Study of structural, optical and electrochemical properties of ZnO nanostructures and ZnO-PANI nanocomposites

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Abstract
In this study, different morphologies like plate, flower, spherical particles and flakes of ZnO, which have been prepared by simple sol gel method using Sodium dodecyl Sulphate (SDS), Trisodium Citrate, and Cetyl trimethyl ammonium bromide (CTAB) as different stabilizers have been reported. These products have been systematically investigated by UV-Visible spectroscopy, Fourier Transform Infrared Spectroscopy (FTIR), x-ray diffraction (XRD), Field Emission Scanning Electron Microscope (FESEM) and Photoluminescence (PL) techniques. ZnO-PANI nanocomposites films prepared on ITO, and characterized by XRD and electrochemical techniques. Microstructural details like lattice parameters, lattice volume, crystalline size and crystal phase have been determined from reitveld refinement method of X-diffraction pattern. FESEM technique shows that ZnO nanostructures morphology can be changed from ZnO nanoplate like shape to ZnO nanoflowers assembled with nanorods, ZnO nanoflakes and ZnO spherical particles when Trisodium Citrate, CTAB and SDS used as additives, respectively. Photoluminescence technique shows that there is slight red shift in the UV region and blue shift in the visible region with the addition of surface active molecules to ZnO, with concomitant decrease in the relative intensity of emission peaks. This indicates that the defects in the ZnO structure have been decreased as CTAB, SDS and Trisodium citrate added into the precursor solution. Cyclic voltammetry results reveal that the current intensity of PANI enhances with the addition of ZnO and surfactant modified ZnO. The urea biosensor, fabricated using urease enzyme on the trisodium citrate assisted ZnO/PANI/ITO nanocomposites, exhibits linearity in the concentration range of 10–80 mg dl⁻¹ with detection limit of 2 mg dl⁻¹ and sensitivity 7.30 μA mM⁻¹ cm⁻².

Introduction
Zinc oxide (ZnO), is a n-type semiconductor with large exciton binding energy and wide band-gap of 60 meV and 3.37 eV respectively even at room temperature and excellent chemical stability. Due to its attractive properties, ZnO has great many applications in sensors [1–3], optoelectronic and electronic devices [4, 5], field emission devices [6], photocatalysts [7, 8], and electroluminescent devices [9]. Morphology, crystal structure and size distribution plays an important role in the performance of material application [10, 11]. X-ray diffraction analysis is a powerful non destructive phenomenon used for the analysis of nature of arrangement of atoms in crystals. Apart from this, lattice parameters, lattice strain and crystallite size can also be determined from this technique [12]. In recent years, various types of ZnO structures have been synthesized by researchers such as nanorods, nanobelts, nanorings, nanoflowers, nanowhiskers, nanocolumns, nanotubes etc [13–18]. They have been synthesized by different method such as hydrothermal method [19], solution precipitation method [20], thermal decomposition [21] microwave assisted technique [22], spray pyrolysis [23], and many more. CTAB assisted ZnO nanoflowers synthesized by hydrothermal method using an autoclave as reported by Yang et al [19]. Ge and co-workers have used facile precipitation route for the synthesis of ZnO hollow sphere-set using trisodium citrate as capping agent [24]. Chrysanthemum-like ZnO nanorods have been synthesized using SDS.
for 24 h at temperature 120 °C [25]. Majority of methods require expensive and complicated setups for carrying out the overall reaction. Capping agents or structure-directing agents or growth control additives are often employed to synthesize ZnO particle of different shapes. Sodium dodecyl sulphate (SDS), cetyl trimethyl ammonium bromide (CTAB), Trisodium citrate, ethylenediamine, hexamethylene tetramine and citric acid are generally used as capping agents [19, 24, 25]. In the field of biological sensing, nanomaterials plays an important role with the surface modification, which allows them to interact with target biomolecules. ZnO modified nanostructures have extremely large potential for applications in the biomedical field, with their biocompatible nature, with controlled morphology, high electron transfer rate and high isoelectric point [26–28]. Interleukin-6 (IL-6) (cancer biomarker) can be detected using carbon nanotube array biosensor at low concentration and early stage of cancer [29]. Single and small bundle of nanotube array functionalized with specific antibodies shows high sensitivity towards breast cancer cells [30]. Khosravi et al developed nanotube—CTC (Circulating tumor cells) chip for the detection of spiked breast cancer cells [31].

In this paper, firstly we synthesized different morphologies of ZnO like flower, nanoflakes, nanosheets and nanoparticles by a simple sol gel method using different capping agents and subsequently prepared their composites with Polyaniline (PANI). The advantage of these nanocomposite leads to number of applications including urea sensor, creatinine sensor, pH sensor and electrochroic sensor. These surfactants based nanocomposites form a new emerging materials which provide new opportunities in urea sensing. We have further investigated the micro structural parameters (like lattice strain, lattice parameters and crystallographic size) using reitveld refinement, morphology, photoluminescence and cyclic voltammetry properties. We have also successfully fabricated PANI, ZnO/PANI and Trisodium citrate assisted ZnO/PANI electrodes on ITO surface. Thereafter immobilization of urease enzyme has been performed to fabricate high performance urea sensor.

This method used in the present work, is efficient, cost effective and energy saver for the preparation of ZnO nanostructures in large quantity for practical applications point of view. We believe that presented method is simple one to synthesize ZnO nanostructures.

**Experimental procedure**

In order to synthesize ZnO nanocrystals, a solution of 0.5M Zinc acetate dihydrate in 80 ml distilled water has been prepared. After addition of 2M NaOH to above solution drop by drop, white precursors solution has been observed after complete dissolution of NaOH under constant stirring for 2 h. Thereafter sample has been aged for 24 h. Finally the obtained solution has been filtered by suction filtration and washed with double distilled water to remove further impurities.

For synthesis of ZnO nanocrystals modified by surfactant, we have used were 0.05M CTAB along with 0.5M zincacetatedihydrate in 80 ml distilled water, in order to study the behaviour of CTAB on ZnO nanostructures. Also, to probe the effect of different surface active molecules (SDS and Trisodium citrate) on ZnO nanostructures, similar synthesis procedure has been employed.

**Synthesis of PANI and ZnO/PANI composites**

To synthesize nanocomposite, PANI has been used in dimethylformamide (DMF) solvent. The above solution has been stirred for 6 h; thin film has been prepared by solution casting method for undoped polyaniline on ITO substrate. Similarly, ZnO composites with polyaniline have been obtained by using ZnO, trisodium citrate assisted ZnO, CTAB assisted ZnO and SDS assisted ZnO in DMF. Resultant solution has been stirred for 6 h. Thin films of PANI, ZnO/PANI, trisodium–ZnO/PANI, CTAB–ZnO/PANI and SDS–ZnO/PANI composite have been prepared by solution casting method on ITO coated glass substrate.

**Enzyme electrode preparation**

To study the sensing behaviour of ITO coated trisodium citrate assisted ZnO/PANI/ITO nanocomposites, electrode has been activated with the help of 1% glutaraldehyde solution by spreading on it and allow it to dry for 2 h at room temperature. The undesirable amount of glutaraldehyde has been removed by washing it with the help of phosphate buffer solution. The urease enzyme (1 mg ml⁻¹) has been immobilized by spreading 8 μl urease solution onto glutaraldehyde activated trisodium citrate assisted ZnO/PANI/ITO electrodes. The above prepared electrodes have been kept at 4 °C temperature for 3 h.

Synthesis schematic illustration of ZnO nanostructures has been shown in figure 1. In the present study CTAB, trisodium citrate, SDS has been used, which are anionic, antioxidant or stabilizer and cationic surfactant respectively. Antioxidants (trisodium citrate) can act as reducing agents. Due to this inhibiting property, it can prevent or inhibit the faster growth of certain or most of the faces of ZnO. A surfactant is an additive which can lower the surface tension of solution in which it is dissolved. It contains both hydrophilic (heads) and hydrophobic or lipophilic (tails) parts in it. The surfactant when mixed in a solvent, spreads in a peculiar
micelle shape in which the water seeking heads spread out and the oil or protein seeking tails aggregate at the centre of a circular pattern which can be called as ‘arms of the wheel like’ structure. CTAB completely ionized in water. In SDS negative part participate, the negative part of SDS ion assembled and forms spherical micelles, which encapsulate the ZnO nanocrystal. This attachment results in capping of nanocrystal.

Results and discussion

XRD results
The XRD pattern for the sample ZnO, trisodium assisted ZnO, CTAB assisted ZnO and SDS assisted ZnO has been shown in figure 2. From the XRD it is evident that all the noticeable peaks could be related to the P63mc space group of wurtzite symmetry. All the well resolved and diffracted peaks observed for all the samples correlated to the reflection planes (100), (002), (101), (102), (110), (103), (200), (112) and (201) are well matched with the JCPDS card no PDF 36-1451 and provide information that all the samples are single phase hexagonal wurtzite structure. The XRD of prepared samples show good crystallinity and shows no new peak in the surfactant modified ZnO. The average crystalline size calculated from Debye–Scherrer’s formula equation (1)

\[
D = \frac{k\lambda}{\beta \cos \theta}
\]

where D is average crystalline size of prominent peaks, \(\lambda\) is x-ray radiation wavelength (0.154 nm), \(\beta\) is full width at half maxima, and \(\theta\) is diffraction angle. The estimated crystalline size using above equation for ZnO, ZCTAB, ZTrisodium and ZSDS is 23.10 nm, 23 nm, 18.20 nm and 16.14 nm respectively. Further rietveld refinement technique has been employed to extract the values of diffraction angles, lattice parameters ‘a’ & ‘c’, FWHM and lattice volume ‘V’ with the help of the Fullprof Suite program. The x-ray data and Rietveld refined data have been shown in the figures 3, 4 and 5 for the samples ZnO, ZTrisodium and ZCTAB. The value of \(\chi^2\) referred to as goodness of fit could be reduced to low for all the samples. The lattice parameters ‘a’ & ‘c’, \(\chi^2\), lattice volume
'V', crystalline size and reliability factors - $R_p$, $R_{Bragg}$, $R_{wp}$, and RF obtained from refinement are listed in the table 1.

FESEM results
The morphology of ZnO nanostructures with and without surfactants as capping agents examined with the FESEM technique. It is noticed that surfactants play an efficient part in the preparation of ZnO nanostructures. Figures 6(a)–(d) shows the FESEM micrographs of all the four samples. With the addition of different...
surfactants on the surface of ZnO, the FESEM micrographs clearly show different morphologies. ZnO (figure 6(a)) displays a disc or plate like configuration. Flower shaped morphology of ZnO composed of large number of hierarchal flower like nanostructures assemblies has been obtained in the presence of trisodium citrate (figure 6(b)). The observed flowers have different size but almost similar shape. Single flower has an average diameter in the range 3 μm with spheroidal hierarchical nanostructures. Each flower is assembled with large number of nanosheets with an average thickness 30 nm. ZnO-CTAB (figure 6(c)) shows large quantity of flower shaped nanostructures. The floral nanostructure resulted from the assemblage of numerous of ZnO nanoflakes which were created from single axis. It is interesting that an individual flower-like structure is composed of many sword-like nanoflakes of 50–80 nm in diameter and 0.5–1 μm in length with sharp edges. These nanoflakes align in a radial way from center. Spherical morphology with agglomerated particles has been observed for the sample (d) (ZnO-SDS).

FTIR results
Figures 7(a)–(d) exhibits the infrared absorption spectra of ZnO samples prepared without surfactant, and with the presence of trisodium citrate, CTAB and SDS respectively. All samples exhibit broad peak between 3400 and 3200 cm⁻¹ which corresponds to hydroxyl group (O–H stretching mode) from water molecules [32]. Presence of bands due to symmetric and asymmetric vibrations of CH₃ group has been observed at 2924 cm⁻¹ and 2849 cm⁻¹, 2915 cm⁻¹ and 2843 cm⁻¹, 2916 cm⁻¹ and 2841 cm⁻¹ for ZnO, CTAB assisted ZnO, SDS assisted ZnO respectively. In trisodium assisted ZnO, symmetric and asymmetric vibrations of CH₃ group have not been observed. The stretching modes close to 1450 cm⁻¹ and 1600 cm⁻¹ attributed to C=O asymmetrical and symmetrical stretching mode of vibration, respectively due to the presence of residue from Zn(CH₃COO)₂·2H₂O the initial material. A band at 1214.9 cm⁻¹ attributed to S=O stretching vibration of SO₄ from SDS in sample figure 7(d). A peak at 709.3 / 664 / 709.1 / 708 cm⁻¹ is attributed to the stretching mode of Zn–H in ZnO/Trisodium / ZCTAB/ ZSDS respectively. All samples exhibit the characteristics band of metal oxide vibrations near 500 cm⁻¹. This is clear signal of ZnO formation and its lattice vibration [33]. With the

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Table 1. Reliability factors (R_p, R_w, R_B, R_F and χ²), lattice constant, lattice volume and crystallite size for all the samples.

| Parameters                  | ZnO             | ZnO/(Trisodium) | ZnO/(CTAB)     | ZnO(SDS)       |
|-----------------------------|-----------------|-----------------|----------------|----------------|
| R_p (%)                     | 9.70            | 7.65            | 11.0           | 15.8           |
| R_w (%)                     | 11.1            | 6.46            | 12.1           | 15.6           |
| R_B (%)                     | 7.61            | 8.97            | 8.95           | 11.9           |
| R_F (%)                     | 0.651           | 0.258           | 0.405          | 0.524          |
| χ²                          | 2.131           | 1.571           | 1.821          | 1.701          |
| Lattice Volume              | 47.981          | 47.677          | 47.281         | 47.9423        |
| a = b(A)                    | 3.25484         | 3.2419          | 3.25832        | 3.2576         |
| c(A)                        | 5.21137         | 5.2074          | 5.21861        | 5.2168         |
| c/a                         | 1.601114        | 1.60628         | 1.60162        | 1.60142        |
| Crystallite size (nm)       | 23.61           | 19.88           | 21.58          | 17.29          |

Figure 5. Rietveld refinement of ZnO nanostructure prepared using surfactant CTAB.
Figure 6. FESEM micrographs of ZnO nanostructures (a) ZnO, (b) Trisodium assisted ZnO, (c) CTAB assisted ZnO and (d) SDS assisted ZnO.

Figure 7. FTIR spectra of (a) ZnO, (b) ZTrisodium, (c) ZCTAB and (d) ZSDS.
presence of surfactants on the ZnO surface, there is slight shift of all bands towards lower wavenumber due to nanostructure size variation and different morphology.

**UV—visible results**

Figures 8(a)–(d) shows the UV-visible spectra of ZnO, trisodium citrate assisted ZnO, CTAB assisted ZnO and SDS assisted ZnO respectively. The recorded optical spectra show absorption bands in figure 8 at 374 nm for ZnO (without surfactant), at 365 nm for trisodium assisted ZnO, at 371 nm for CTAB assisted ZnO and at 367 nm for SDS assisted ZnO. The optical absorption peak of surfactant assisted ZnO samples decreases as compared to ZnO. For the nanostructures capped with trisodium citrate, CTAB and SDS, there is blue shift as compared to the ZnO. The change in morphology of ZnO clearly correlates with the blue shift as compared to bulk in the excitonic absorption spectra. We can estimate optical band gap energy using sigmoidal formula given by O’Donneal and co workers [34]

\[
\alpha = \frac{\alpha_0}{1 + \exp\left(\frac{E_a - E}{\Delta E}\right)}
\]

where E\textsubscript{a} is effective band gap energy, broadening parameter is represented by \Delta E. Sigmoidal fit for ZnO, Trisodium citrate assisted ZnO (ZTrisodium), SDS assisted ZnO (ZSDS) and CTAB assisted ZnO (ZCTAB) has been shown in figures 9(a)–(d). Optical band gap energy as determined from above graphs is 3.30 eV, 3.34 eV, 3.32 eV and 3.31 eV respectively. This is in agreement with XRD and FTIR results.

**Photoluminescence results**

The photoluminescence (PL) spectra of different ZnO nanostructures have also been used to investigate the influence of different capping agents. It has been reported that photoluminescence spectrum of ZnO is affected by crystalline size, shape and synthesis conditions [35]. Generally, UV emission peak is denoted as the emission peak of ZnO and ascribed to the near band edge emission originated due to excitonic recombination of free excitons. Intrinsic defects such as oxygen intersites, oxygen vacancies, zinc vacancies, zinc interstitials are responsible for the emission in visible region. Despite of several reports, origin of visible emission peaks of ZnO is debatable. Figure 10 shows the photoluminescence graph of samples ZnO and trisodium citrate assisted ZnO, CTAB assisted ZnO and SDS assisted ZnO measured at excitation wavelength of 325 nm. All the samples exhibit similar photoluminescence spectra. Figures 10(a)–(d) shows the UV emission peak at 378 nm for pure ZnO and strong UV peak at 390 nm for Trisodium assisted ZnO, CTAB assisted ZnO and SDS assisted ZnO, respectively. It has been ascribed to near band edge emission peak originated due to excitonic recombination of free excitons. As can be seen from figure 10, in the visible region, the weak blue emission at 488 nm, 470 nm, 468 nm and 467 nm for ZnO, SDS assisted ZnO, trisodium citrate assisted ZnO and CTAB assisted ZnO, respectively is due to intrinsic defects present due to transition of electron from donor level to the valence band top [36]. Green emission peak at 563 nm for figure 10(a) and at 545 nm for figures 10(b)–(d). This green emission arises due to the recombination of deep trap hole in oxygen vacancy which is singly ionized with delocalized electron present close to the conduction band. It is noticeable from the figure 10 that the location of the UV emission peak and visible emission peak center changes due to addition of surface active molecules to ZnO surface. There is slight shift of UV emission peak and visible emission peak toward higher wavelength and lower wavelength,
respectively, of ZnO assisted with (trisodium citrate, CTAB and SDS) due to quantum confinement effect. With the introduction of different surfactants the intensity of the emission peaks decreases. The surface active molecule helps to form less defect structure during their formation and it keeps the particle size minimum with attachment to the particle surface.

XRD of composites
The XRD spectra of the PANI, ZnO-Polyaniline composites have been shown in figure 11. The x-ray diffractograms of PANI (figure 11(a)) shows that the broad diffraction peak observed around 17°–28° due to some crystallinity, as benzenoid and quinoid rings are present in PANI chains. The x-ray diffraction pattern of ZnO-PANI nanocomposites (figure 11(b)) shows reflection peaks of ZnO nanoparticles of wurtzite structure along with the presence of PANI peak. The presence of the ZnO related peaks confirms the presence and phase stability of ZnO nanoparticles in PANI matrix. The crystal structure of trisodium citrate assisted ZnO nanocomposites shown in (figure 11(c)) has quite high crystallinity than CTAB and SDS surfactants assisted ZnO nanocomposites. With the introduction of PANI into ZnO nanostructure, the intensity of ZnO/PANI composites has been reduced. This is due to the well encapsulation of PANI onto the ZnO particles.
Cyclic voltammetry study
The cyclic voltammetry study has been recorded for samples in the range of \(-0.4 < E_{\text{SCE}} < 1.2\) V at \((\text{d}E/\text{dt})\)\(-50\) mV s\(^{-1}\) (scan rate) on an ITO electrode. The electrochemical behaviour of all electrodes under same conditions has been recorded using mixture of [Fe(CN)\(_6\)]\(^{3-}/4-\) and PBS (0.1M) as redox probe by cyclic voltammetry. Figure 12 shows the different modified electrodes–polyaniline (PANI), ZnO/PANI, trisodium citrate-ZnO/PANI, CTAB-ZnO/PANI and SDS-ZnO/PANI. The current intensity increases and potential separation decreases for surfactant modified ZnO/PANI electrodes that demonstrates the enhancement of the electrochemical performance of the electrodes because of the rise in electron transfer rate, conductivity and catalytic ability. Though, lowest potential peak separation and greatest peak current are perceived when the electrode is modified with trisodium citrate-ZnO/PANI which can be associated to the synergistic contribution of trisodium citrate in ZnO nanoparticles.

Electrochemical results reveal that the current intensity of PANI enhances with the addition of ZnO and surfactant modified ZnO. Among all the surfactants, trisodium citrate has higher value of current intensity as compared to CTAB and SDS assisted ZnO/PANI nanocomposites and pure PANI which is due to the better dispersion of nanoparticles in PANI matrix. We choose trisodium citrate assisted ZnO/PANI nanocomposites for the fabrication of urea biosensor due to its higher current intensity as compared to other nanocomposites as shown in figure 12.

Scan rate influence
From figures 13(a)–(b), we have studied the diffusion controlled behaviour of trisodium citrate assisted ZnO/PANI-NCs/ITO electrode. Figure 13(a) shows CV measurements of electrode as a function of scan rate from 10
to 90 mV s\(^{-1}\). The linear relationship of anodic and cathodic peak currents in the diffusion controlled system has been observed as a function of square root of the scan rates in the range of 10–90 mV (the value of square of correlation coefficient \(R^2\) is 0.99395 for \(I_{pa}\) and 0.99900 for \(I_{pc}\) respectively). The surface concentration (\(C\)) of Urs/ZnO/PANI/ITO electrode has been quantified using Brown–Anson model from \(I_p\) plot versus square root of scan rate using equation (2).

\[
I_p = n^2F^2CA\theta / 4RT
\]

where \(I_p\), \(n\), \(F\), \(A\), \(\nu\), \(R\) and \(T\) represent here peak current, electron stoichiometry, Faradays constant (96584 C mol\(^{-1}\)), surface area of electrode (0.25 cm\(^2\)), scan rate (10 mV s\(^{-1}\)), gas constant (8.314 J mol\(^{-1}\) K and temperature (298K). The value of surface concentration (\(C\)) comes out to be 8.035 \(\times\) 10\(^{-8}\) mol cm\(^{-2}\).

The value of diffusion coefficient, \(D\) of ZnO/PANI/ITO electrode could be therefore estimated using Sandel–Sevcik equation (3).

\[
I_p = (2.69 \times 10^5)n^{1/2}AD^{1/2}C_v^{1/2}
\]

Figure 14(a) displays the electrochemical behaviour of trisodium citrate assisted Urs ZnO/PANI NCs electrode of blank sample and electrodes with variation of urea concentration from 10 mg–80 mg dl\(^{-1}\) using cyclic voltammetry technique. Figure 14(b) shows linear relationship of oxidation peak current with respect to urea concentration in the two regions: region 1 linear range (0 mg/dl–60 mg dl\(^{-1}\)) and region 2 (above 60 mg dl\(^{-1}\)) have shown in inset of figure 14(b) in logarithmic scale. This has been ascribed to the increased amount of released electrons during oxidation of urea. The reaction between urea and urease leads to production of two NH\(_4\)\(^+\) and one CO\(_3\)\(^-\) from uncharged component (urea). The NH\(_4\)\(^+\) ions react with pre adsorbed surface oxygen of ZnO/PANI material with increase in conductivity of sensor. Further, good biocompatibility of PANI is convenient for immobilization of urease enzyme, which leads to more adsorption and diffusion of ammonium ions. The linear equation for urea sensor in linear range from 0 mg/dl–60 mg dl\(^{-1}\) is \(I(A) = 1.82507 \times 10^{-6} \times (X) + 0.000147\), with regression coefficient \(R^2 = 0.976\). Sensitivity, defined as smallest absolute change in the amount that can be distinguished by measurement is calculated from linearity graph to be 7.30 \(\mu\)A (mM cm\(^{-2}\)).

Low limit of detection (LOD) defined as estimation of lowest value of substance that can be detected from absence of that substance calculated from below relationship (4)
here SD and S represent standard deviation of blank sample and slope of linearity curve respectively. From above equation (4) the limit of detection estimated is 2 mg dl$^{-1}$.

Further, efforts will be made to check the selectivity towards biomolecules and determining the value of urea in serum samples using this ZnO/PANI/ITO electrode.

**Conclusion**

ZnO and surfactant modified ZnO nanostructures have been prepared using simple sol gel method. ZnO-PANI nanocomposites films have also been deposited on ITO substrate. FESEM technique shows that with the introduction of surfactant on the ZnO surface, morphology can be changed. Photoluminescence study suggests defects in the ZnO structure decrease with the introduction of surfactants. Electrochemical results suggest that the current intensity of PANI enhances with ZnO and surfactant modified ZnO. For the diagnosis of liver and kidney disease, the estimation value of urea in blood/urine sample is necessary. It is well known that in urine and blood normal urea range is 8–20 mg dl$^{-1}$. With the fabrication of urea biosensor, using immobilization of urease enzyme on the trisodium citrate assisted ZnO/PANI/ITO nanocomposites exhibit linearity with increase in urea concentration 10–80 mg dl$^{-1}$ with detection limit $\sim$2 mg dl$^{-1}$. It has been defined as estimation of lowest value of substance that can be detected from absence of that substance. Sensitivity calculated as $\sim$7.30 $\mu$A mM$^{-1}$ cm$^{-2}$, has been defined as smallest absolute change in the amount that can be distinguished by measurement. The above proposed urea sensor can be used for determining the presence of urea in serum samples and further, efforts will be made to check the selectivity towards biomolecules.
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