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Room temperature stable ClPrNTf₂ ionic liquid utilizing for chemical sensor development

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ABSTRACT

A stable ionic liquid was prepared at room-temperature using the metathesis reaction, which was consummated by the reaction of L-Phenylalanine ethyl ester hydrochloride (chlorpromazine hydrochloride) with lithium-bis(trifluoromethane)sulfonamide in water (shortly, ClPrNTf₂). The prepared ClPrNTf₂ was characterized in details with various conventional methods. Here, a thin-layer of ClPrNTf₂ onto glassy carbon electrode (GCE; Surface area: 0.0316 cm²) is deposited with conducting coating agents (5% nafion) to fabricate a selective and selective 3-methoxy phenol sensor in short response time in phosphate buffer solution. The fabricated phenolic chemical sensor is also exhibited higher sensitivity, large-dynamic concentration ranges, long-term stability, and improved electrochemical performances towards 3-methoxy phenol. The calibration plot is linear ($r^2 = 0.9836$) over the large 3-methoxy phenol concentration ranges (0.09 nM to 0.9 mM). The sensitivity and detection limit is ~2.3244 µAcm⁻²µM⁻¹ and ~0.022 ± 0.002 nM (signal-to-noise ratio, at a SNR of 3) respectively. This novel effort is initiated a well-organize way of efficient sensor improvement with ClPrNTf₂ ionic liquid for toxic pollutants in environmental and health-care fields in large scales.

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1. Introduction

The low melting ionic liquids often have practically no vapor pressure. These compounds are considered excellent alternatives to conventional organic solvents. Characteristic interesting properties of these liquid salts include good thermal stability, wide liquid temperature range, considerable ionic conductivity, a broad electrochemical window, and a wide solubility and miscibility range [1,2]. In addition, stable ionic liquid can be designed or tuned for specific applications by altering either the cation or anion [3]. Various ionic liquids have been used in electrochemical sensing, such as imidazole ionic-liquids. [4], pyridinium, [5,6] and other functionalized [7] N-Butyl-N-methylpyrrolidinium bis(trifluoromethylsulfonyl)imide $(BMPyNTf_2)$ is one of the

pyrrolidinium ionic liquids (PILs) with excellent electrochemical properties [8]. There is an ever increasing demand for simple, selective and inexpensive methods for determining the presence of chemical species in the environment. These problems could be conceivably avoided by replacing conventional electrochemical solvents with room temperature ionic liquids. These low melting salts display large electrochemical windows, negligible vapor pressure, good thermal stability and electrical conductivity which make them quite attractive [9]. In fact, some amperometric sensors were recently proposed which were assembled by casting a thin layer of ionic liquid on the surface of either a three electrode cell or a microelectrode array. Even though these chemi-sensors are able to operate as membrane-free amperometric devices, their responses remain conditioned by the rate of both gas dissolution into the ionic liquid and its diffusion through the medium towards the working electrode. Thus, their sensitivity and response time continue to be affected by fairly slow steps, even though they are faster compared to permeation through membranes. In particular, it is advisable to achieve a very close contact between the electrode material and ionic liquid, thus allowing analytes from gaseous







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samples to undergo electron transfer just as they reach the working-electrode-material/ionic-liquid inter-phase, without involving any analyte diffusion and/or dissolution step [10]. Ionic liquids are molten salts with a melting point close to or below room temperature. Their good solvating properties, high conductivity, non-volatility, low toxicity, as well as large electrochemical window and good electrochemical stability make them tremendously popular for electrochemical sensing [11,12].

The development of simple, reliable and sensitive techniques was used for the detection of toxic phenolic compounds for environmental safety, protection, food quality control, and health [13]. Phenolic compounds have been confidential as "priority pollutants" by both the United States Environmental Protection Agency (USEPA) and the European Commission. Phenolic compounds are comparatively general in waste streams of diverse large-scale processing and manufacturing where they serve as precursor materials in various industries such as coal mining, crude oil refining, paper bleaching, and production of dyes, resins, plastics, explosives, detergents, pharmaceuticals, pesticides, and herbicides [14,15]. In difference, few phenols of plant origin have been originated to display a broad range of attractive physiological characteristics as antioxidants, anti-inflammatories, and cardiovascular prophylactics, promoting their use as additives in some alcoholic beverages and food products [16,17]. Recent determination methods such as spectro-photometry, fluorimetry, gas or liquid chromatography, mass spectrometry and capillary electrophoresis are usually perceptive and consistent but possess limitations, such as being expensive, time-consuming and requiring preconcentration and extraction steps that increase the risk of sample loss and generation of other hazardous byproducts [18]. Electrochemical sensing of phenolic compounds represents a promising approach that can be utilized to complement already existing methods owing to collective characteristics such as high sensitivity and selectivity, low cost, simple instrumentation and potential for miniaturization [19,20].

In addition, it has been evidenced that ionic liquids are exceptional and versatile solvents in a host of analytical and chemosensing applications [21,22]. ILs have also continual concern in environmental areas because of their potential as greener solvent for many organic, inorganic, and polymeric substances as compared to conventional environmentally damaging organic solvents [23]. The good thermal stability, high ionic conductivity, miscibility with other solvents, no effective vapor pressure, and non-reactive and recyclable nature of ILs are a few other properties that make these compounds appropriate solvents for different applications [24-27]. Room-temperature ionic liquids belong to a class of potentially benign solvents and are molten salts that are liquid around ambient conditions [27]. Both ILs and molten salts are composed of ions. The presence of bulky organic cations in ILs interrupts the crystal packing and lowers the melting temperature. RTILs have potential for many different applications, including catalysis and synthesis. For instance, conventional organic solvents have been replaced by ILs in organic synthesis [28]. They have also been used in solvent extractions [29], liquid-liquid extractions [30], enzymatic reactions [31], pharmaceutical studies [32], electrochemical studies [33], dye-sensitized solar cells and batteries [34], as buffer additives in capillary electrophoresis [35], as stationary phases in gas-liquid chromatography [36], and as ultralow volatility liquid matrixes for matrix-assisted laser desorption/ionization (MALDI) mass spectrometry [37]. In addition, the high thermal stability allows the use of ILs for high temperature gas sensing [38]. Recently, there has been a large focus on the effectiveness of ILs as environmentally friendly, "green" solvents and as a host of practical applications to which they are amenable [39]. In addition, understanding the mechanism and solvation in ILs is a difficult and challenging task because of their complex nature [40,41]. Most of analytical methods involve fast atom bombardment (FAB) mass spectrometry [42], Xray crystallography [43], and X-ray absorption fine structure (XAFS) [44]. These methods have shown considerable promise in studying the physicochemical properties of room temperature ionic liquids.

Here, the ClPrNTf₂ with conducting coating binders fabricated onto GCE have significant properties such as large surface area (surface-to-volume ratio), non-toxicity, chemical stability, and high electrical conductivity; which offers high electron communication features that enhanced the direct electron communication towards the target 3-methoxy phenol analytes. As 3-methoxy phenol is highly carcinogenic and serious to health as well as environment, it is urgently required to fabricate a simple and reliable chemical sensor. Consequently, based on the 3-methoxy phenol sensing properties with CIPrNTf₂/binders/GCE surfaces, it has been fabricated and developed selective and sensitive chemical sensors in this report. The simple fabrication technique is used for the preparation of ClPrNTf₂-GCE electrode with conducting coating binders, which is measured by simple and reliable I-V method. Enhancement of the ClPrNTf₂/GCE as chemical sensors is in the initial stage and no other reports are available. To best of our knowledge, this is the first report for highly selective and sensitive detection of 3methoxy phenol with ClPrNTf2 using simple I-V technique in short response time.

2. Experimental sections

2.1. Materials and methods

Analytical grade of 3-methoxy phenol, ethyl acetate, disodium phosphate (Na₂HPO₄), butyl carbitol acetate, monosodium phosphate (NaH₂PO₄), and other chemicals was used and purchased from Sigma-Aldrich Company. 0.1 M phosphate buffer phase (PBP) at pH 7.0 is prepared by mixing of equi-molar concentration of 0.2 M Na₂HPO₄ and 0.2 M NaH₂PO₄ solution in 100.0 ml de-ionize water at room conditions. Stock solution of 3-methoxy phenol (0.09 M) was made using ultra-pure water from the purchased 3methoxy phenol chemical. As received 3-methoxy phenol is used to make various concentrations (0.09 nM-0.09 M) in DI water and used as a target analyte. 10.0 ml of 0.1 M PBS is kept constant during whole measurements. Chlorpromazine hydrochloride (ClPrCl) and lithium-bis(trifluoromethane)-sulfonamide (LiNTf₂) were also purchased from Sigma-Aldrich.¹H NMR spectra was acquired in the single-pulse mode on a Perkin Elmer 600 MHz spectrometer. All NMR measurements were recorded in CDCl₃ by use of tetramethyl silane (TMS) as an internal standard. ¹H NMR spectra were collected using a 7 µs pulse, 16 scans, and 1 s delay between scans. The spectra were processed by zero filling the FID from 16 to 32 K and applying a line-broadening of 30 Hz. Flat GCE electrode was fabricated with as prepared ClPrNTf₂ with conducting coating binders (5% ethanolic nation solution) as ClPrNTf₂/Nation/GCE (working electrode sensor assembly) at room condition. ClPrNTf₂/Nafion/GCE was air dried for 6 h for making smooth, stable and uniform sensor surfaces. ClPrNTf₂/Nafion/GCE electrode was dipped into the PBS solution with counter electrode to measure the I-V current from 0 to +1.5 V potential ranges.

Thermal infrared spectra were recorded on a Shimadzu IR 470 spectrophotometer in the range 4000–600 cm⁻¹. The Melting point (T_m) was determined by differential scanning calorimetry (DSC) using a thermal analysis instrument TA SDT2960 at a scanning rate of 5.0 °C min⁻¹. Thermal gravimetric analyses were performed using a thermal analysis instrument TGA-7 HR V6.1A (module TGA 1400.0 °C). Determination of the thermal decomposition temperature (T_{dec}) for ClPrNTf₂ was obtained at a heating rate of 5.0 °C min⁻¹ under nitrogen from 20.0 to 700.0 °C. In addition, the

UV/Visible absorption measurements were collected by use of a Perkin-Elmer UV-Vis scanning spectrophotometer. Absorption spectra were collected using a 10.0 mm quartz cuvette. Fluorescence measurements were performed using a Perkin-Elmer luminescence spectro-fluorometer equipped with a 20-KW for 8.0 μ s duration xenon lamp and gated photomultiplier tube (PMT) and red-sensitive R928 PMT detectors. All fluorescence measurements were collected at room temperature. The emission spectra of ClPrNTf₂ were recorded in a 10.0 mm guartz fluorescence cuvette with slit widths set for entrance and exit bandwidths of 5.0 and 5.0 nm on both excitation and emission monochromators, respectively. Fluorescence emission spectra of ionic liquid were excited at 315 nm for ClPrNTf₂. All fluorescence spectra were blank subtracted before proceeding in data analyses. Time-based fluorescence steady-state experiments used to evaluate the photo-stability of ClPrNTf₂ were acquired with excitation and emission band-pass set at 15.0 and 5.0 nm, respectively, in order to increase the photobleaching. The excitation and emission wavelengths were set at 315 and 450 nm for ClPrNTf₂. The fluence level of the excitation source was open for a period of 30.0 min.

2.2. Synthesis of ClPrNTf₂ ionic liquid

The ClPrNTf₂ ionic liquid was prepared according to procedures previously reported by Bonhôte et al. [45]. Specifically, 1.0 g from the desired salt (ClPrCl) was separately dissolved in 18.2 M Ω cm distilled deionized water and mixed with an equimolar amount of LiNTf₂. The resultant reaction mixture was stirred for 2.0 h at room temperature. The reaction resulted in two layers. The lower layer was separated and dried under vacuum overnight (Scheme 1). The purification by vacuum drying is performed at a drying temperature of 353 K and vacuum of 0.4 kPa. A stock solution of the ionic liquid was prepared individually in ethanol by dissolving an appropriate amount of the ionic liquid. The stock solution was stored in the dark at 4.0 °C. For both fluorescence and UV-Vis spectroscopic study, standard solutions of 10.0 µM ClPrNTf₂ were prepared by adding appropriate amounts of ionic liquid stock solution. These observations were reported in our previous study [46]

This ionic liquid ClPrNTf₂ was red in color, resulted in 1.54 g (91% yield). It was extremely viscous liquid at room temperature. ¹H NMR δ (ppm) study was made as 2.00 (q, 2H, CH₂NH), 2.60 (m, 2H, CH₂), 3.05 (q, 2H, CH₂NH), 5.15 (s, 1H, NH), 6.70–7.10 (m, 7H, Ar-H), 7.50 (s, 1H, NH). IR absorbances ν (cm⁻¹): 3580, 3147 (NH); 1591, 1567 (C=C); 1457, 1276 (C–S); 1345, 1186 (NSO₂); 854, 794, 738 (C–H). Elemental Analysis of calculated for C₁₉H₂₀N₃ClO₄S₃F₆: C (38.02); H (3.33); N (7.00). Found: C (37.32); H (3.18); N (6.39). This compound was thermally stable up to 232 °C, which is presented our previous study [47]. Two broad bands were observed at 248 and 315 nm in the UV–Vis absorption spectrum of ClPrNTf₂. Absorption



Scheme 1. ClPrNTf₂ ionic liquid preparation. Synthesis of ClPrNTf₂ ionic liquid by metathesis method using L-Phenylalanine ethyl ester hydrochloride (chlorpromazine hydrochloride) with lithium-bis(trifluoromethane)sulfonamide in water.

maxima of ClPrNTf₂ was noticed at 248 nm. The optical behavior of the ClPrNTf₂ included in this study not only indicates that ionic liquid ClPrNTf₂ do have significant absorption in the UV region, but it also brings into light a very interesting fluorescence behavior. In general, high background fluorescence was observed in the emission spectra of the ClPrNTf₂. These results further support the purity of synthesized ClPrNTf₂ and are in good agreement with the data obtained from the elemental analysis [48]. However, a close examination indicates that these ClPrNTf₂ absorb in the UV region and exhibit fluorescence that covers a large part of the visible region. The total characterization of 1,10-PhenanNTf₂ is already reported previously by Marwani [49]. Finally, the preparation and spectroscopic evaluation of these ionic liquid may show a step towards exploring their potential applications.

2.3. Fabrication of ClPrNTf₂/GCE

The ClPrNTf₂/GCE was applied for fabrication of chemi-sensor, where 3-methoxy phenol was measured as target analyte. The fabricated-surface of ClPrNTf2 ionic liquid-sensor was prepared with conducting binders (EC & BCA) on the GCE surface, which is presented in Scheme 2a. The fabricated GCE electrode was put into the oven at low temperature (60.0 °C) for 2.0 h to make it dry, stable, and uniform the surface totally. I-V signals (Scheme 2b) of 3methoxy phenol chemical sensor are anticipated having ClPrNTf₂/ GCE on thin-film as a function of current versus potential. The resultant electrical responses of target 3-methoxy phenol are investigated by simple and reliable I-V technique using CIPrNTf₂/ GCE, which is presented in Scheme 2c. The holding time of electrometer was set for 1.0 s. A significant amplification in the current response with applied potential is noticeably confirmed. The simple and possible reaction mechanism is generalized in Scheme 2d in presence of 3-methoxy phenol on ClPrNTf₂/GCE sensor surfaces by I-V method. In presence of ClPrNTf₂ ionic liquid, the electrons are released in presence of 3-methoxy phenol by adsorbing reduced oxygen, which improved and enhanced the current responses against potential during the I-V measurement at room conditions.

3. Results and discussions

The potential application of ClPrNTf₂ ionic liquid deposited onto GCE as chemical sensors (especially 3-methoxy phenol analyte in buffer system) has been executed for measuring and detecting target chemical. The ClPrNTf₂/GCE sensors have advantages such as stability in air, non-toxicity, chemical inertness, electro-chemical activity, simplicity to assemble, ease in fabrication, and chemosafe characteristics for the detection of environmental toxins. As in the case of 3-methoxy phenol sensors with GCE, the incident of rationale is focused that the current response in I-V method of ClPrNTf₂/GCE considerably changes when aqueous phenolic analytes are absorbed/adsorbed.

The ClPrNTf₂ ionic liquid was employed for the detection of 3methoxy phenol in liquid phase. I-V responses were measured with ClPrNTf₂ ionic liquid coated thin-film (in two electrodes system). In experimental section, it was already outlined the 3methoxy phenol sensing protocol using the ClPrNTf₂/GCE modified electrode. The concentration of 3-methoxy phenol was varied from 0.09 nM–0.09 M by adding de-ionized water at different proportions. Here, Fig. 1(a) is represented the I-V responses for uncoated-GCE (gray-dotted) and ClPrNTf₂/GCE (orange-dotted) electrodes. In PBS system, the ClPrNTf₂/GCE electrode shows that the reaction is reduced slightly owing to the presence of ionic liquid on bare-GCE surface. A considerable enhancement of current value with applied potential is demonstrated with fabricated ClPrNTf₂/ GCE in presence of target 3-methoxy phenol analyte, which is



Scheme 2. Fabrication and mechanism of sensor development. Schematic view of (a) CIPrNTf₂ coated GCE with conducting coating binders, (b) detection I-V method (theoretical), (c) observed I-V responses by CIPrNTf₂/GCE, and (d) proposed adsorption mechanisms of 3-methoxy phenol detection in presence of CIPrNTf₂ onto GCE. Surface area of GCE: 0.0316 cm²; Method: I-V. Delay time: 1.0 s.

presented in Fig. 1(b). The orange-dotted and green-dotted curves were indicated the response of the fabricated film after and injecting 25.0 μ L 3-methoxy phenol in 10.0 ml PBS solution respectively measured by fabricated ClPrNTf₂/GCE films. Significant increases of current are measured after injection of target component in regular interval.

I-V responses to varying 3-methoxy phenol concentration (0.9 nM–0.09 M) on thin ClPrNTf₂/GCE were investigated (time delaying, 1.0 s) and presented in Fig. 2(a). Analytical parameters (such as sensitivity, detection limit, linearity, and linear dynamic range etc) were calculated from the calibration curve (current vs. concentration), which was presented in Fig. 2(b). A wide range of 3-methoxy phenol concentration was selected to study the possible detection limit (from calibration curve), which was examined in 0.9 nM–0.09 M. The sensitivity was calculated from the calibration curve, which was close to ~2.3244 $\mu Acm^{-2}\mu M^{-1}$. The linear dynamic range of the ClPrNTf₂/GCE sensor was employed from 0.9 nM to 0.9 mM (linearly, $r^2 = 0.9836$), where the detection limit was calculated about ~0.022 \pm 0.002 nM (ratio, ${}^{3}N'_{S}$). The ClPrNTf₂/GCE

was exhibited mesoporous behaviors, where the electrical resistance decreases under the presence of target 3-methoxy phenol in PBS phase. The film resistance was decreased gradually (increasing the resultant current) upon increasing the 3-methoxyphenol concentration in bulk system.

In two-electrode system, I-V characteristic of the ClPrNTf₂/GCE is activated as a function of 3-methoxy phenol concentration at room conditions, where improved current response is observed. As obtained, the current response of the ClPrNTf₂ ionic liquid is increased with the increasing concentration of 3-methoxy phenol; however similar phenomena for toxic chemical detection have also been reported earlier [50–53]. For a low concentration of 3-methoxy phenol in liquid medium, there is a smaller surface coverage of 3-methoxy phenol molecules on ClPrNTf₂/GCE film and hence the surface reaction proceeds steadily. By increasing the 3-methoxy phenol concentration, the surface reaction is increased significantly (gradually increased the response as well) owing to large surface area contacted with 3-methoxy phenol molecules. Further increase of 3-methoxy phenol concentration on ClPrNTf₂/



Fig. 1. Study of control experiment. I-V responses of (a) GCE (without ionic liquid) and CIPrNTf₂/GCE (with CIPrNTf₂); (b) CIPrNTf₂/GCE (in absence) and 3-methoxy phenol/ CIPrNTf₂/GCE (in presence) of 3-methoxy phenol in the solution system.



Fig. 2. Analysis of chemical responses. I-V responses of (a) concentration variations (0.9 nM–0.9 M) of 3-methoxy phenol, (b) calibration plot of CIPrNTf₂ ionic liquid fabricated GCE electrode (at +0.5 V).

GCE surface (measoporous), it is exhibited a more rapid increased the current responses, due to larger surface covered by 3-methoxy phenol chemical. Usually, the surface coverage of 3-methoxy phenol molecules on ClPrNTf₂/GCE surface is reached to saturation, based on the regular enhancement of current responses.

Selectivity was studied for 3-methoxy phenol sensor in presence other chemicals like bisphenol A (BPA), hydrazine (Hyd), methanol, xanthine (Xan), 3-methoxy phenol (Phen), dichloromethane (DCM), acetone and blank (only buffer) using the ClPrNTf₂/GCE, which is presented in Fig. 3(a). The concentrations of all analytes are kept constant at 0.1 μ M level in PBS system. From the current response of each individual analytes, it is calculated the percentile of responses at +0.5 V of BPA (2.1%), Hyd (1.7%), methanol (4.03%), Xan (2.41%), 3-methoxy phenol (59.81%), DCM (1.08%), acetone (4.63%), and blank (0%) with ClPrNTf₂/GCE sensors. Here, it is clearly demonstrated the ClPrNTf₂/GCE electrode sensor is most selective toward 3-methoxy phenol (59.81%) compared with other chemicals, which is presented in Fig. 3(b).

To check the reproducibly and storage stabilities, I-V response for ClPrNTf₂/GCE sensor was examined and presented in Fig. 4(a). After each experiment (each runs), the fabricated ClPrNTf₂/GCE substrate was washed thoroughly with the phosphate buffer solution and observed that the current response was not significantly decreased. The current loss in each experiment is calculated and presented in Fig. 4(b). Here it is observed the current loss in each reading is negligible compared to initial response of sensors using ClPrNTf₂/GCE. The sensitivity was retained almost same of initial sensitivity up to seven days, after that the response of the fabricated ClPrNTf₂/GCE electrode gradually decreased. The 3-methoxy phenol chemical sensor based on ClPrNTf₂/GCE is displayed good reproducibility and stability for over week and no major changes in sensor response are found. After a week, the chemical sensor response with ClPrNTf₂/GCE was slowly decreased, which may be due to the weak-interaction between fabricated ClPrNTf₂/GCE active surfaces and 3-methoxy phenol chemical.

The significant result was achieved by ClPrNTf₂/GCE, which can be employed as proficient electron mediators for the development of efficient chemical sensors. Actually the response time was around 10.0 s for the fabricated ClPrNTf₂/GCE to reach the saturated steady-state level. The higher sensitivity of the fabricated ClPrNTf₂/ GCE could be attributed to the excellent absorption (porous surfaces in ClPrNTf₂/conducting-binders/GCE) and adsorption ability, high catalytic-decomposition activity, and good biocompatibility of the ClPrNTf₂ ionic liquid. The estimated sensitivity of the fabricated sensor is relatively higher and detection limit is comparatively lower than previously reported chemical sensors based on other nano-composites or nano-materials modified electrodes measured by I-V systems [54-62]. Due to high specific surface area, ClPrNTf₂/



Fig. 3. Selectivity study with analytes by CIPrNTf₂/GCE electrodes. (a) I-V responses of various analytes and (b) Current responses in percentile of analytes at +0.5 V (3-methoxy phenol); 0.1 μ M. Potential range: 0 to +1.5 V; Delay time: 1.0 s.



Fig. 4. Reproducibility study with analytes (0.1 µ**M) using CIPrNTf₂/GCE electrodes.** (a) I-V responses of all reproducible signals (Run-1 to Run-6) with 3-methoxy phenol, and (b) Current responses of analyte at +0.5 V (3-methoxy phenol); Analyte concentration was taken at 0.1 µM. Potential range: 0 to +1.5 V; Delay time: 1.0 s.

Table 1

Comparison of phenolic sensor performances based on various electrochemical approaches by different electrode assembly.

Sensing layer	Analyte	Transduction	Performances	Ref
MnO ₂ /screen-printed sensor	Phenol	Voltammogram	Sensitivity: 0.123 mA µM ⁻¹ cm ⁻²	[63]
			DL: 0.64 μM,	
			LDR: up to 716 μ M	
SiO ₂ /Nb ₂ O ₅ Sol-gel	Phenol	Potentiometry	Sensitivity: 3.2 nA dm ³	[64]
			DL: 0.5 μ mol dm ⁻³	
			LDR: 5–25 μ mol dm ⁻³	
Ag ₂ S QD/GCE	Phenol	Amperometry	Sensitivity: 0.0612 μ A μ M ⁻¹ cm ⁻²	[65]
			DL: 0.015 μM	
			LDR: 1 µM to 16 mM	
Graphene-polyaniline/GCE	Aminophenol	DPV	Sensitivity: 1.776042 μ A μ M ⁻¹ cm ⁻²	[66]
			DL: 0.065 μM	
			LDR: 0.2–20, 20–100 μM	
RGO/P-L-GSH/GCE	Aminophenol	Amperometry	Sensitivity: 0.0272 mA μ M ⁻¹ cm ⁻²	[67]
			DL: 0.03 μM	
			LDR: 0.4–200 μM	
ClPrNTf ₂ /GCE	3-methoxy phenol	I-V method	Sensitivity:2.3244 μA cm ⁻² μM ⁻¹	This work
			DL: 0.022 ± 0.002 nM (at SNR of 3)	
			LDR: 0.09 nM to -0.9 mM	
			Linearity, $r^2 = 0.9836$	
			Response time: 10 s	

GCE provides a favorable nano-environment for the 3-methoxy phenol detection with good quantity. The high sensitivity of ClPrNTf₂/GCE provides high electron communication features which enhanced the direct electron transfer between the active sites of ClPrNTf₂ and coated-GCE. The ClPrNTf₂/GCE system is demonstrated a simple and reliable approach for the detection of toxic chemicals. It is also revealed that the significant access to a large group of chemicals for wide-range of ecological and biomedical applications in environmental and health-care fields respectively. Here, Table 1 shows some selected 3-methoxy phenolic sensor applications with various nanocomposite materials by electrochemical approaches [63-67].

4. Conclusions

The ClPrNTf₂ ionic liquid has been prepared using simple metathesis technique at room condition. The chemical sensor was fabricated using ClPrNTf₂ with the conducting coating binders onto glassy carbon electrodes, which displayed higher sensitivity and selective for chemical sensing applications. The analytical

performances of the fabricated 3-methoxy phenol sensors are excellent in terms of sensitivity, detection limit, linear dynamic ranges, selectivity, and in short response time. ClPrNTf₂/GCE assembly is exhibited higher-sensitivity (~2.3244 μ Acm⁻² μ M⁻¹) and lower-detection limit (~0.022 ± 0.002 nM) with good linearity in short response time, which efficiently utilized as chemi-sensor for 3-methoxy phenol onto ClPrNTf₂/GCE. This novel approach is introduced a well-organized route of efficient chemical sensor development for environmental pollutants and health-care fields in broad scales.

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