

## Supporting Information

### Mesoporous SBA-15 Modified with Titanocene Complexes and Ionic liquids: Interactions with DNA and other Molecules of Biological Interest Studied by Solid State Electrochemical Techniques.

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## 1. Experimental Section

### 1.1. Reagents and solutions

The chemicals used in this study tetraethylortosilicate (TEOS) 98%, Poly(ethylene glycol)-block-poly(propylene glycol)-block-poly(ethylene glycol) (Pluronic P123,  $M_{av} = 5800$ ), tetraethoxysilane, 98% (TEOS), (3-chloropropyl)triethoxysilane, 95% (CPTS), titanocene  $[Ti(\eta^5-C_5H_5)_2Cl_2]$ , guanosine (G), bovine serum albumin (BSA), single-stranded DNA of fish sperm (s-DNA) and double stranded DNA of fish sperm (d-DNA) and transferrin were purchased from (Sigma-Aldrich) and used as received, without further purification. Organic solvents were purchased from VWR. They were distilled and dried before use, when needed, according to conventional literature methods.<sup>1</sup> Buffer phosphate solutions were prepared using  $KH_2PO_4$  and  $Na_2HPO_4$ , HCl 35% (Scharlau) and ultrapure water (Milli-Q, Micropore). The hexagonal material (SBA-15) was prepared using a poly (alkaline oxide) triblock copolymer surfactant in acidic medium, according to the method of *Zhao et al.*<sup>2</sup> The ionic liquid 1-methyl-3-[[triethoxysilyl]propyl]imidazolium chloride (IMIL)<sup>3</sup> and the lithium compound  $Li\{C_5H_4(CMePh(CH_2CH_2CH=CH_2))\}$  [16] were synthesized following reported procedures.

### 1.2. Characterization

X-ray diffraction (XRD) patterns of the silica were obtained on a Philips Diffractometer model PW3040/00 X'Pert MPD/MRD at 45 KV and 40 mA, using Cu-K $\alpha$  radiation ( $\lambda = 1.5418 \text{ \AA}$ ).  $N_2$  gas adsorption-desorption isotherms were obtained using a Micromeritics ASAP 2020 analyser, and pore size distributions were calculated using the Barret-Joyner-Halenda (BJH) model on the adsorption branch. Infrared spectra were recorded on a Nicolet-550 FT-IR spectrophotometer (in the region 4000 to 400  $cm^{-1}$ ) as nujol mulls between polyethylene pellets and KBr disks.  $^{13}C$ -CP MAS NMR (4.40  $\mu s$  900 pulse, spinning speed of 6 MHz, pulse delay 2 s)

spectra were recorded on a Varian-Infinity Plus Spectrometer at 400 MHz operating at 100.52 MHz proton frequency. X-Ray Fluorescence Spectroscopy (XRF, Philips Analytical) was employed to determine the quantity of titanium in the functionalized materials. The DRUV-Vis spectroscopic measurements were carried out on a Varian Cary-500 spectrophotometer equipped with an integrating sphere and polytetrafluoroethylene (PTFE) as reference, with  $d = 1 \text{ g cm}^{-3}$  and thickness of 6 mm. The cyclic voltammograms were recorded with a potentiostat/galvanostat Autolab PGSTAT302 Metrohm. A conventional three electrode system was used throughout the electrochemical experiments at the room temperature with a modified carbon paste electrode (CPE) as working electrode, a platinum wire as auxiliary electrode, and a saturated Ag/AgCl/KCl (3 M) electrode (Metrohm) as reference electrode against which all potentials were measured. The phosphate buffer used as electrolyte solution in the cell was purged with high purity nitrogen gas for at least 5 min to remove dissolved oxygen and then a nitrogen atmosphere was kept over the solution during measurements.

### 1.3. Synthesis of materials

#### 1.3.1. Synthesis of $[\text{Ti}(\eta^5\text{-C}_5\text{H}_5)\{\eta^5\text{-C}_5\text{H}_4(\text{CMePh}(\text{CH}_2\text{CH}_2\text{CH}=\text{CH}_2))\}\text{Cl}_2]$ .

A solution of  $\text{Li}\{\text{C}_5\text{H}_4(\text{CMePh}(\text{CH}_2\text{CH}_2\text{CH}=\text{CH}_2))\}$  (1.00 g, 4.35 mmol) in THF (50 mL) was added dropwise during 15 min to a solution of  $[\text{Ti}(\eta^5\text{-C}_5\text{H}_5)\text{Cl}_3]$  (0.91 g, 4.15 mmol) in THF (50 mL) at 0 °C. The reaction mixture was allowed to warm to room temperature and stirred for 2 h, Solvent was removed *in vacuo* and a toluene / hexane 9:1 mixture (50 mL) added to the resulting solid. The suspension was filtered and the filtrate concentrated (20 mL) and cooled to 30 °C to give the title compound as a red solid. Yield: 1.70 g, 81%, FT-IR (KBr):  $\nu = 3096 \text{ cm}^{-1}$  for  $\nu_{\text{CH}}$ ,  $1638 \text{ (m) cm}^{-1}$  for  $\nu(\text{C}=\text{C})$ ,  $^1\text{H NMR}$  (400 MHz,  $\text{CDCl}_3$ , 25 °C):  $\delta = 1.81$  (s, 3H, CMePh), 2.08 (m, 2H,  $\text{CH}_2\text{CH}_2\text{CH}=\text{CH}_2$ ), 2.36 (m, 2H,  $\text{CH}_2\text{CH}_2\text{CH}=\text{CH}_2$ ), 4.92 (m, 2H,  $\text{CH}_2\text{CH}_2\text{CH}=\text{CH}_2$ ), 5.75 (m, 1H,  $\text{CH}_2\text{CH}_2\text{CH}=\text{CH}_2$ ), 6.08 and 6.44 (m, each 2H,  $\text{C}_5\text{H}_4$ ), 6.15 (s, 5H,  $\text{C}_5\text{H}_5$ ), 6.86 (t, 1H, H in para position of Ph), 7.26 (m, 2H, H in meta position of Ph), 7.37 (d, 2H, H in ortho position of Ph) ppm,  $^{13}\text{C}\{^1\text{H}\}$  NMR (100 MHz,  $\text{CDCl}_3$ , 25 °C):  $\delta = 23.7$  and  $28.7$  ( $\text{CH}_2\text{CH}_2\text{CH}=\text{CH}_2$ ), 42.2 (CMePh), 44.1 (CpC), 113.8 ( $\text{CH}_2\text{CH}_2\text{CH}=\text{CH}_2$ ), 114.5, 117.2 and 144.9 ( $\text{C}_5\text{H}_4$ ), 120.5 ( $\text{C}_5\text{H}_5$ ), 121.9, 126.7, 127.4 and 128.4 ( $\text{C}_6\text{H}_5$ ), 138.3 ( $\text{CH}_2\text{CH}_2\text{CH}=\text{CH}_2$ ) ppm.

#### 1.3.2. Preparation of SBA-15 functionalized with ionic liquid (IMIL-SBA-15).

The ionic liquid 1-methyl-3-[(triethoxysilyl)propyl]imidazolium chloride (IMIL) (1.3 g, 4 mmol) was dissolved in chloroform and added to 1.0 g SBA-15 (dehydrated at 150 °C in vacuum for 12 h). The mixture was refluxed at 80 °C for 24 h. The material was isolated by filtration and

washed with dichloromethane (3 x 30 mL) and hexane (1 x 30 mL). The resulting material, designated as IMIL-SBA-15, was dried under vacuum and store under inert atmosphere.

### 1.3.3. Immobilization of titanocene dichloride derivatives onto SBA-15, TiCp<sub>2</sub>-SBA-15 and TiCpCp<sup>R</sup>-SBA-15.

The titanium containing mesoporous material was prepared by reaction of [Ti(η<sup>5</sup>-C<sub>5</sub>H<sub>5</sub>)<sub>2</sub>Cl<sub>2</sub>] (TiCp<sub>2</sub>Cl<sub>2</sub>) or [Ti(η<sup>5</sup>-C<sub>5</sub>H<sub>5</sub>){η<sup>5</sup>-C<sub>5</sub>H<sub>4</sub>(CMePh(CH<sub>2</sub>CH<sub>2</sub>CH=CH<sub>2</sub>))}Cl<sub>2</sub>] (TiCpCp<sup>R</sup>Cl<sub>2</sub>) with SBA-15. In a typical experiment, 1.5 g of SBA-15, previously dehydrated in vacuum at 110 °C for 12 h, was suspended in 30 mL of THF and a solution of [Ti(η<sup>5</sup>-C<sub>5</sub>H<sub>5</sub>){η<sup>5</sup>-C<sub>5</sub>H<sub>4</sub>(CMePh(CH<sub>2</sub>CH<sub>2</sub>CH=CH<sub>2</sub>))}Cl<sub>2</sub>] (0.100 g, 0.25 mmol) in 10 mL of THF was added. The suspension was stirred for 24 h at reflux temperature. The resulting pale orange solid, labelled as TiCpCp<sup>R</sup>-SBA-15, was isolated by filtration and washed with dichloromethane (4 x 30 mL) until the washings became colourless in order to ensure the complete elimination of the non-immobilized titanocene derivative. The solid was dried under vacuum and stored under inert atmosphere.

### 1.3.4. Immobilization of titanocene dichloride derivatives onto IMIL-funcionalized SBA-15, TiCp<sub>2</sub>-IMIL-SBA-15 and TiCpCp<sup>R</sup>-IMIL-SBA-15.

The nanostructured materials containing titanocene complexes and ionic liquid were prepared by reaction of TiCp<sub>2</sub>Cl<sub>2</sub> or TiCpCp<sup>R</sup>Cl<sub>2</sub> with SBA-15 previously functionalized with 1-methyl-3-[(triethoxysilyl)propyl]imidazolium chloride (IMIL). In a typical experiment, 1.0 g of IMIL-SBA-15, was suspended in 30 mL of THF and a solution of TiCpCp<sup>R</sup>Cl<sub>2</sub> (0.10 g, 0.25 mmol) in 10 mL of THF was added, The suspension was stirred for 24 h at reflux temperature. The resulting pale orange solid, labelled as TiCpCp<sup>R</sup>-IMIL-SBA-15, was isolated by filtration and washed with dichloromethane (4 x 30 mL) until the filtrate until the washings became colourless in order to ensure the complete elimination of the excess of the titanocene derivative. The solid was dried under vacuum and stored under inert atmosphere.

## 1.4. Electrode preparation.

The modified carbon paste electrodes (MCPE) used as working electrode were prepared by mixing with a pestle in an agate mortar the previously modified mesoporous microspheres with graphite (Metrohm) (6-10% (w,w) ratio) and mineral oil as agglutinant (Sigma-Aldrich) until a uniform paste was obtained. The resulting material was packed into the end of a Teflon cylindrical tube equipped with a screwing stainless steel piston providing an inner electrical contact. All of the initial electrode activity could always be restored by simply removing the outer layer of paste by treatment with polishing paper. DPV parameters were as follows: the

initial potential of -1.0 V, the end potential -1.75 or -2.0 V, the modulation time 0.057 s, the time interval 0.2 s, the step potential 1.05 mV/s, the modulation amplitude of 75 mV.

## 2. Supplementary Figures

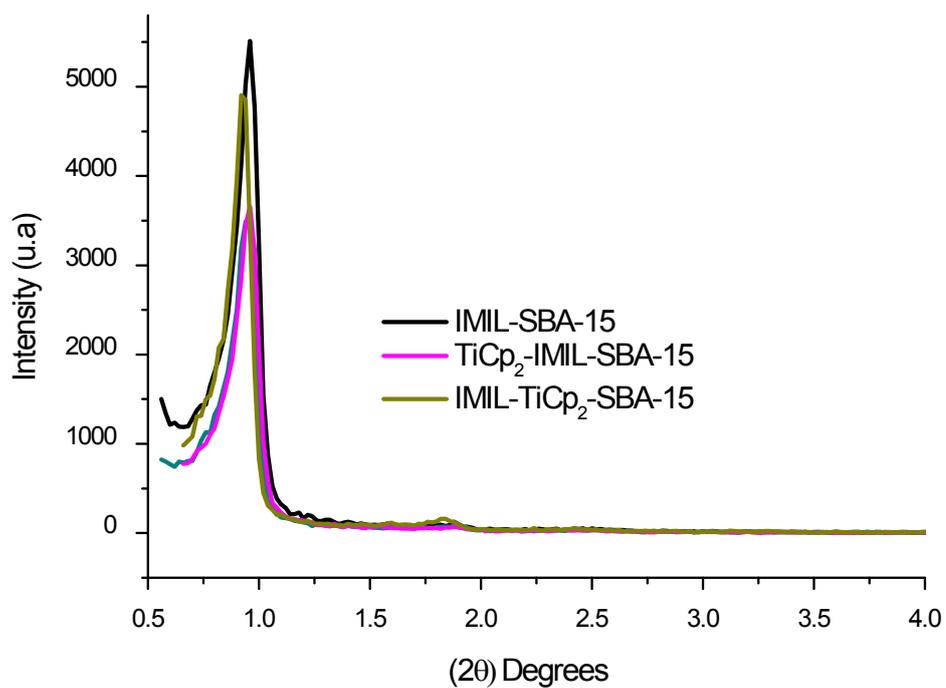
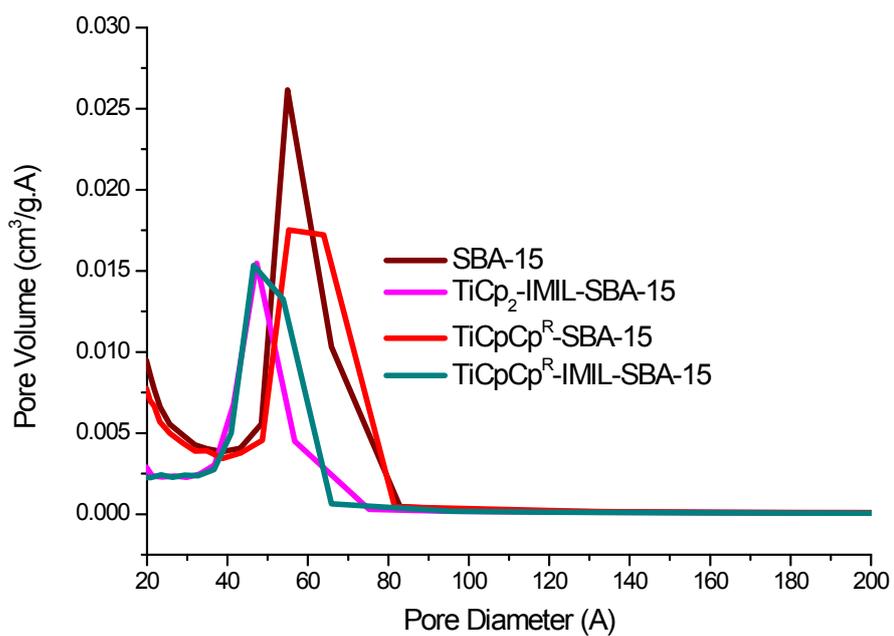
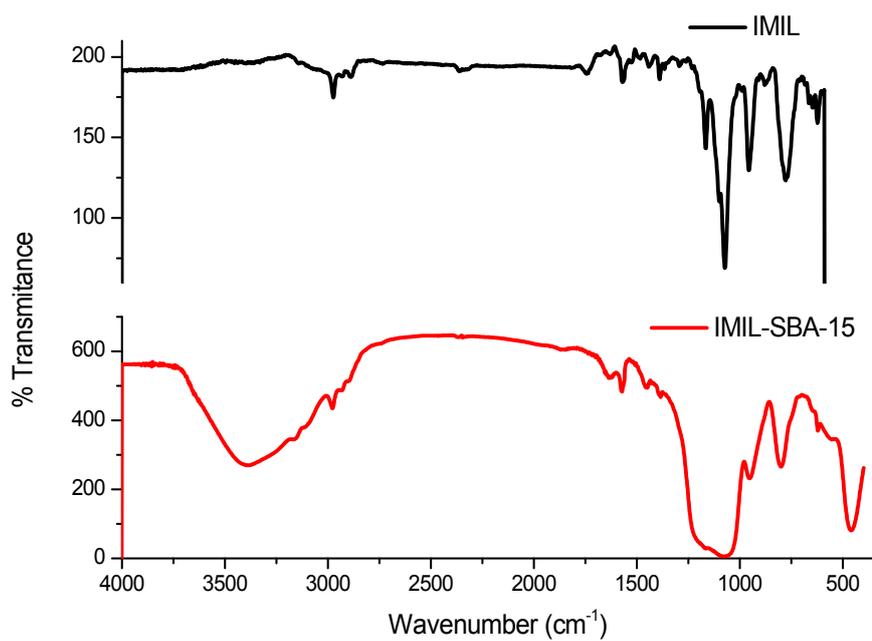
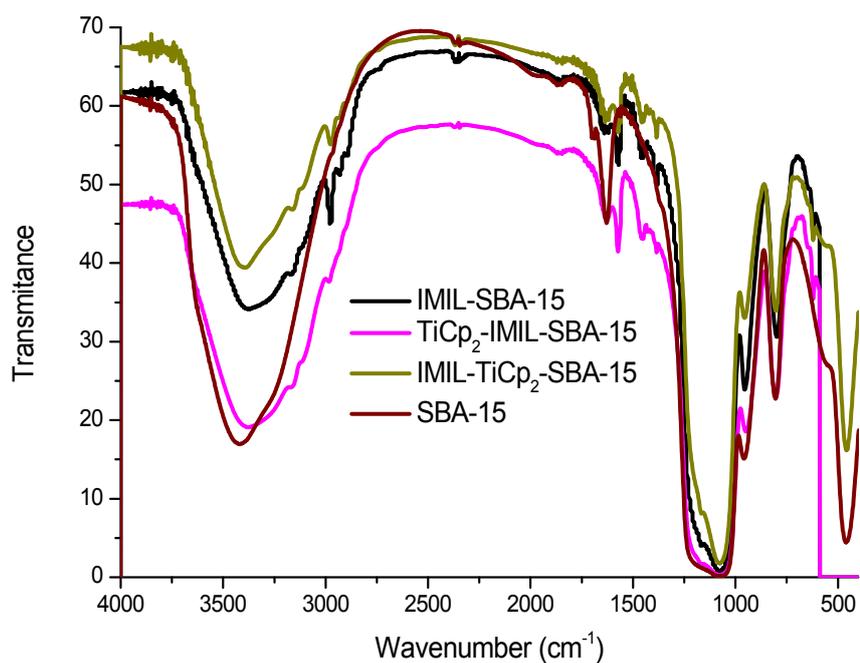


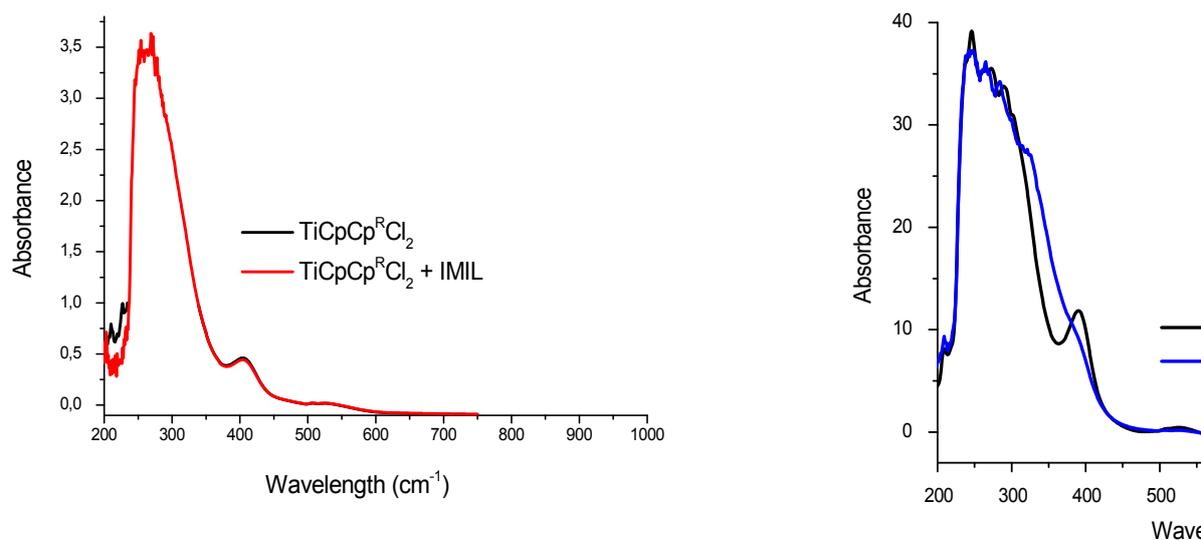
Figure S1. DRX patterns of IMIL-SBA-15, IMIL-TiCp<sub>2</sub>-SBA-15 and TiCp<sub>2</sub>-IMIL-SBA-15.



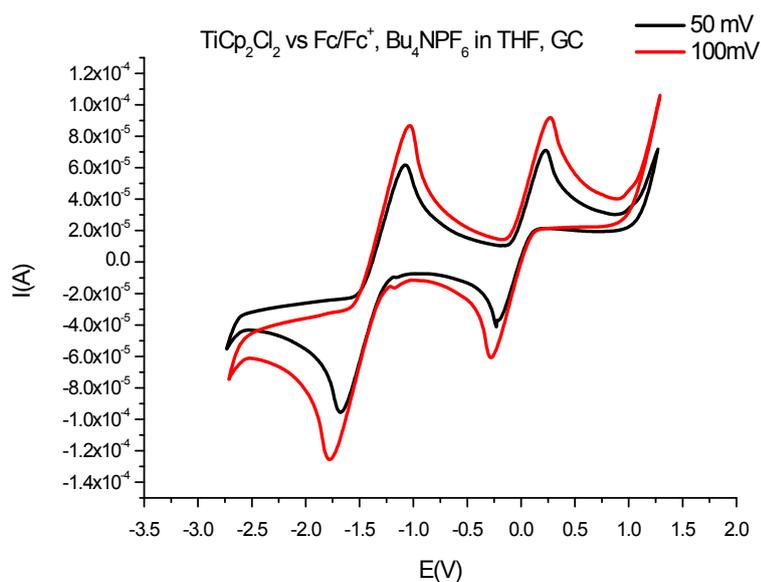
**Figure S2.** Nitrogen adsorption/desorption isotherms and pore size distribution of SBA-15, TiCpCp<sup>R</sup>-SBA-15, TiCpCp<sup>R</sup>-IMIL-SBA-15 and TiCp<sub>2</sub>-IMIL-SBA-15 Type IV isotherms typical of mesoporous silica are exhibited



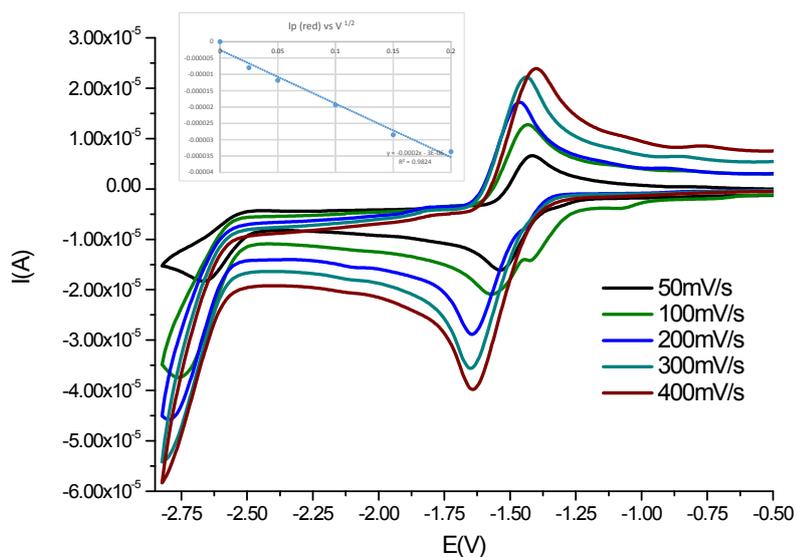
**Figure S3.** FTIR Spectra of SBA-15, IMIL-SBA-15, TiCp<sub>2</sub>-SBA-15 and IMIL-TiCp<sub>2</sub>-SBA-15, and FTIR of 1-methyl-3-[(triethoxysilyl)propyl]imidazolium chloride (IMIL) in comparison to IMIL-SBA-15.



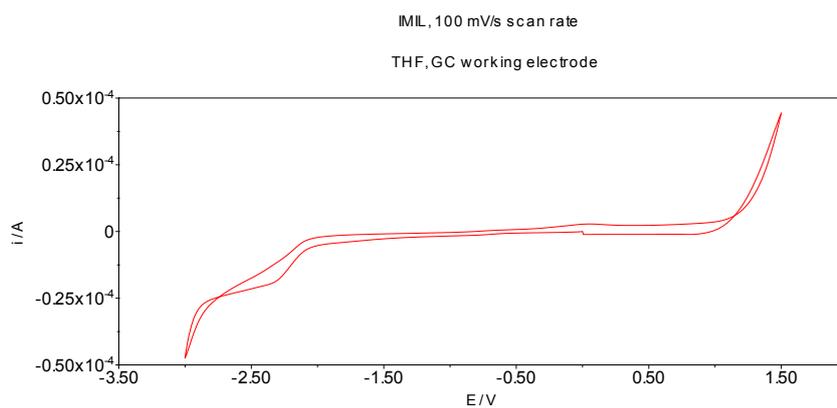
**Figure S4.** UV-Vis Spectra of  $\text{TiCpCp}^{\text{R}}\text{Cl}_2$ ,  $\text{TiCpCp}^{\text{R}}\text{Cl}_2$ -IMIL,  $\text{TiCp}_2\text{Cl}_2$  and  $\text{TiCp}_2\text{Cl}_2$ -IMIL in dichloromethane solution.



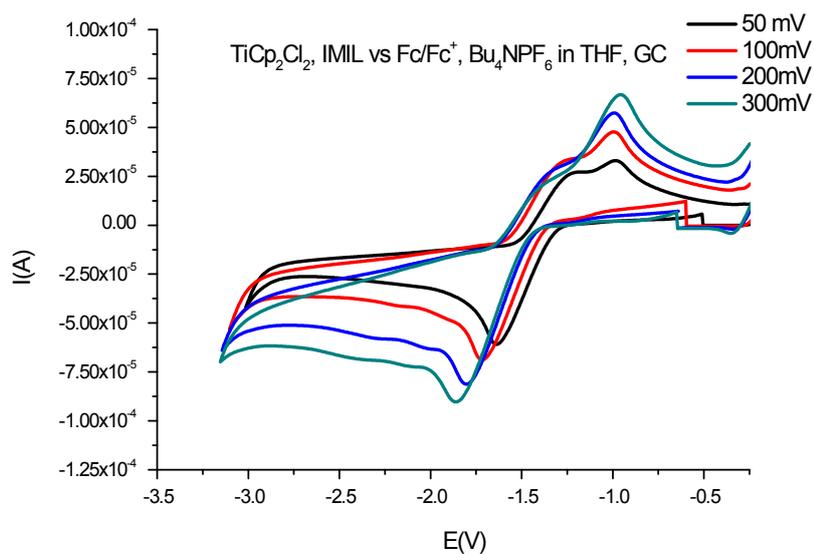
**Figure S5.** Cyclic voltammogram of  $\text{TiCp}_2\text{Cl}_2$  scan rate 50 and 100 mV/s, in THF as solvent,  $\text{Bu}_4\text{NPF}_6$  as electrolyte (0.2M), GC as working electrode, Pt as counter electrode and ferrocene/ferrocenium ( $\text{Fc}/\text{Fc}^+$ ) couple as internal standard.



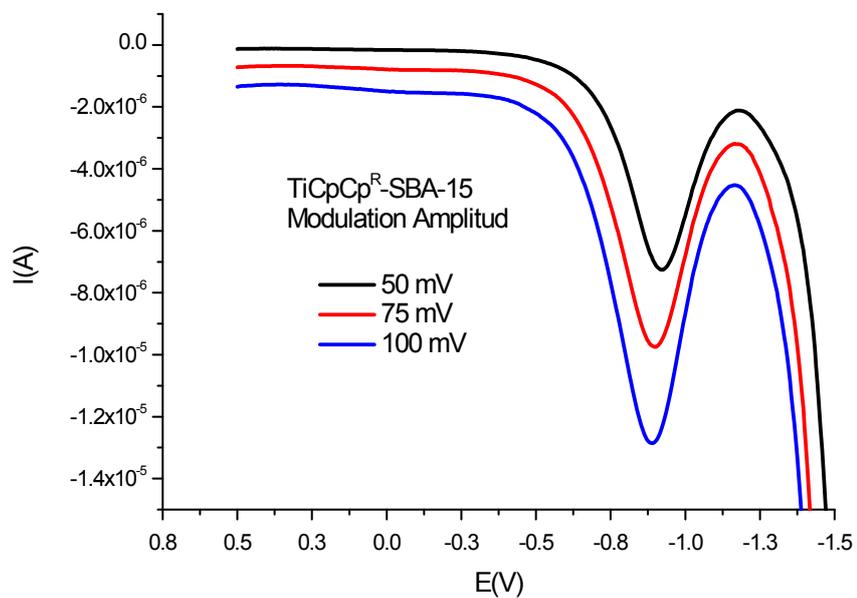
**Figure S6.** Figure Cyclic voltammogram of  $\text{TiCpCp}^{\text{R}}\text{Cl}_2$  scan rate from 50-400 mV/s in THF as solvent,  $\text{Bu}_4\text{NPF}_6$  as electrolyte (0.2M), GC as working electrode, Pt as counter electrode and  $\text{Fc}/\text{Fc}^-$  as internal standard.



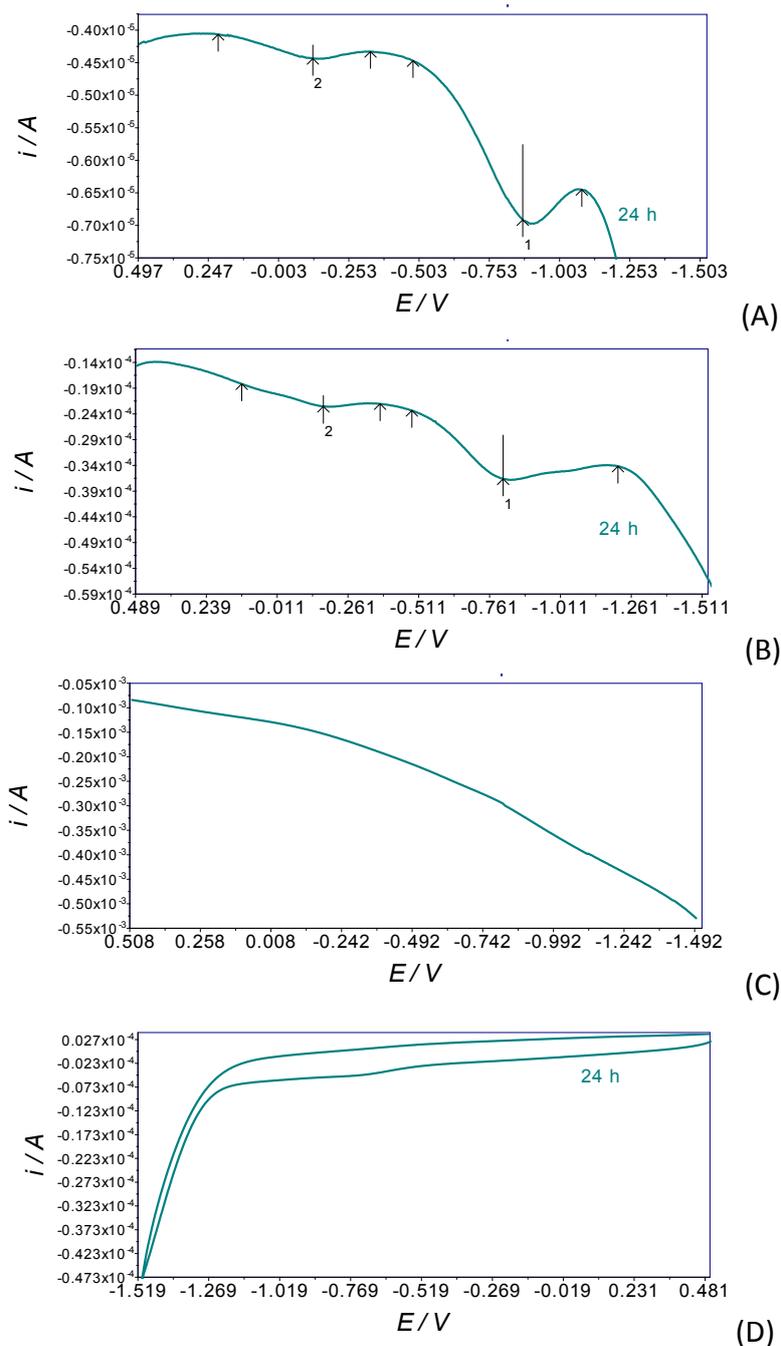
**Figure S7.** Cyclic voltammogram of IMIL scan rate 100 mV/s, in THF as solvent,  $\text{Bu}_4\text{NPF}_6$  as electrolyte (0.2M), GC as working electrode, and Pt as counter electrode.



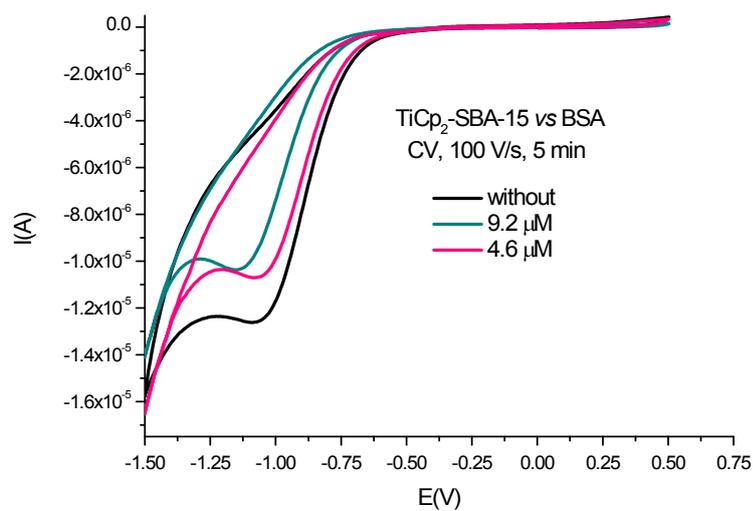
**Figure S8.** Cyclic voltammogram of  $TiCp_2Cl_2$ -IMIL scan rate from 50-100 mV/s, in THF as solvent,  $Bu_4NPF_6$  as electrolyte (0.2M), GC as working electrode, Pt as counter electrode and  $Fc/Fc^+$  as internal standard.



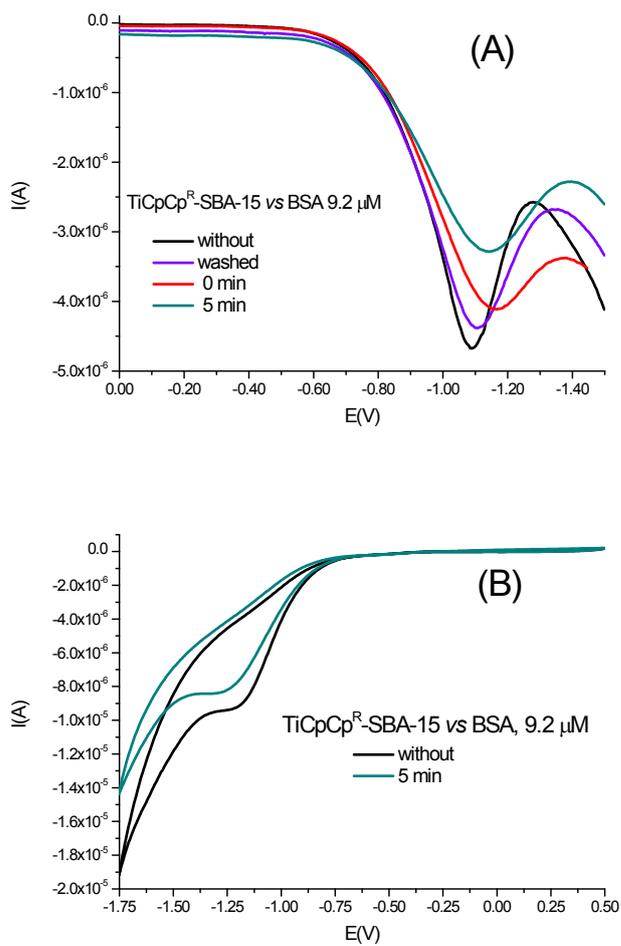
**Figure S9.** DPV of  $TiCpCp^R$ -SBA-15 immediately after immersion in aqueous phosphate buffer pH 7.4 as electrolyte at different values of modulation amplitude vs  $Ag/AgCl/KCl$  (3 M) as reference electrode.



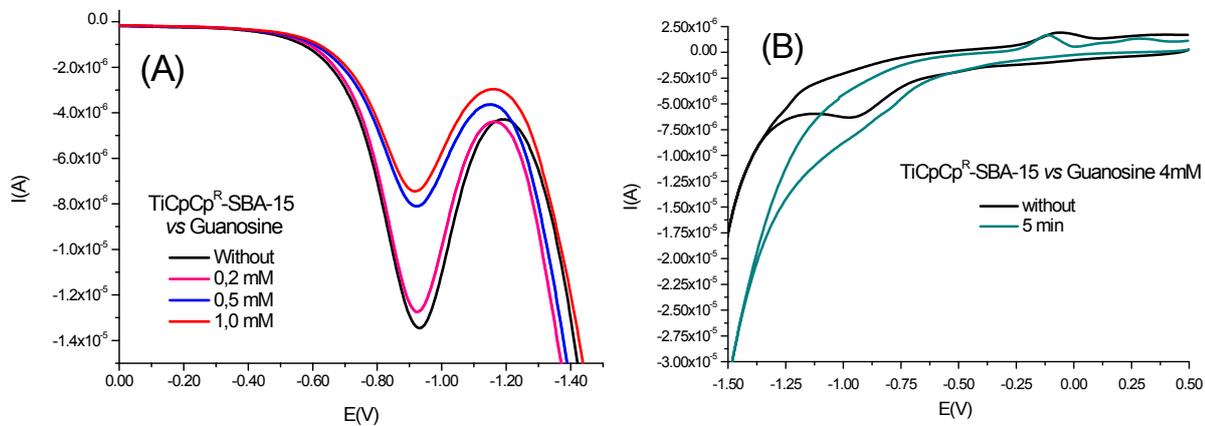
**Figure S10.** A) DPV of TiCpCp<sup>R</sup>-SBA-15 24 h after immersion in aqueous phosphate buffer pH 7.4 as electrolyte. B) DPV of TiCpCp<sup>R</sup>-SBA-15 24 h after immersion in freshly aqueous phosphate buffer pH 7.4 as electrolyte. C) and D) DPV and CV of aqueous phosphate buffer electrolyte used in (A) by using a commercial glassy carbon electrode as working electrode vs Ag/AgCl/KCl (3 M) as reference electrode.



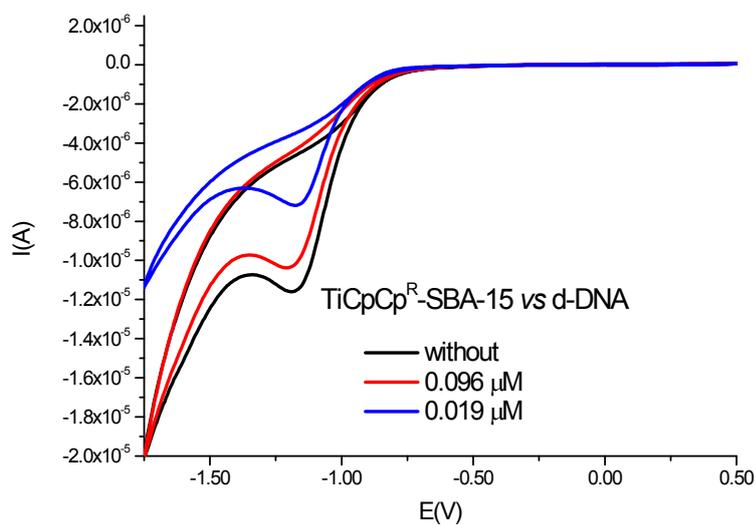
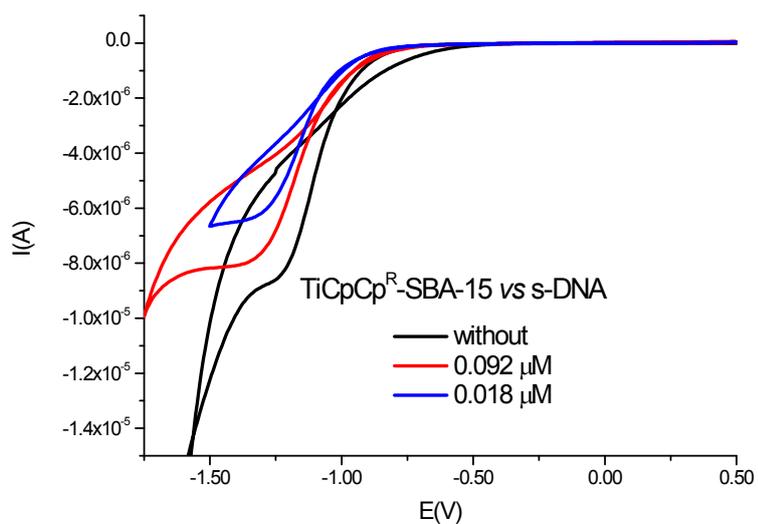
**Figure S11.** CV of TiCp<sub>2</sub>-SBA-15 /graphite electrode before and 5 minutes after immersion in a bovine serum albumin solution 4.6 and 9.2 μM, In aqueous phosphate buffer pH 7.4 as electrolyte vs Ag/AgCl/KCl (3 M) as reference electrode.



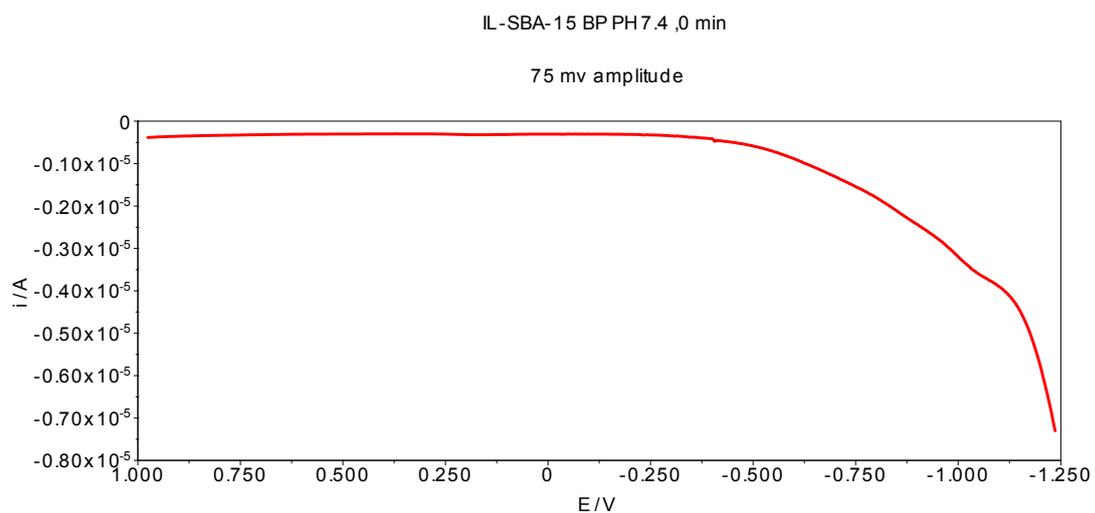
**Figure S12.** (A) DPV (75 mV modulation amplitude) and (B) CV (100mV/s) voltammograms of TiCpCp<sup>R</sup>-SBA-15 /graphite electrode 5min after immersion in a bovine serum albumin solution 9.2  $\mu$ M, in aqueous phosphate buffer pH 7.4 as electrolyte vs Ag/AgCl/KCl (3 M) as reference electrode.



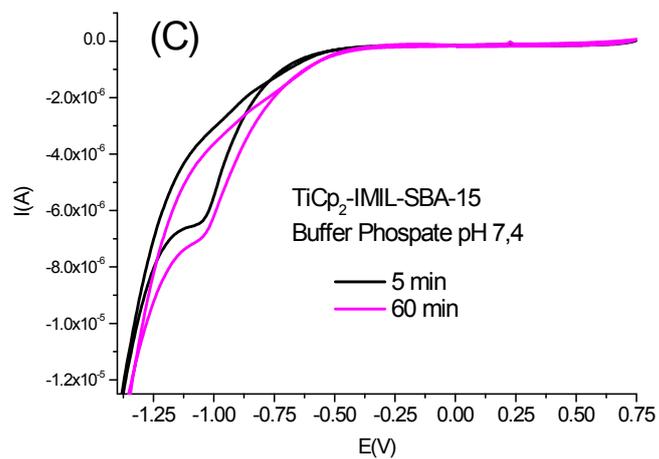
**Figure S13.** DPV (75 mV modulation amplitude) of TiCpCp<sup>R</sup>-SBA-15 vs Guanosine concentrations in the range 1.0-0.08 mM in aqueous phosphate buffer pH 7.4 (A) Guanosine 4mM at different times after immersion (B) Cyclic voltammogram of TiCpCp<sup>R</sup>-SBA-15 before and after 5 min immersion into the aqueous guanosine 4mM solution using as electrolyte vs Ag/AgCl/KCl (3 M) as reference electrode.



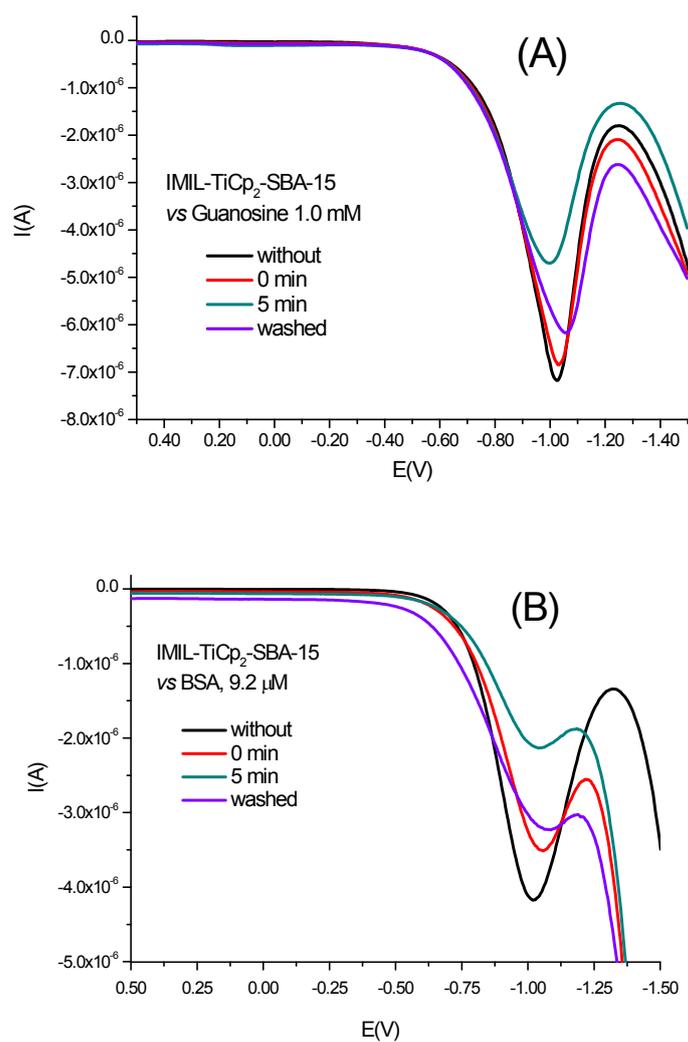
**Figure S14.** Cyclic voltammogram (100mV/s scan rate) of TiCpCp<sup>R</sup>-SBA-15 vs single and double DNA 5 minutes after immersion and concentrations 0.092 and 0.018 mM in aqueous phosphate buffer pH 7.4 as electrolyte vs Ag/AgCl/KCl (3 M) as reference electrode.



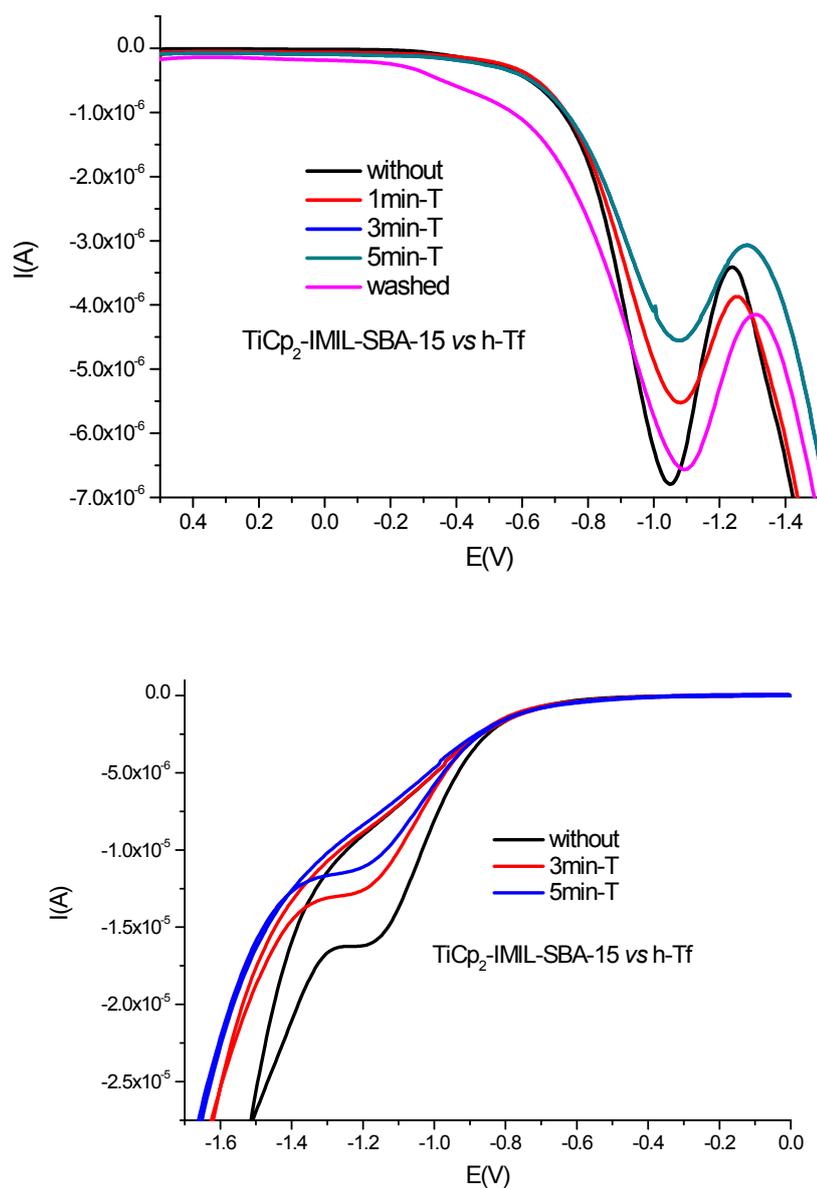
**Figure S15.** DPV of IMIL-SBA-15 after immersion in aqueous phosphate buffer pH 7.4 as electrolyte vs Ag/AgCl/KCl (3 M) as reference electrode.



**Figure S16.** CV of TiCp<sub>2</sub>-IMIL-SBA-15 /graphite electrode as a function of time after immersion into the aqueous phosphate buffer pH 7.4 as electrolyte, vs Ag/AgCl/KCl (3 M) as reference electrode.



**Figure S17.** A) DPV (75 mV modulation amplitude) of IMIL-TiCp<sub>2</sub>-SBA-15 /graphite electrode after immersion into the aqueous Guanosine 1.0 mM as a function of time vs Ag/AgCl/KCl (3 M) as reference electrode, (B) DPV (75 mV modulation amplitude) of IMIL-TiCp<sub>2</sub>-SBA-15/graphite electrode after immersion into BSA aqueous solution as a function of time vs Ag/AgCl/KCl (3 M) as reference electrode



**Figure S18.** Differential pulse voltammograms (75 mV modulation amplitude) TiCp<sub>2</sub>-IMIL-SBA-15 vs transferrin/graphite electrode after immersion into the aqueous transferrin as a function of time vs Ag/AgCl/KCl (3 M) as reference electrode.

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2. D. Zhao, Q. Huo, J. Feng, B. F. Chmelka, G. D. Stucky, *J. Am. Chem. Soc.* **1998**, 120, 6024–6036.
3. T. Sasaki, C. Zhong, M. Tada, Y. Iwasawa. *Chem. Commun.* **2005**, 2506–2508.