Selective Sensing of Bisphenol A and Bisphenol S on Platinum/Poly(diallyl dimethyl ammonium chloride)-diamond Powder Hybrid Modified Glassy Carbon Electrode

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In this work, a new platinum (Pt) nanoparticles-functionalized poly(diallyl dimethyl ammonium chloride) (PDDA)-diamond powder (DMP) composite-modified glassy carbon electrode (GCE) was fabricated for electrochemical sensing of the selective or simultaneous determination of bisphenol A (BPA) and bisphenol S (BPS). The Pt/PDDA-DMP hybrid was characterized by Scanning electron microscopy, Transmisson electron microscopy, Fourier transform infrared, X-ray diffraction analyzer. This hybrid exhibited remarkable electrocatalytic activity towards the oxidation of BPA and BPS. The simultaneous determination of BPA and BPS by cyclic voltammetry yielded a difference of 0.316 V, which was sufficiently large for their potential recognition and simultaneous detection in mixtures. Differential pulse voltammetry was successfully used to simultaneously quantify BPA and BPS within the concentration range of 5–30 and 10–60 μM under optimal conditions, respectively. The detection limits (S/N = 3) of Pt/PDDA-DMP/GCE for BPA and BPS were 0.6 and 2.0 μM, respectively. The fabricated electrode showed good sensitivity, stability, and selectivity. The proposed method was successfully applied to determine BPA and BPS in biological samples.

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Bisphenol A (BPA) [2,2-bis (4-hydroxyphenyl) propane (C15H16O2)] is an important chemical raw material that is widely used in industrial production and daily life.1-3 It is extensively used in food cans, packing materials, water bottles, and baby bottles.4 As an environmental hormone material that causes abnormal hormone activity, BPA causes irreversible damage to organisms and the environment, and low doses can even result in human endocrine disorders.5-7 In addition, BPA negatively affects female hormones, which can lead to a series of female diseases, such as induced precocious puberty, reproductive dysfunction, endometrial hyperplasia, and recurrent miscarriage.8,9 Canada and China banned the use of BPA in baby bottles in 2010 and 2011, respectively, because of its negative effects on humans, particularly to children and infants.9 In recent years, numerous companies and factories are currently using bisphenol S (BPS) [4,4’ sulfonyldiphenol (C12H9O2S)] instead of BPA.10 BPS is widely used in polyethersulfone. The production and use of BPS as a chemical additive in pesticides, dyestuffs, colorfast agents, dye dispersants, and monomer in cyclic carbonates are increasing and will be used in polyethylene terephthalate.11-13 Although BPS has high thermal stability and low biodegradability,13 it also has biological toxicity14,15 and negative hormone effects.16-18 BPS and BPA disrupt the human endocrine system by interfering with several functional nuclear receptors.18 Thus, BPS is not a safe and reliable replacement for BPA. Several methods are available for state of the art tools for detecting BPS and BPA, such as automated on-line column-switching high performance liquid chromatography isotope dilution tandem mass spectrometry,19 analytical parallel gas chromatography mass spectrometry,20 synchronous fluorescence spectroscopy,21 and molecularly implanted solid-phase extraction.22 These techniques are highly sensitive and have a low detection limit. However, they are inconvenient in their operation, have a narrow range of applications, and require excessive time consumption for sample pretreatments. In addition, they are expensive and complicated for on-site measurements.23 Sample pretreatment of environmental hormones is also complicated. Therefore, an easy and sensitive analytical method for the determination of BPA and BPS is urgently needed.

In recent years, electrochemical detection techniques have proven quite promising because they are simple, have a rapid response speed, inexpensive, and are widely accepted analytical systems for detecting BPA. With the development of technology, sensors are becoming increasingly diverse, such as sensors based on enzymes,24-25 proteins,26 various carbon nanomaterials,27,28 and nanoparticles.29-30 Among them, platinum (Pt) nanoparticles are used for the measurement of BPA and BPS because of their high catalytic performance, huge surface area, and porous channels.31 To reduce the amount of Pt nanoparticles and enhance its catalytic capabilities, controllable preparation and a reasonable supporting material are necessary. Various base materials, such as the conducting polymer as the base material of loaded platinum nanoparticles,32 graphene, and carbon nanotubes have been investigated.33-34 Such materials all have different levels of adsorption to the target, thereby reducing the stability of the electrochemical response.

Activated carbon has been widely utilized as a support material for metal or metal oxide-loaded catalysts. Activated carbon is composed of amorphous sp2 carbon atoms, and it can be used for catalytic processes. However, no carbon material that consists of pure sp2 carbon atoms (diamond) has been examined as a catalyst support material.35 Diamond has long been chemically considered an inert material. A previous study reported that the surface of diamond behaves as an organic substance in certain chemical reactions.36 The diamond surface is expected to have possibility of chemical reactivates as an organic substance.37 These findings led us to develop a novel utilization of diamond as a material of a catalyst or as a catalyst support for chemical reactions.

To date, several scholars have focused on the diamond series, such as diamond electrodes,38,39 and modified electrodes that use various types of diamonds,40 but only a few studies on electrochemical sensors for diamond powder (DMP) detection of BPA and BPS have been reported. DMP is a pure carbon material with abundant negative charge. It has high chemical and electrochemical properties, as well as strong resistance to high temperature and corrosion. Its electrochemical response can remain stable for a long time.42-44 The advantage of using DMP as a catalyst support is the weak interaction between loaded metal and DMP.45 However, DMP is a hydrophobic material. Moreover, no specific study concerning the dispensability of DMP in water by the functionalization process has been conducted, and the determination of BPA and BPS by electrocatalytic oxidation using a functional DMP composite as an electrochemical sensor has not been investigated.

In this study, we used a novel and highly effective polyelectrolyte functionalization method for DMP using poly(diallyl dimethyl

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ammonium chloride) (PDDA), which is a water-soluble quaternary ammonium and strong polyelectrolyte. Pt nanoparticles were then synthesized in situ on the surface of PDDA-DMP using \( \text{H}_2\text{PtCl}_6 \) as the precursor by reduction of ethylene glycol. The working electrode used was glass carbon electrode (GCE) modified with Pt/PDDA-DMP hybrid by physical adsorption. Subsequently, a stable, sensitive, rapid, inexpensive, and selective analytical method was successfully applied in the determination of BPA and BPS in simulated urine samples.

Experimental

**Reagents.**—BPA was obtained from the Tianjin Institute of Fine Chemicals. BPS was obtained from Accu Standard Inc. (USA). Dopamine (DA), uric acid (UA), and urea (UR) were obtained from Alfa Aesar Co., Ltd. Ascorbic acid (AA) was obtained from Shanghai guangnuo Chemical Technology Co., Ltd. DMP was provided by Professor Chunning Wang. All chemicals were of analytical grade and used without further purification. PBS (0.1 M, pH 6.0) was prepared by mixing standard solutions of \( K_2\text{HPO}_4 \) and \( K\text{H}_2\text{PO}_4 \), and its pH was adjusted using 0.5 M \( \text{H}_3\text{PO}_4 \) or 1.0 M \( \text{NaOH} \). All aqueous solutions were prepared using Milli-Q ultrapure water (Millipore, ≥18 MΩcm).

**Preparation of Pt/PDDA-DMP.**—The PDDA-DMP hybrid was prepared by the self-assembly method. In a typical procedure, 40 mg of DMP, which was pretreated by milling for 30 min in agate mortar, was added into 40 mL of water containing 40 μL of PDDA; subsequently, the mixture was ultrasonically treated for 30 min and magnetically stirred for 5 h. This suspension was centrifuged for 5 min at 12,000 rpm to remove excess DMP and PDDA. The product was washed thoroughly with water and ethanol (3 × 50 mL), centrifuged at room temperature, and dried in a vacuum at 60 °C for 12 h. Similarly, sodium dodecyl sulfate-DMP (SDS-DMP) and polyvinylpyrrolidone-DMP (PVP-DMP) hybrid were prepared by the same procedures, respectively. Pt nanoparticles were loaded by hydrothermal reduction. First, 30 mg of PDDA-DMP was placed into an agate mortar and milled for 30 min. The mixture was then added into 30 mL of Milli-Q ultrapure water and ultrasonically treated for 1.5 h to form a stable PDDA-DMP colloid. About 10 mL of aqueous solution containing \( 1 \text{mM} \text{H}_2\text{PtCl}_6 \) was added to the PDDA-DMP colloid and then magnetically stirred for 3 h to form a stable \( \text{PtCl}_2^-/\text{PDDA-DMP} \) precursor. Subsequently, 100 mL of ethylene glycol was injected into the precursor with magnetic stirring for 3 h, and the mixture was maintained at 130 °C for 12 h under magnetic stirring. Finally, the above mixture solution was centrifuged at 12,000 rpm for 5 min to remove excess PDDA-DMP and \( \text{H}_2\text{PtCl}_6 \). The product was washed thoroughly with water and ethanol (3 × 50 mL), centrifuged at room temperature, and dried in a vacuum at 60 °C for 12 h, and denoted as Pt/PDDA-DMP.

**Characterization of materials.**—The surface morphologies of samples were characterized by scanning electron microscopy (SEM, KYKY-1000B) and transmission electron microscopy (TEM, Tecnai G2 F30, FEI, USA). Fourier transform infrared (FTIR) spectra were obtained (TENOR 27). The phase structures of the samples were measured by X-ray diffraction (XRD) using an XRD analyzer (Rigaku D/max-2400, Cu Kα radiation, λ = 0.15418 nm).

**Preparation of the working electrode and electrochemical measurement.**—A glassy carbon electrode was polished to a mirror finish with 1.0 and 0.3 μm alumina suspensions. The polished electrode was washed with ethanol/water solution (1:1, v/v) and then ultrasonically treated in ultra-pure water for 5 min. The electrode was then ready to use as a substrate of the working electrode. The electrodes for electrochemical measurements were fabricated by dispersing 1.0 mg of Pt/PDDA-DMP hybrid in 1.0 mL of ultra-pure water under an ultrasonic bath for 0.5 h. Approximately 6.0 μL of the suspension was dropped on the glassy carbon electrode, and the solvent was evaporated at room temperature. The modified electrode was denoted as Pt/PDDA-DMP/GCE.

Electrochemical experiments were carried out in an electrochemical cell with a three-electrode configuration using a CHI660C electrochemical workstation (CHI, USA). Pt/PDDA-DMP hybrid supported on GCE were used as a working electrode. The Pt wire and a saturated calomel electrode (SCE) served as a counter electrode and reference electrode, respectively.

**Results and Discussion**

In this study, a Pt/PDDA-DMP hybrid was prepared and characterized by a simple synthetic method. The PDDA-DMP, SDS-DMP, and PVP-DMP hybrid were prepared using the same method. The results indicated that only PDDA-DMP could easily form a well-dispersed solution, because PDDA could bind with negatively charged DMP to prevent the aggregation of DMP through electrostatic repulsion. Therefore, the present work offers a new avenue to broaden the applications of DMP in electrochemical sensors.

**Characterization of Pt/PDDA-DMP.**—Morphologies of Pt nanoparticles deposited on PDDA-DMP hybrid were characterized by SEM, TEM, and high resolution TEM (HRTEM). Fig. 1A shows a typical SEM image of this hybrid. Figs. 1C and 1D show a typical TEM image and HRTEM image of the as-synthesized hybrid, respectively. Fig. 1C shows that Pt nanocrystals were uniformly distributed on the PDDA-DMP hybrid. Moreover, Pt/PDDA-DMP was decorated by nanosized Pt nanoparticles, indicating a strong interaction between PDDA-DMP support and particles. Fig. 1D reveals the lattice fringe with interplanar spacing of 0.266 nm, which was assigned to the (111) plane of the face-centered-cubic (fcc) crystal structure of Pt/PDDA-DMP. Selected area electron diffraction (SAED) (the inset of Fig. 1D) suggested that the as-synthesized hybrid was polycrystalline structures with diffraction cycles. Fig. 1B presents the XRD patterns of DMP, PDDA-DMP, and Pt/PDDA-DMP. The curve of Pt/PDDA-DMP showed that the strong diffraction peaks at \( 20 = 39.6^\circ, 46.0^\circ, 67.5^\circ \), and 81.2° could be assigned to the characteristic (1 1 1), (2 2 0), and (3 1 1) crystalline planes of Pt, respectively, which possessed a fcc structure. The intensive reflections at 43.8° (1 1 1) and 75.2° (2 2 0) were assigned to the characteristic (2 2 0) and (3 1 1) crystalline planes of Pt, respectively.

![Figure 1](image-url)
were typical of cubic DMP lattice reflections, which could be observed from the curves of PDDA-DMP and DMP. The XRD curves confirmed that the Pt nanoparticles were successfully loaded on the surfaces of support materials. Highly dispersed nanoparticles on supports with large surface areas showed extraordinary advantages in catalytic activity and sensor sensitivity. Therefore, Pt/PDDA-DMP hybrid was a potential material for use in future nanotechnology.

The FTIR spectra of samples were also examined (SI. 1.1). Although the absorption peaks of PDDA-DMP and Pt/PDDA-DMP were weaker than those of DMP, no other differences were observed between them.

Characterization of electrochemical behavior of Pt/PDDA-DMP/GCE.—The electrochemical behavior of Pt/PDDA-DMP/GCE was analyzed (SI. 1.2). The Pt/PDDA-DMP hybrid demonstrated obvious electrocatalysis for probes, which promoted the transfer of electrons on the probe to the surface of the electrode. To evaluate the catalytic activity and stability of catalysts, chronoamperometry experiments were carried out in 0.1 M PBS solution containing 0.1 mM BPA (A) and BPS (B) under constant potentials of 0.63 and 0.95 V, respectively. The constant current was 200 s. Double layers charging and abundant active sites resulted in high initial current density available for BPA and BPS activation (Fig. 2). As shown in Fig. 2A, Pt/PDDA-DMP/GCE (c) presented the highest limiting current density, which was over five times compared with PDDA-DMP/GCE (b) and GCE (a). Similarly, the response of BPS on different electrodes was observed in Fig. 2B; the current on Pt/PDDA-DMP/GCE (c) was about 10 times than that on PDDA-DMP/GCE (b) and GCE (a). These results confirmed that the electrocatalytic stability for BPA and BPS oxidation on the Pt/PDDA-DMP/GCE catalyst was the highest than those on the PDDA-DMP/GCE and GCE catalysts, thereby implying that Pt nanoparticles improved the stability and electrocatalytic activity of the catalysts.

For further characterization of the modified electrode, electrochemical impedance spectroscopy was also performed. Fig. 2C presents the Nyquist diagrams of bare GCE, PDDA-DMP/GCE curve c, and Pt/PDDA-DMP/GCE (curve b) in 5.0 mM [Fe(CN)₆]³⁻/⁴⁻ (1:1) containing 0.10 M KCl. Fig. 2 (curve a) shows the lowest Rct on the bare GCE electrode, which indicated the fastest electron transfer rate between bare electrode and [Fe(CN)₆]³⁻/⁴⁻. The
diameter of the semicircle for PDDA-DMP modified GCE electrode was larger than that of bare GCE electrode, which suggested that the PDDA-DMP film on the surface of the GCE electrode hindered electron transfer between the redox probe of $[\text{Fe(CN)}_6]^{3-/4-}$ and the electrode surface. Thus, DMP was not conductive for the GCE electrode. However, when Pt nanoparticles were loaded on the PDDA-DMP film, the diameter decreased significantly. Electron transfer resistance decreased when GCE was modified with Pt/PDDA-DMP film, which facilitated the electron transfer of $[\text{Fe(CN)}_6]^{3-/4-}$. These results further demonstrated that Pt/PDDA-DMP was successfully immobilized onto the GCE surface.

**Electrochemical behaviors of BPA and BPS on Pt/PDDA-DMP/GCE.**—Figs. 2D and 2E show the curves of BPA and BPS on different electrodes in PBS solution (pH 6.0) respectively. As shown in Fig. 2D, 2E, and 2f, the electrode responses of BPA and BPS were a typical irreversible electrode reaction, which corresponded to related reports.\(^7,47,50\) Fig. 2D (curve b) shows that the oxidation peak of BPA was at 0.643 V on Pt/PDDA-DMP/GCE. A weak response was observed on PDDA-DMP/GCE, and a broad oxidation peak appeared at 0.614 V. The comparison of curves (a) and (b) of Fig. 2D revealed that the peak current notably increased, and the peak potential shifted positively in curve b. This finding indicated that Pt/PDDA-DMP exhibited significant electrocatalytic activity toward the oxidation reaction of BPA. The condition of BPS was similar to that of BPA, as shown in the oxidation peak at 0.94 V on Pt/PDDA-DMP/GCE. By contrast, the peak current of Fig. 2E (curve b) was higher than that of Fig. 2E (curve a), which indicated that the Pt/PDDA-DMP hybrid obviously enhanced the electrocatalytic oxidation of BPS. Therefore, the detection effect of Pt/PDDA-DMP/GCE was satisfactory. Fig. 2F shows the cyclic voltammetry (CV) curves of Pt/PDDA-DMP/GCE in black solution (curve a) and in 0.1 M PBS (pH 6.0) containing 0.1 mM BPA and BPS (curve b). As Fig. 2F (curve b) shows, Pt/PDDA-DMP/GCE was used for the simultaneous determination of BPA and BPS. The oxidation peak potentials of BPA and BPS appeared at 0.66 and 0.976 V, respectively; the difference was 0.320 V, which was large enough to allow for the simultaneous determination of BPA and BPS.

**Influence of pH.**—CV was employed to characterize the effect of solution pH on the redox peak potential and peak current of BPA [Fig. 3A and 3B] and BPS [Fig. 3C and 3D] on Pt/PDDA-DMP/GCE. As shown in Fig. 3A and 3C, the oxidation peak potential shifted negatively with the increase in pH, which suggested that protons participated in the electrode reaction processes.\(^1,2\) The anodic peak potential (Epa) of BPA and BPS was proportional to the solution pH in the range of 2.0–9.0. The linear regression equations were $E_{\text{pa}} (\text{V}) = 0.9628 - 0.0578 \, \text{pH} (R = 0.992)$ for BPA and $E_{\text{pa}} (\text{V}) = 1.248 - 0.0497 \, \text{pH} (R = 0.997)$ for BPS [Fig. 3B and 3D]. Shifts of 57.8 mV for BPA and 49.7 mV for BPS per pH unit were close to the theoretical value of 57.6 mV per pH unit, which indicated that electron transfer was accompanied with an equal number of protons in the electrode reaction.\(^3\) The peak current increased as the solution pH increased from 2.0 to 6.0 and then decreased as the pH further increased to 9.0. Fig. 3B and 3D show that the peak current peaked at pH 6.0.
Therefore, pH 6.0 was selected as the optimal pH for BPA and BPS assays. According to related reports,\textsuperscript{9,47,52} the possible reaction mechanism for BPA was as follows: BPA was catalytically oxidized to corresponding o-quinine in the presence of Pt nanoparticles. As demonstrated in the linear relationship between E\text{pa} and pH, the number of electrons and protons involved in the electrochemical oxidation of BPA was equal to 2,\textsuperscript{7,28,47} which can be illustrated as follows:

\[
\text{BPA} + 2\text{e}^{-} + 2\text{H}^{+} \rightarrow \text{o-quinine}
\]

Influence of scan rate.—Fig. 4A and 4C illustrate the CV curves of 0.1 mM BPA and BPS on Pt/PDDA-DMP/GCE with different scan rates, respectively. As shown in Fig. 4B and 4D, the peak currents increased linearly with the scan rate in the range of 10–90 mV/s. The regression equations were I\text{pa} (\mu\text{A}) = 0.799 + 0.0257 v (mV/s) (R = 0.992) for BPA and I\text{pa} (\mu\text{A}) = 0.627 + 0.0234 v (mV/s) (R = 0.995) for BPS. Thus, the oxidation of BPA and BPS on Pt/PDDA-DM/GCE was an adsorption-controlled process.

According to the reaction mechanism of BPA, the possible reaction mechanism of BPS could be speculated as a two-electron and two-proton process as follows:

\[
\text{BPS} + 2\text{e}^{-} + 2\text{H}^{+} \rightarrow \text{o-quinine}
\]
The successive CV of BPA and BPS on Pt/PDDA-DMP/GCE were also examined (SI. 1.3). A well-defined oxidation peak corresponding to BPA and BPS was observed at 0.64 V in the first cycle. The attenuation of the peak current was due to the fouling phenomenon, in which the oxidative product or polymeric product of BPA and BPS was deposited on the electrode surface and blocked further oxidation of BPA and BPS monomers completely.

**Interference of interfering species.** One of the most important problems in practical applications of sensors in real samples is the effect of interfering species. The possible interferences of several organic compounds were tested with 0.05 mM BPA and BPS using differential pulse voltammetry (DPV). Organic compounds of twofold excess, such as UR, UA, DA, and AA, were tested (Fig. 5). The results showed that UR did not exhibit any peak; three individual anodic peaks appeared at 0.364, 0.296, and 0.228 V, which were attributed to the oxidations of UA, AA, and DA, respectively. The anodic peaks to anodic peaks of BPA and BPS were more than 0.3 V, which illustrated that the signals of BPA and BPS were not influenced. Similarly, some inorganic ions, such as 100-fold concentrations of \( \text{SO}_4^{2-}, \text{PO}_4^{3-}, \text{NO}_3^-, \text{NH}_4^+, \text{Mg}^{2+}, \text{and Ca}^{2+}, \) exerted no influence on the determination of BPA and BPS. These results indicated that Pt/PDDA-DMP/GCE exhibited selective reactivity to BPA and BPS.

**Analytical performance.** The BPA and BPS concentrations using Pt/PDDA-DMP/GCE were determined by DPV (Fig. 6). Various concentrations of BPA were mixed with a constant amount of BPS (0.04 mM), and DPV curves were recorded at the surface of Pt/PDDA-DMP/GCE [Fig. 6A]. The peak current of BPS was almost constant...
The linear equation was $I_{\text{P} \text{BPA}} (\mu \text{A}) = 10.42 C_{\text{BPA}} + 0.0428$ ($R = 0.999$), and the detection limit was $2 \mu \text{M}$ ($S/N = 3$). Similarly, Fig. 6D shows that $I_{\text{P} \text{BPA}}$ was linear with the concentration of $\text{BPS}$ in the range of $10^{-6}$–$10^{-5}$ M.

The excellent reproducibility and stability achieved on the Pt/PDDA-DMP modified electrode indicated that Pt/PDDA-DMP could be treated as a promising sensing platform for the selective determination of $\text{BPA}$ and $\text{BPS}$. As Fig. 6B shows, $I_{\text{P} \text{BPA}}$ was proportional to the concentration of $\text{BPA}$ in the range of $5$–$30 \mu \text{M}$ ($R = 0.999$), and the detection limit was $0.6 \mu \text{M}$ ($S/N = 3$). Similarly, Fig. 6C shows the DPV curves of solutions containing a constant concentration of $\text{BPA}$ ($0.04 \text{mM}$) and various concentrations of $\text{BPS}$, which showed no change in the peak current of $\text{BPA}$ with various concentrations of $\text{BPS}$. Fig. 6D shows that $I_{\text{P} \text{BPA}}$ was linear with the concentration of $\text{BPS}$ in the range of $10^{-6}$–$60 \mu \text{M}$. The following linear equation was obtained: $I_{\text{P} \text{BPS}} (\mu \text{A}) = 2.881 C_{\text{BPS}} - 0.0755$ ($R = 0.999$), and the detection limit was $0.6 \mu \text{M}$ ($S/N = 3$).

The results of DPV showed that a novel electrochemical method was proposed for the determination of $\text{BPA}$ and $\text{BPS}$ in simulated urine samples. The Pt/PDDA-DMP/GCE represented a novel electrochemical sensor was compared with several previously reported electrochemical sensors for $\text{BPA}$ detection, as exhibited in Table I. It appears that the present detection limit is somewhat lower than those previously reported.

To evaluate the performance of the fabricated sensor (Pt/PDDA-DMP/GCE) in practical analytical applications, the determination of $\text{BPA}$ and $\text{BPS}$ in simulated urine samples was carried out via recovery study according to the abovementioned analytical procedure. The results of $\text{BPA}$ (Table II) showed that the recoveries were $99.8$–$108.4\%$, and $\text{RSD}$ were all less than $3.0\%$. Table III lists the results of $\text{BPS}$; the recoveries were $97\%$–$99.9\%$, and $\text{RSD}$ were all less than $3.5\%$. The results of DPV showed that a novel electrochemical method was proposed for the determination of $\text{BPA}$ and $\text{BPS}$ in simulated urine samples. Thus, Pt/PDDA-DMP/GCE was a potential sensor for the determination of $\text{BPA}$ and $\text{BPS}$ in physiological solution.

### Conclusions

In this study, Pt/PDDA-DMP hybrid were synthesized by the self-assembly method and then used for the fabrication of a selective and sensitive electrochemical sensor for $\text{BPA}$ and $\text{BPS}$. Numerous methods were used to characterize this hybrid. Electrochemical study demonstrated that the Pt/PDDA-DMP hybrid exhibited novel electrocatalytic activity toward the catalytic oxidation of $\text{BPA}$ and $\text{BPS}$. The excellent reproducibility and stability achieved on the Pt/PDDA-DMP-modified electrode indicated that Pt/PDDA-DMP could be treated as a promising sensing platform for the selective determination of $\text{BPA}$ and $\text{BPS}$. Pt/PDDA-DMP represented a novel electrochemical material that would be useful for electrochemical sensors and other applications.

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