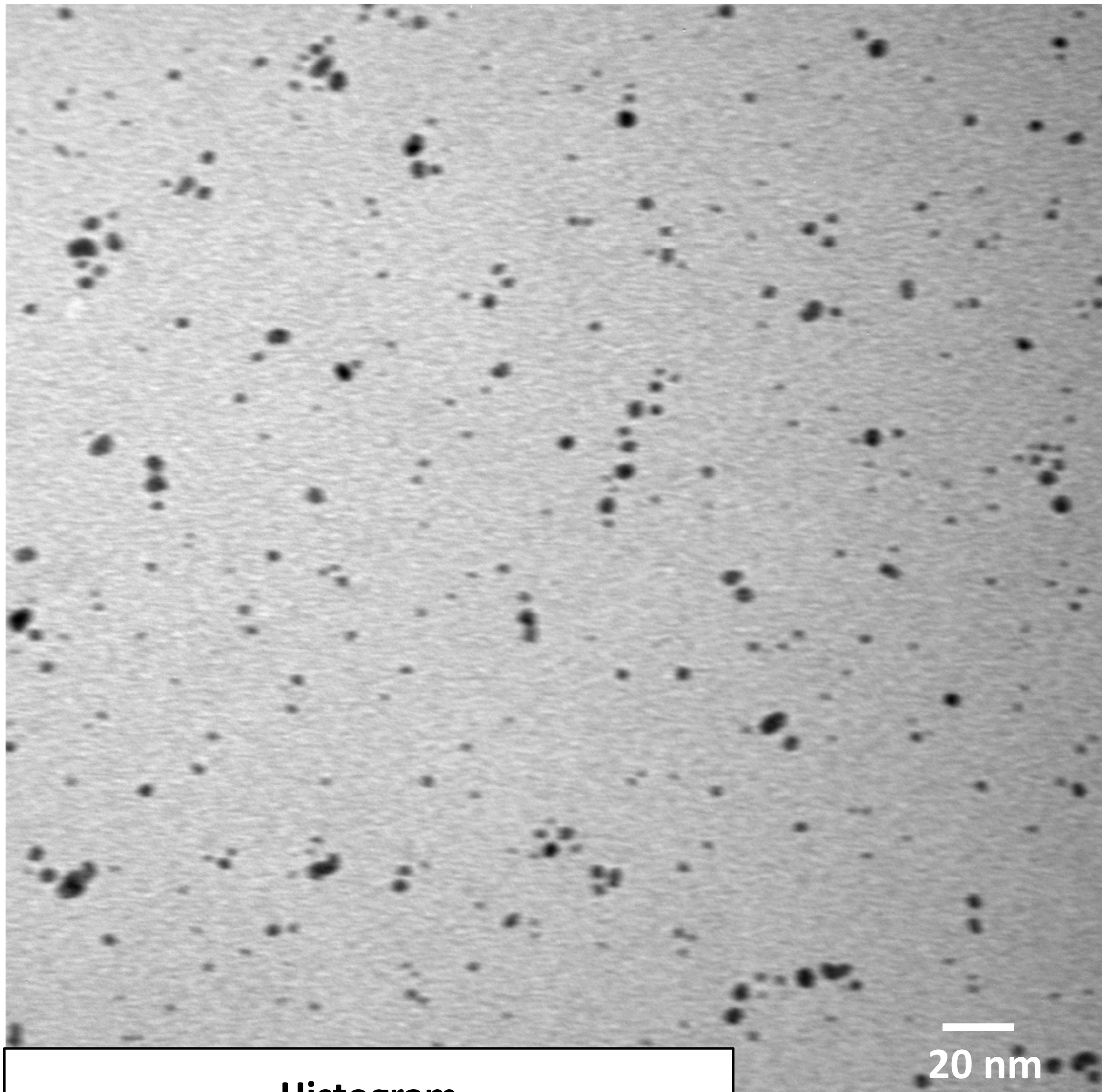


Figure SI-14. Example TEM imaging and Image J histogram analysis of MPCs with *average* composition of $Au_{225}C6_{75}$.



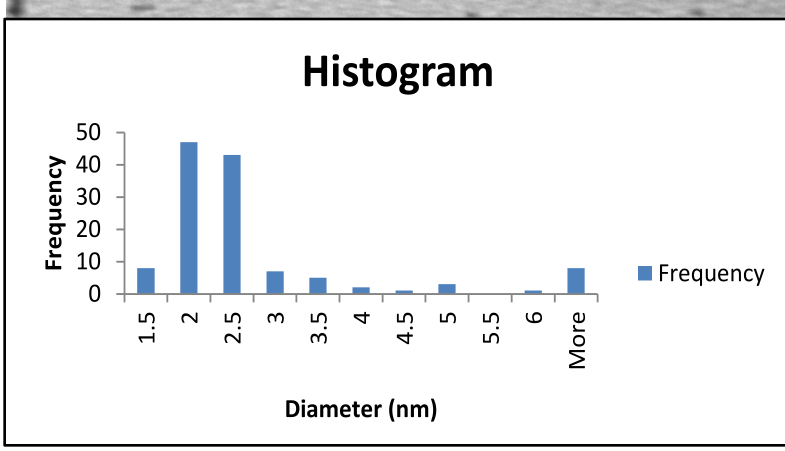


Figure SI-15. Example TEM imaging and Image J histogram analysis of MPCs with *average* composition of $Au_{314}C6_{90}$.

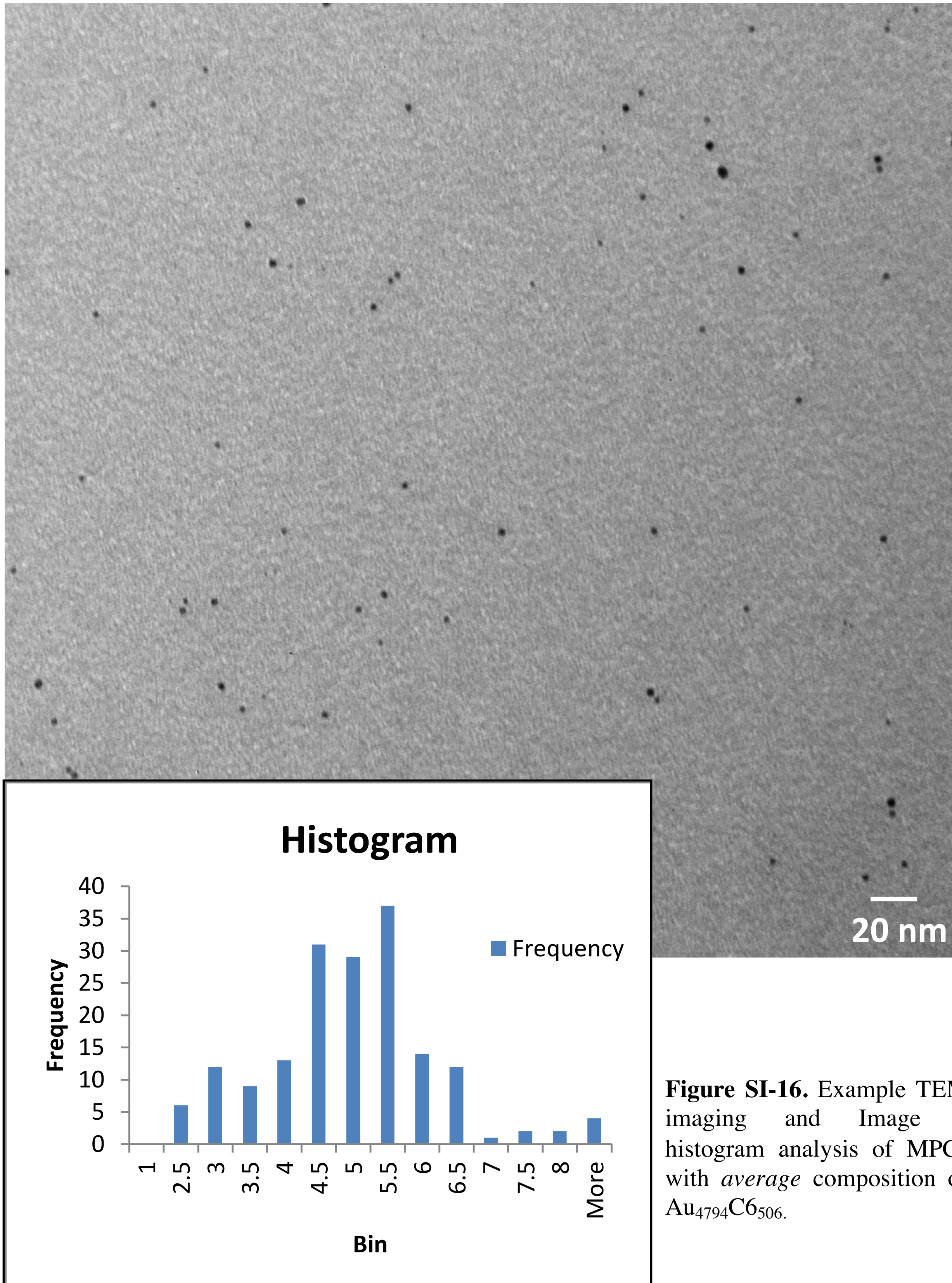


Figure SI-16. Example TEM imaging and Image J histogram analysis of MPCs with *average* composition of $Au_{4794}C6_{506}$.

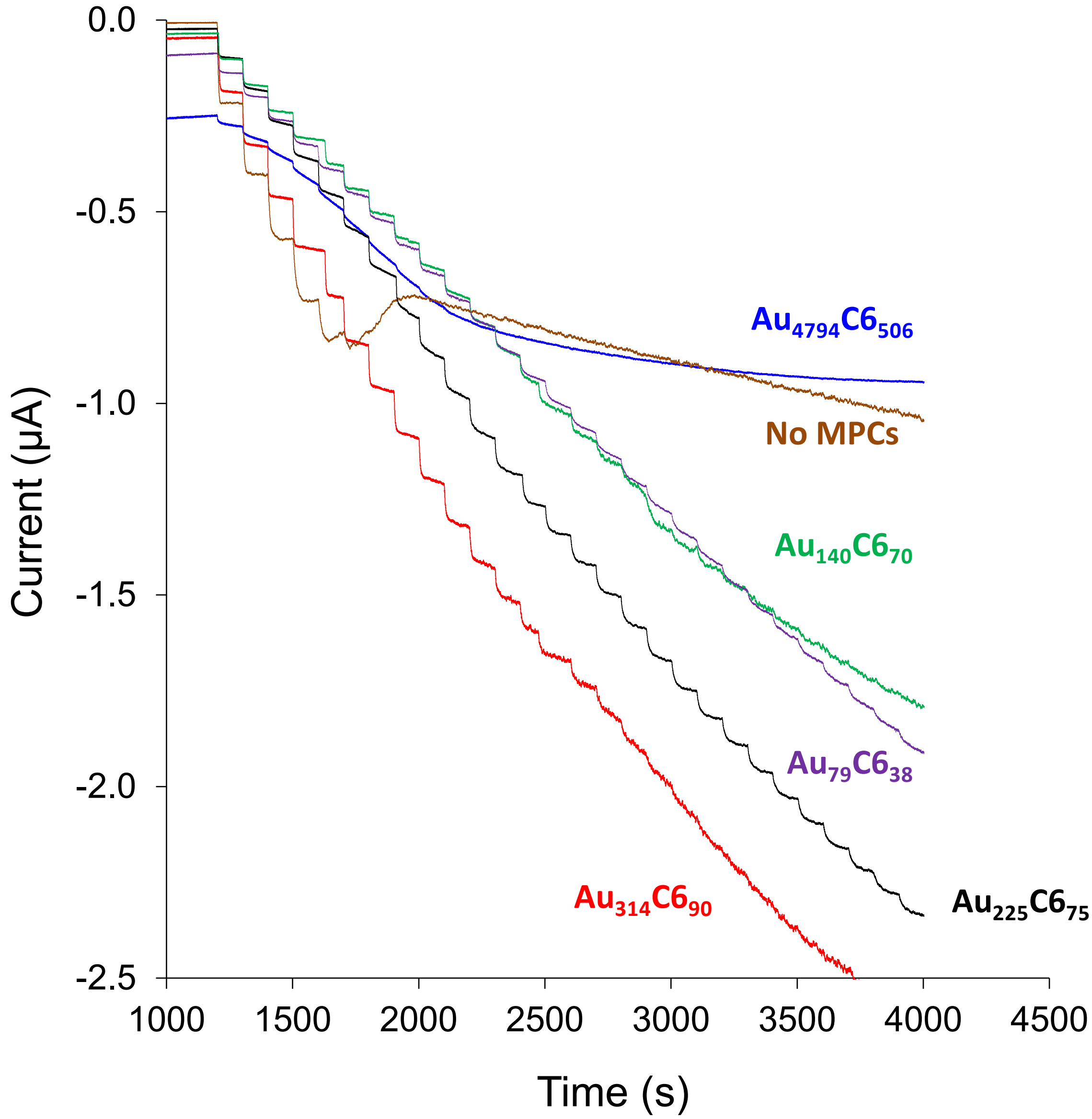


Figure SI-17. Unmodified Representative amperometric I-t curves during successive 1 mM injections of glucose at platinum electrodes modified with GOx embedded MPTMS xerogel doped with MPCs of different core sizes as well as a control xerogel with no MPCs. Note: Figure 5 without offset.

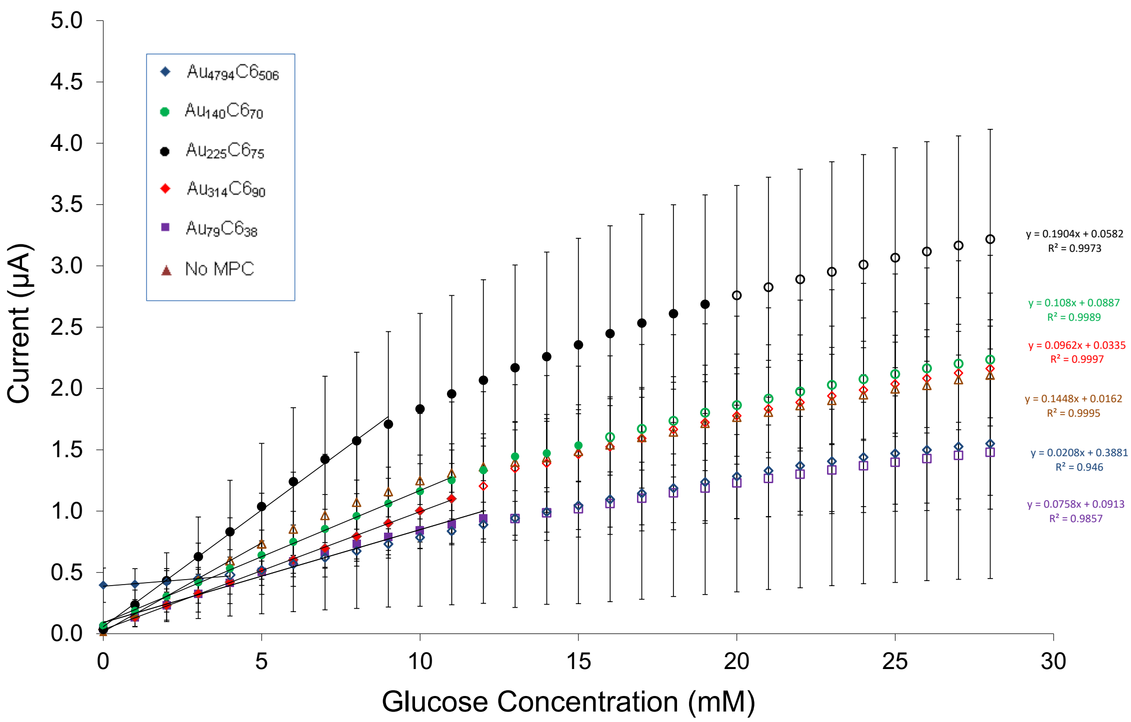


Figure SI-18. Corresponding calibration curves during successive injections of glucose at platinum electrodes modified with GOx embedded MPTMS xerogels doped with different MPCs varying by core size: $Au_{4794}C6_{506}$-MPCs, $Au_{140}C6_{70}$-MPCs, $Au_{225}C6_{75}$-MPCs, $Au_{314}C6_{90}$-MPCs and $Au_{79}C6_{38}$-MPCs, and no MPCs during film deposition, each coated with a PU outer layer. Solid symbols (▲,●,■,♦) indicate a step-like response to glucose concentration increases whereas open symbol (Δ,○,□,◇) indicate a non-step response (dynamic range).

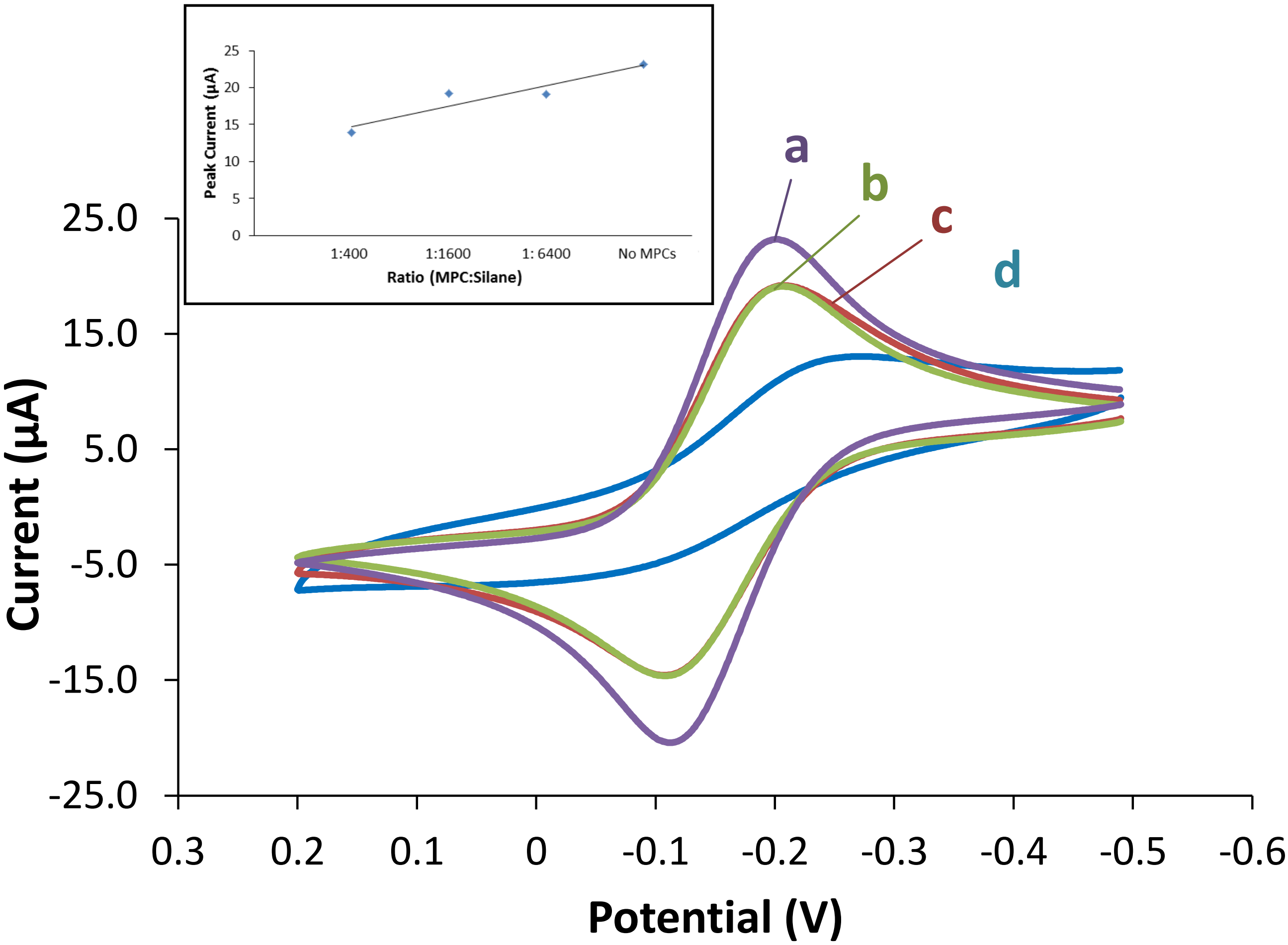


Figure SI-19. Cyclic voltammetry (CV) of 2.5 mM Hexaammineruthenium (III) chloride at platinum electrodes modified with GOx embedded MPTMS xerogels with (a) no MPCs and doped with C6 MPCs at a MPC:Silane ratio of (b) 1:6400, (c) 1:1600, and (d) 1:400. **Inset:** Reductive peak current from CVs. Voltammetry was recorded at 100 mV/s in 0.1 M KNO_3 vs. Ag/AgCl (Satrd. KCl) reference electrode.

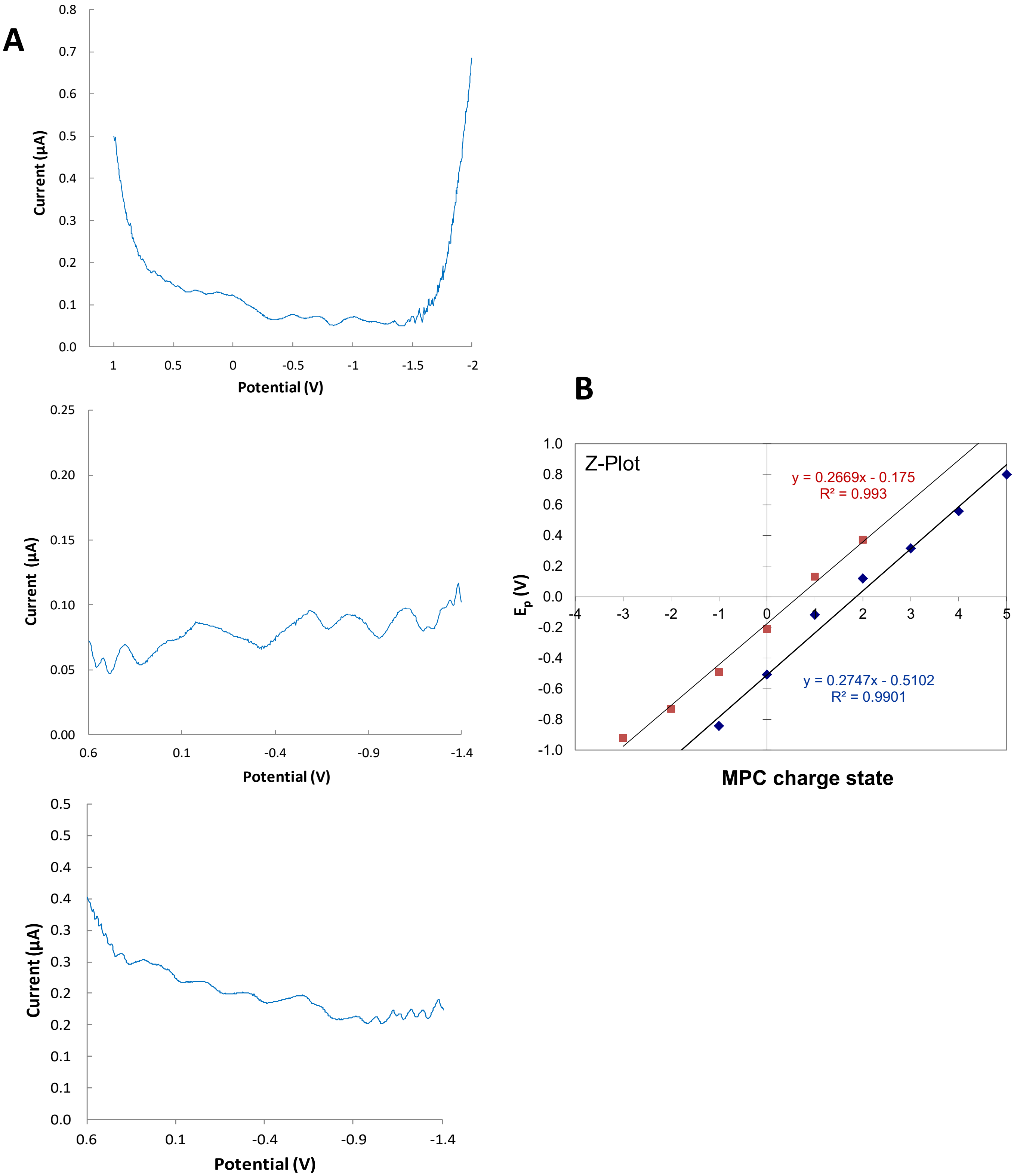


Figure SI-20. **(A)** More typical examples of differential pulse voltammetry (DPV) of MPC-doped MPTMS xerogel showing quantized double layer charging peaks from three different electrodes. The regular pattern of peaks was notably absent from DPV of undoped xerogel systems. (Solution: 0.1 M TBAP/CH_2Cl_2); **(B)** Typical Z-plot analysis for the DPV shown in Figure 6B comparing DPV analysis of MPC-doped ( ) and un-doped (■) xerogels.