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A New Non-Enzymatic Amperometric Sensor Based on Nickel Decorated ZIF-8 Derived Carbon Nanoframe for the Glucose Determination in Blood Samples

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The present study demonstrated a highly sensitive non-enzymatic glucose biosensor in real blood samples based on simple evaluated nickel deposited on N-doped porous carbon modified glassy carbon electrode (Ni/NPC/GCE) by applying electrochemical deposition method. The prepared material initially were characterized by cyclic voltammetry, the morphology structure of the as-prepared samples was observed by SEM, and composition, crystals structure of Ni/NPC were identified by SEM mapping and EDS tests. The Ni/NPC/GCE compared with NPC/GCE and NiNPs/GCE performed the best electrocatalytic behavior towards oxidation of glucose in 0.1 M KOH medium. By applied potential of +0.6 V Ni/NPC/GCE showed very high sensitivity of 3753.78 $\mu AmM^{-1}cm^{-2}$ in linear range of 1-7940 µM with the correlation coefficient of R^2=0.995. The linear ranges get views above the concentration up to 7940 µM with the detection limit of 0.3 µM (S/N=3). Amperometric time responses of prepared electrode towards different glucose concentrations are 0.8-1.3s. Finally, several positive characteristics such as very high sensitivity, weak working potential, nice anti-interference properties, long stability, good selectivity, and comparison with some other non-enzymatic sensors Ni/NPC/GCE executed high sensitivity, low detection limit and wide linear range to glucose sensing, thus the selected electrode is supplying for future glucose level determination design.

Keywords: Nickel deposition, N-doped porous carbon, electrodeposition, glucose biosensor

1. INTRODUCTION

Diabetes mellitus is a heterogeneous disease, which is developing under the result of unhealthy lifestyle, wrong eating habits, it was considered to violation variety of carbohydrate metabolism, manifested by hyperglycemia, impaired glucose tolerance, increasing glucose level in blood which is leading causes of death, reducing the patient's life quality and makes shot the life duration and in total disability of most organs[1–4]. So the requirement for diagnoses of diabetic patients is to manage and control the glucose level in blood. Glucose determination is the most important parameters in several area fields such as biochemical and clinical diagnostics, industry products and ecological monitoring[5–8]. In the few last decades the glucose determination level were provided by different methods and techniques, including optics[9], fluorescence[10], plasmatic resonance[11], HPLC[12] and electrochemical test[13]**.** The electrochemical method among analytical fields was extensively evaluated due to its sensitivity, selectivity, stability, innocence and portability[14]. Also the disadvantages of enzymatic sensor are immobilization and sensitive process, expensive, control temperature and prepare good environmental medium to fabricate real life for glucose detection[15–17], but to solve this problem were paid more attention to develop the non-enzymatic sensors[18]. Due to this purpose several non-enzymatic sensors based on metal such as Au[19], Pt[20], Cu[21], Bi and Ni[22], based on metal oxide: CuO[23], NiO[24], Co_3O_4[25], MnO_2[26], RuO_2[27] and based on nanomaterials such as Pt-nanoparticles[28], Pt nanoporous[29], Au@Pd nanoparticles[30], Pd nanocubes[31], Au nanoporous[32], Pt-Ru nanoparticles[33], Ni-Pd nanoparticles[34], Pt-Pb nanowire[35] and Cu@Ni nanoparticles[36] were fabricated for glucose detection.

Recently, N-doped porous carbon (NPC) was fabricated from zeolitic imidazolate framework (ZIF-8) and has been quickly became an electrochemical nanomaterial due to its remarkable structure, plain surface square, the best electro-conductivity, long stability and stable mechanical properties[37]. Thus, to obtain the precursor material, chemical-vapor-deposition (CVD) processes were used for the successful syntheses of N-doped porous carbon[38].

In present research we have successfully fabricated a non-enzymatic electrode based on nickel nanoparticles deposited on N-doped porous carbon modified GCE, which was developed for the glucose detection in real samples. Due to the previously publications up to submission time there is no any glucose application based on nickel deposited on N-doped porous carbon modified GCE. The electrodeposition method was used to nickel deposition on NPC/GCE surface. In comparison with GCE, NPC/GCE and NiNPs/GCE Ni/NPC/GCE has performed the best electrocatalytic activity for glucose detection in real samples.

2. EXPERIMENTAL SECTION

2.1. Chemical Reagents and Materials

Existing D-Glucose in blood and 2-Methylimidazole were bought from Aladdin (Shanghai, China), uric Acid (UA), ascorbic acid (AA) and dopamine hydrochloride were obtained from Macklin

Biochemical (Shanghai, China), sodium nitrate, potassium hydroxide, zinc nitrate and nickel nitrate were purchased from Hongyan (Tianjin, China), absolute ethanol, methanol and N,N-dimethil formamide were purchased from Oubokai (Tianjin, China), serum samples were got from local hospital (Urumqi, China). All the chemical agents were analytical sort and used without any subsequent purification. To produce ultrapure water Milli-Q system (≥18.2 MΩ) was used for providing experiments. The electrochemical measurements were carried in 0.1 M KOH medium. N_2 was provided in experiment to exclude O_2 disturbance before the nickel electrodeposition.

2.2. Equipments

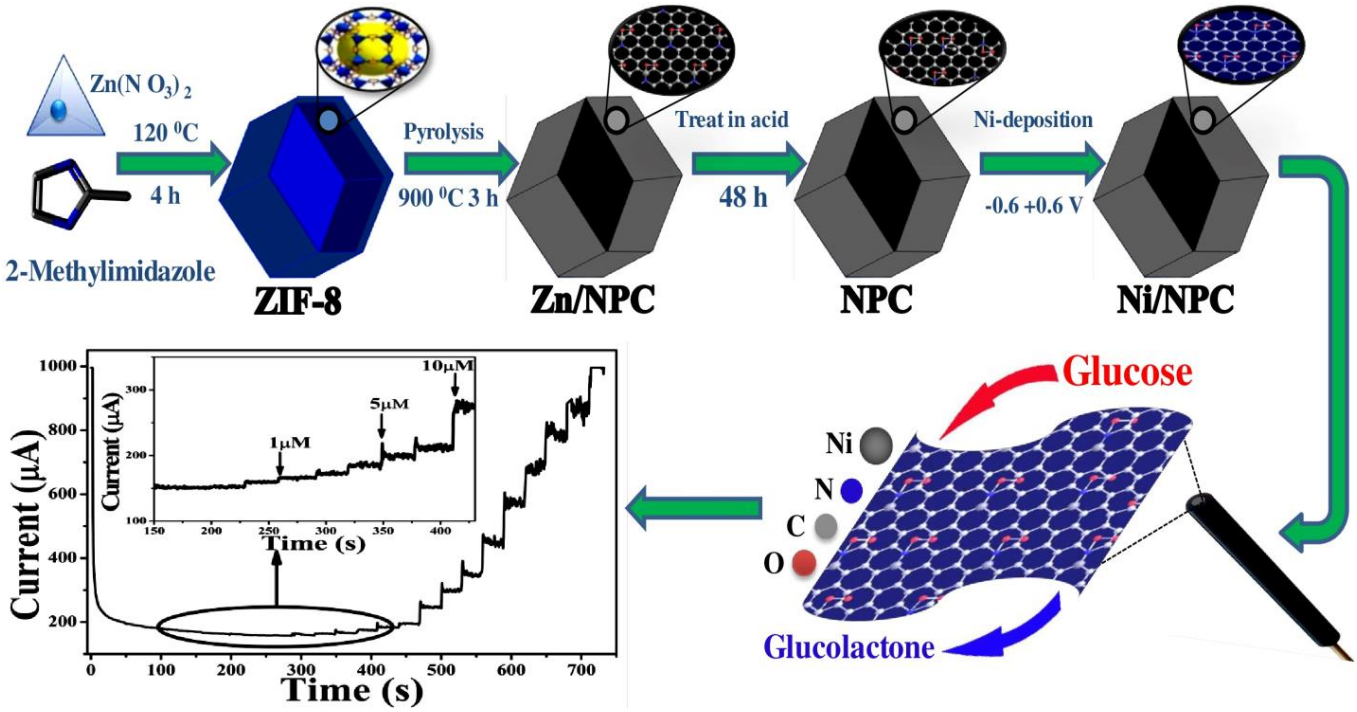
The morphological characterization of N-doped porous carbon (NPC) and nickel deposited on NPC were noticed by scanning electron microscope (SEM), SUPRRA-55VP (ZEISS, Germany), crystal structures and composition were identified by EDS and SEM mapping. CHI-1040C electrochemical workstation (Shanghai, China) was used for all electrochemical and amperometric surveillance with the standard three-electrodes installation by applying Ag/AgCl as a reference electrode, the platinum wire as a counter electrode and Ni deposited on NPC casted GCE (0.3 mm) as a working electrode in 0.1 M KOH at ambient temperature. Glucose determination by using enzymatic method have done in Traditional Chinese Medicine Hospital of Urumqi, the blood samples and glucose concentration data based on enzymatic method for comparison were received from this hospital.

2.3. N-doped porous carbon preparation and fabrication of nickel deposited on NPC modified glassy carbon electrode (Ni/NPC/GCE)

The preparation process is depicted in Scheme.1. Initially, zeolitic imidazolate framework (ZIF-8) was prepared to fabricate NPC. 16 mM 2-Methylimidazole was dissolved in 7.5 mL methanol and remarked a glass A. As a glass B 4 mM zinc nitrate was dispersed in 15 mL methanol. Both glasses were ultrasonicated 15 min, further glass A was added in glass B and kept under magnetic stirring condition for 1 h at room temperature. The mixture was moved into 100 mL stainless-steel Teflon and autoclaved 4 h at 120 ^{0}C. The received substance was centrifuged for separation and erase with methanol and DMF twice, last 12 h under vacuum at 70 ^{0}C was dried. ZIF-8 powder transferred into ceramic tube and heated at 900 ^{0}C (5 ^{0}C min^{-1}) for 3h under argon gas, and then cooled down at room temperature. After pyrolysis of ZIF-8 at 900 ^{0}C under Ar gas, it transformed to N-doped porous carbon (NPC). The obtained substance was kept into 1 M HCl for 48 h at environment temperature to remove metal species contained in NPC and washed with ethanol and water, then dried at 80 ^{0}C. Finally, prepared material was labeled as NPC and used without further treatment.

1 mg NPC powder was dispersed into 1 mL DMF and ultrasonicated 15 min. From homogenous solution 5 µL was dropped on GCE which was polished with Al_2O_3 (1.0; 0.3 and 0.05 µm) and rinsed with ethanol and ultrapure water. Afterwards dried naturally at room temperature and NPC modified GCE was manufactured.

10 mL electrolyte solution containing 0.1 M $NaNO_3$ and 5.0 mM $Ni(NO_3)_2$ which was deoxygenated with N_2 for 20 min to eliminate O_2 interference, was used to electrodeposition of nickel on NPC adjusted GCE by using CV with the voltage windows of -0.6 to +0.6 V, sweep segment number was 40 under the magnetic stirring provision with 100 mVs^{-1} scan rate. Carefully, the electrode was rinsed with ultrapure water and dried naturally at environment temperature. Finally, nickel deposited on NPC modified GCE was tried for glucose determination in alkaline medium. The comparison electrodes: GCE, NPC/GCE and NiNPs/GCE were prepared under the same stipulation.



Scheme 1. Schematically nanomaterial preparation and its application for glucose determination

3. RESULTS AND DISCUSSION

3.1. Characterization of ZIF-8, NPC and Ni/NPC/GCE nanocomposite

Morphological characterization of NPC/GCE and Ni/NPC/GCE were observed by SEM (SUPRRA-55VP, ZEISS, Germany), that is shown in Fig. 1a and b. It is clearly visible that NPC evidently thicker and smooth before the nickel deposition and after existing sheeted (Fig. 1a). There were given more details by SEM to get more information about morphological characterization of nickel deposited on NPC. Fig. 1b performed that Ni/NPC hold its original shape with rough surface. Engrossed Ni^{2+} could be reduces to Ni nucleus and then reformed to NiNPs on surface of NPC by applying electrostatic potential. According the mapping pictures Ni, O, C and N were apportioned uniformly throughout the structure (Fig. 1c). As Fig. 1b demonstrates Ni nanoparticles were slept smoothly on matrix of NPC surface. The dimension of nickel nanoparticles were calculated by ImageJ software with the average diameter of 0.28 nm.

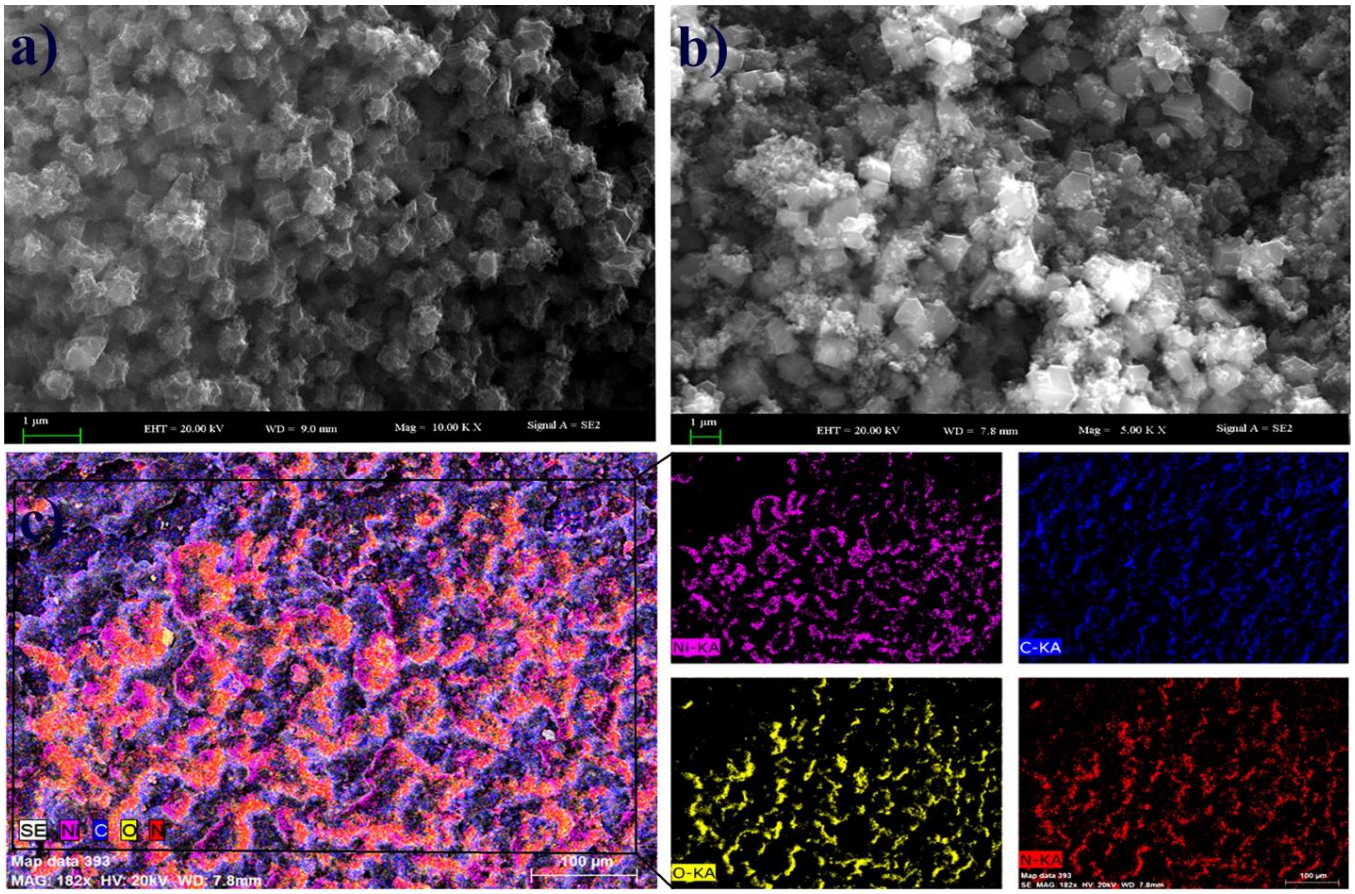


Figure 1. SEM image of NPC (a), Ni/NPC (b), and SEM image corresponding element maps performing the distribution of Ni (pink), C (blue), O (yellow) and N (red) (c).

XRD patterns of the ZIF-8 (blue), NPC before the treatment (red) and NPC after the treatment in acid (black) are performed in Fig. 2A. It is clear from the Fig 2A that the XRD pattern of ZIF-8 in comparison with as published ZIF-8 structure data[39] indicates that as-prepared pure ZIF-8 was obtained. XRD patterns of the NPC after the treatment in acid (Fig 2A (black)) is performing the wide broad shoulder peak in the range of 5-80 theta degree that is the same with NPC before the treatment (Fig 2A (red)), which were derived from the pure ZIF-8 by annealing at 900^0C. This peak was assumed to the 002, which is proving the graphitic carbon structure of as prepared NPC.

The composition structure of Ni/NPC/GCE in atomic level was characterized by EDS which is demonstrated on Fig. 2B and C. The EDS of Ni/NPC/GCE depiction displays that the complex substance was consist from Ni, C, O and N uniformly and proved the coexistence of nickel nanoparticles on NPC matrix. EDS images of Ni deposited on NPC which is NPC before the treatment, coexist with Zn atom (Fig. 2B) and after the treatment in acid (Fig. 2C) (1 M HCl 48 h at room temperature) with absence of Zn atom are displaying in Fig. 2B and C.

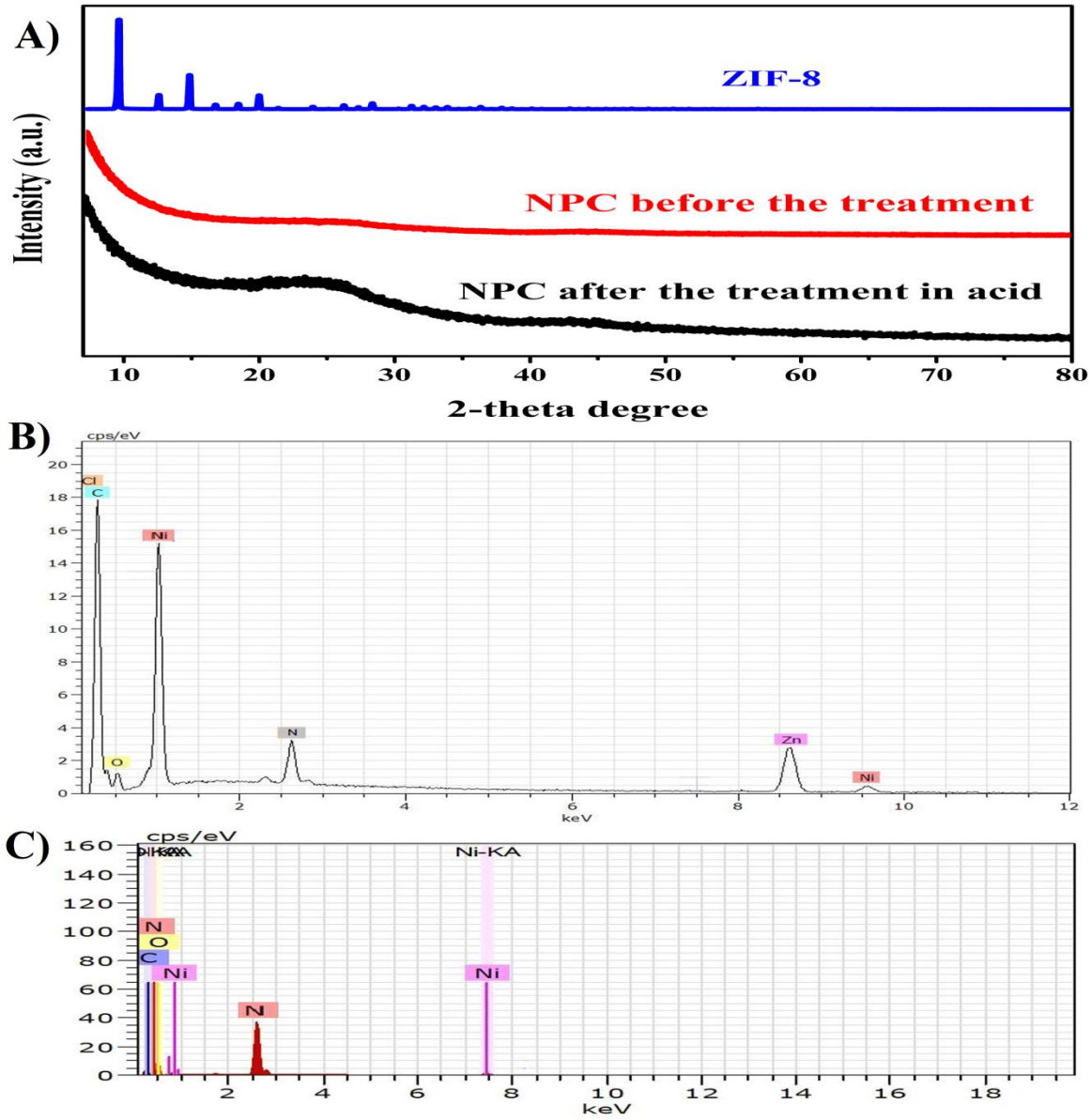


Figure 2. A) XRD patterns of the ZIF-8 (blue), NPC before the treatment (red) and NPC after the treatment in acid (black). B) EDS images of Ni/NPC/GCE, which NPC is before and C) EDS images of Ni/NPC/GCE, which NPC is after the treatment in acid.

3.2. Glucose electrocatalysis by electrochemical behavior of different electrodes and electrocatalytic glucose oxidation on Ni/NPC/GCE

The electrocatalytic behavior of bare and modified electrodes towards glucose oxidation in 0.1 M KOH medium with the absence and attendance of 0.1 M glucose explored by CV test with the voltage window of 0-0.8 V under 100 mVs^{-1} scan rates is shown in Fig. 3. It could be seen that bare GCE and NPC/GCE with absence (curve a, c insert of Fig. 3.) and attendance (curve b, d insert of Fig. 3.) of 0.1 M glucose demonstrated no any redox peak and glucose oxidation on GCE and Ni/GCE surface not achieved. But from Fig. 3. is visible that NiNPs/GCE and Ni/NPC/GCE with the absence (curve e, g) and attendance (curve f, h) of 0.1 M glucose in 0.1 M KOH liquor demonstrated the redox

couple curves, which is refer to Ni(II)/Ni(III) converting in alkaline medium. Ni deposited on modified electrode presented the well-defined oxidation peak, which could be derived from the electrochemical reactions of Ni(II)/Ni(III)[40–42]. The highest and largest current redox peak was investigated by Ni/NPC/GCE (curve g, h) than the other electrodes that are evidence of promoted nickel ions racket filled on NPC sheets adjusted on GCE surface. It could ensure the excellent properties of nickel ions and N-doped porous carbon substance in alkaline aqua which is the top grand design for the glucose determination in biological fluids and real samples. This result is confirming that NPC nanomaterial as intermediate layer is the best electro-conductive nanoframe, play the main role in to the electron transportation.

Nickel ions were deposited on N-doped porous carbon modified GCE to fabricate Ni/NPC/GCE by using CV with the voltage windows of -0.6 to +0.6 V under the varying sweep segments were estimated (data not shown). The electrocatalytic glucose oxidation quality was tested with the deposition sweep segment number of 40 which the Ni/NPC/GCE exhibited tolerable sensibility and durable stability. Thus, the sweep segment number of 40 was elected for Ni/NPC/GCE manufacturing as a working electrode. From the previous studies it was clear that at the potential less than and equal to 0.6 V in alkaline solution Ni first transfer to the $Ni(OH)_2$[43,44] and then intermediate oxidation substances further should be oxidized to NiOOH as below descriptions. NiNPs/GCE and Ni/NPC/GCE with the absence (curve e, g) and attendance (curve f, h) of 0.1 M glucose in alkaline liquor executed a pair redox curves, that could be belong to Ni(II)/NI(III) conformation[45,46], which is displayed in Eqs. 1 and 2.

$$Ni+2OH^- \rightarrow Ni(OH)_2+2e^- \quad (1)$$

$$Ni(OH)_2+OH^- \rightarrow NiOOH+H_2O+e^- \quad (2)$$

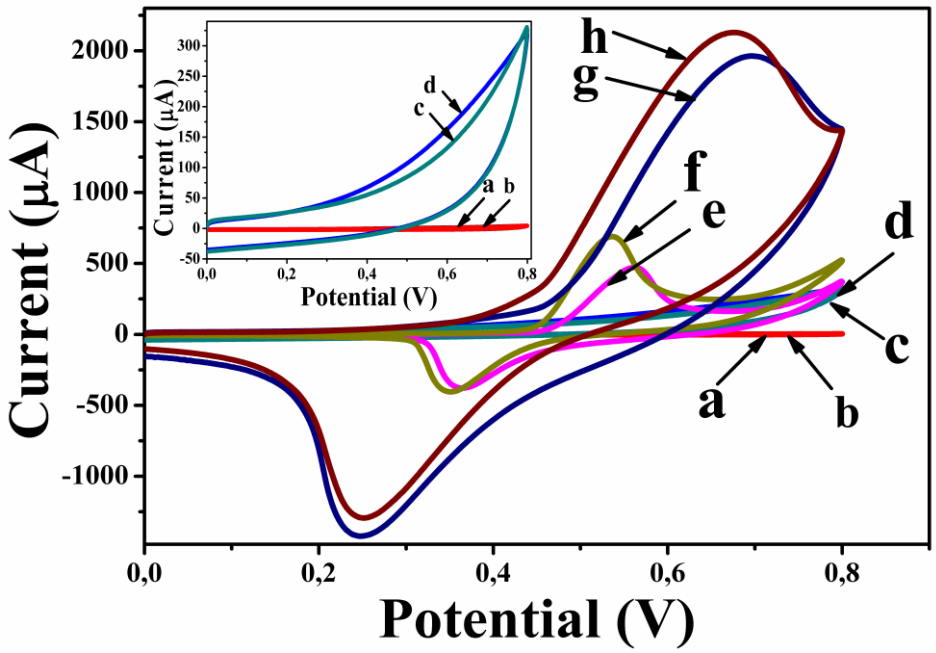


Figure 3. CV of different electrodes with absence of glucose: GCE (a), NPC/GCE (c), NiNPs/GCE (e), Ni/NPC/GCE (g) and with presence of 0.1 M glucose: GCE (b), NPC/GCE (d), NiNPs/GCE (f), Ni/NPC/GCE (h) in 0.1 M KOH. Insert: GCE (a, b) and NPC/GCE (c, d). 100 mVs^{-1} scan rate.

It is established that Ni/NPC/GCE has the highest pair redox curves than NiNPs/GCE (Fig. 3.) that is indicating activity advances was ascribed to maintaining of nickel nanoparticles dissipated and were bound more on NPC modified GCE. Presence of NPC improved the velocity of electron conveyance and current test shows the supercilious property effects, remarkable nanocomposite, especially huge square side and electro conductibility. The demonstrated as-prepared material is the best grand design for the glucose determination in alkaline liquor. Curve h of Fig. 3. performed positive anodic voltage shift by addition of 0.1 M glucose in alkaline system the anodic peaks growing which is indicating the glucose oxidation on surface of modified electrode in alkaline medium, this could be clearly understandable that Ni(III) nanoparticles accordance the following reaction[47] as shown in Eqs. 3, participated in electrocatalytic glucose oxidation.

$$NiOOH + glucose \rightarrow Ni(OH)_2 + glucolactone \qquad (3)$$

From the Eqs. 3 could be observing that electrocatalytic reaction of glucose absorption on Ni/NPC/GCE surface happening in cathodic and anodic side that negative voltage rates of electrochemical operation referred to nickel (II) oxidation. Glucose oxidation on electrode surface at the anodic voltage quickly oxidized by Ni(III) form. The main reason of increasing anodic curves, its increasing of Ni(II) level and decreasing of Ni(III) level in alkaline medium.

3.3. The effect of varying glucose concentrations and scan rates

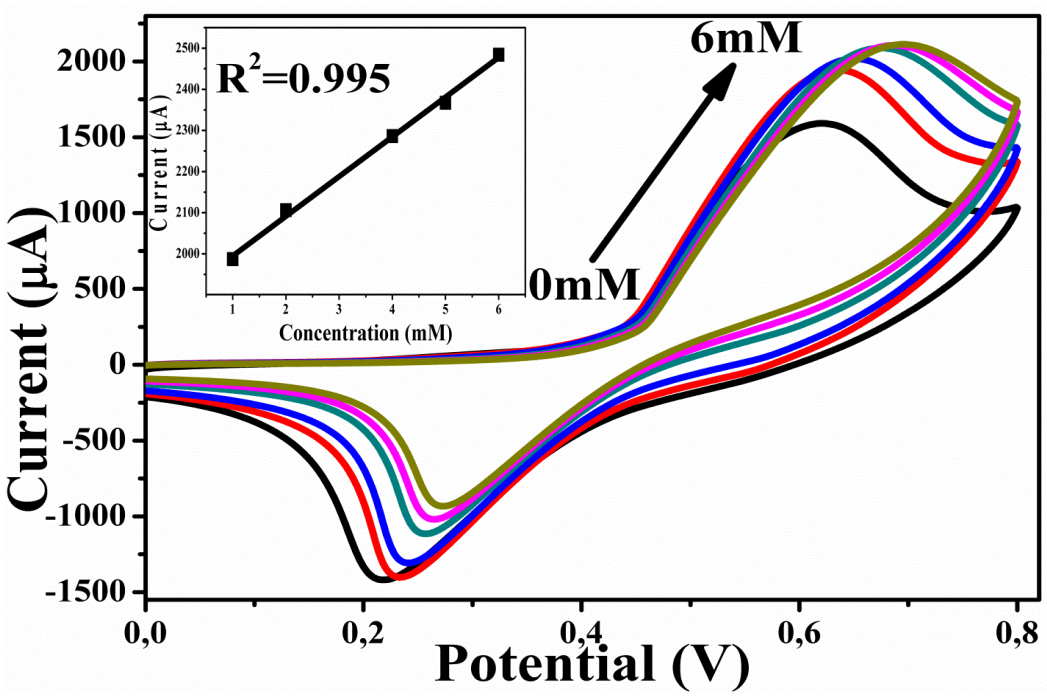


Figure 4. CV of Ni/NPC/GCE during successive addition of varying glucose concentration (0, 1, 2, 4, 5 and 6 mM) in 0.1 M KOH. Insert: the graph current peak with coefficient of correlation R^2=0.995, scan rate of 100 mVs^{-1}.

To investigate the effect of concentration rates, varying glucose concentration (0-6 mM) were added to the CV system with the potential table of 0-0.8 V and applied 100 mVs^{-1} scan rates. The CV of Ni/NPC/GCE with addition of different glucose concentration is illustrated on Fig. 4. It's clearly

noticeable that by growing glucose concentration balanced improvement of redox current is reached relatively, and it could be consecutive with glucose oxidation and NiOOH reduction simultaneously[48]. However, the oxidation of Ni(II) to Ni(III) is difficult according the studied report[49] due to the Ni hydration, but in this study Ni ions were deposited on matrix of NPC film and could be changed the oxidation condition and Ni(II) easily converted to Ni (III). Decreasing glucose absorption on surface of Ni/NPC/GCE is referring to damage effect of secondary and transitional substances. Current study test offers that Ni/NPC/GCE exposed high glucose oxidation catalytic performance with the coefficient of correlation R^2=0.995 in alkaline liquor (insert of Fig. 4.). Thus, the Ni/NPC/GCE by addition varying glucose concentration exhibited the best linearly developing potential of anodic.

Surface reaction process is very important specification of electrode, thus to discover the scan rates effect CV of Ni/NPC/GCE in 0.1 M KOH with addition of 0.1 M glucose at varying scan rates from 20-400 mVs^{-1} in voltage windows of 0-0.8 V were registered (Fig. 5.). By increasing scan rates, peak current of anode and cathode linearly parallel improved with the coefficient of correlation R^2=0.995.Test study has found that success in scan rate growth is high correlate with current curve increasing (insert of Fig. 5.). By increasing the scan rates both the cathodic and anodic peak currents improved proportional, which is indicating the surface controlled electrode process[50].

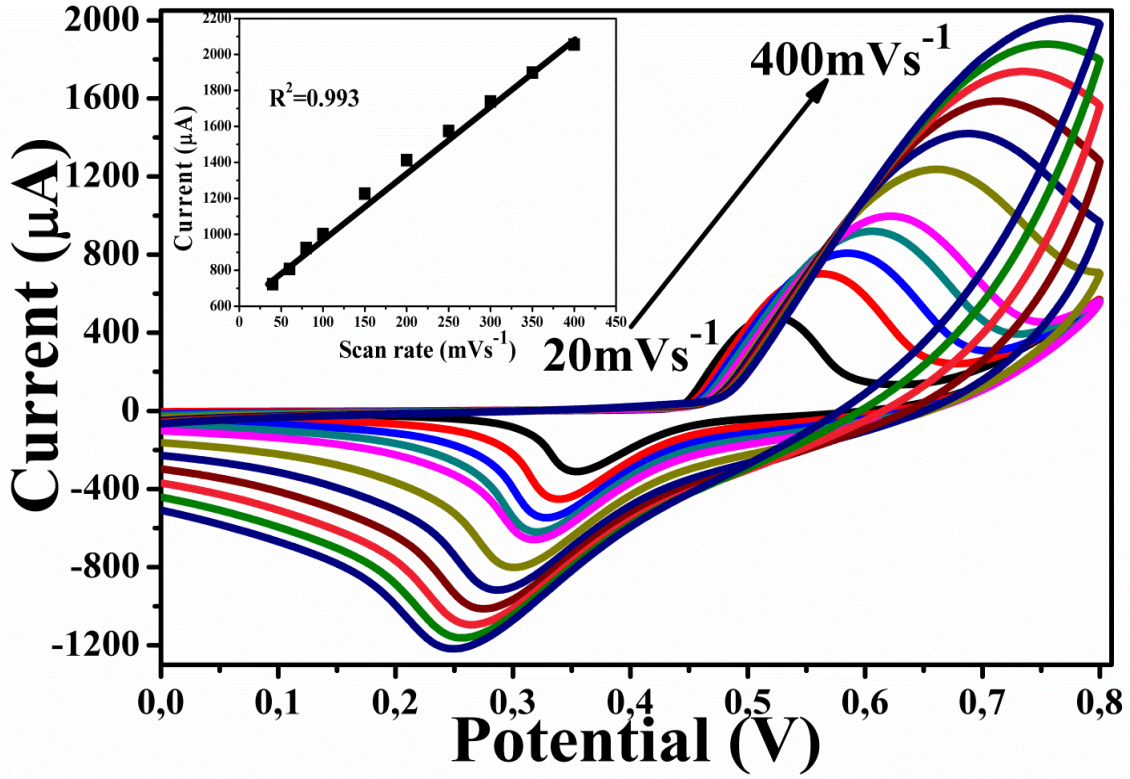


Figure 5. CV of Ni/NPC/GCE upon different scan rates (20, 40, 60, 80, 100, 150,200, 250, 300, 350, and 400 mVs^{-1}) in 0.1 M KOH with 0.1 mM glucose existence. Insert: the plot peak current with correlation coefficient R^2=0.993.

According this result electrochemical kinetics process on surface of Ni/NPC/GCE is operated by glucose absorption and dispersion manageable electron transportation in alkaline electrolyte which

is refer to NiOOH nucleation[44,51], furthermore by increasing scan rates both anodic peaks current and cathodic dislocated to high values.

3.4. The glucose detection effect by amperometric test responses of Ni/NPC/GCE

The applied potential action of Ni/NPC/GCE was systematically discovered by using amperometric i-t curve analyses in 0.1 M alkaline medium with addition of 0.1 M glucose under different applied potential from +0.5 to +0.7 V, the steady peak provision at +0.6 V reached in high maximum level, thus for glucose detection the optimum potential of +0.6 V was elected.

To study the effect of glucose detection, Ni/NPC/GCE was immersed in 0.1 M KOH liquor by applying amperometric i-t curve test with growing addition varying glucose concentration at the optimal potential of +0.6 V under magnetic stirring provision is depicted on Fig. 6A. Amperometric test responses of Ni/NPC/GCE towards subsequence varying glucose concentration infusion shows high performance with quick responses time of 0.8-1.3s, which is evidencing non-enzymatic glucose biosensor has speedy current reply and magnificent sensitivity. The cause is referring to the high potency electrocatalytic feature of Ni/NPC/GCE against glucose. Fig. 6B shows the ΔI value of working electrode with addition varying glucose concentration, which is indicating that by growing glucose concentration the ΔI value increased obviously, then peak current gradually go out of linear range. The calibration curve of varying glucose concentration in linear range of 1-7940 μM with coefficient of correlation R^2=0.995 is displays in Fig. 6B. Compare with some other non-enzymatic glucose sensors Ni/NPC/GCE performed very low detection limit of 0.3 μM (S/N=3) and comparable very high sensitivity as 3753.78 μAmM^{-1} cm^{-2}, that the slope was divided by electrode's square[52,53].

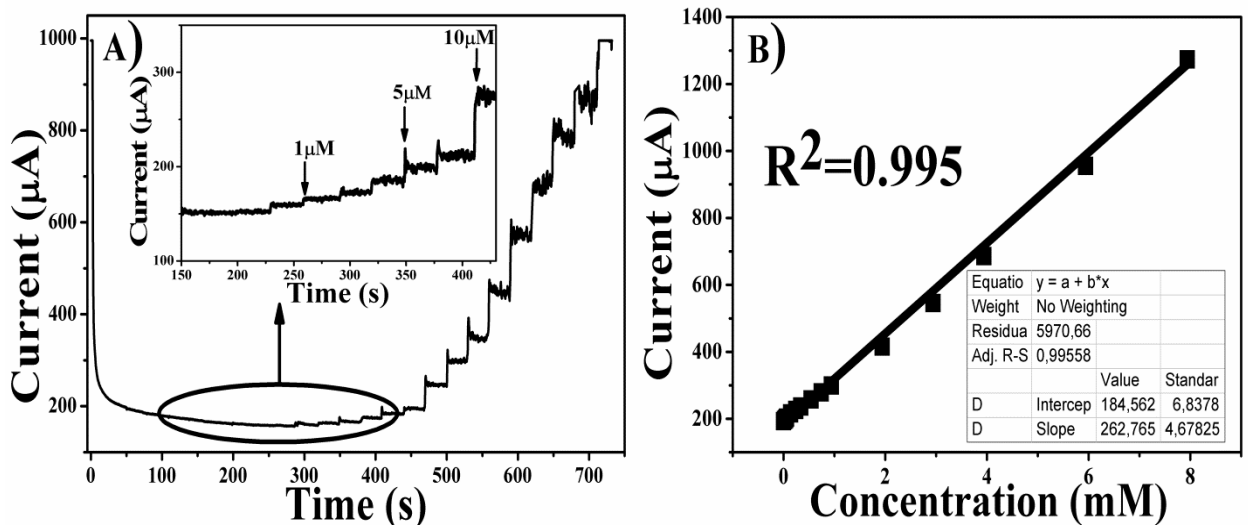


Figure 6. Amperometric test of Ni/NPC/GCE during successive addition of various glucose concentrations with the applied potential of +0.6 V in 0.1 M KOH under magnetic stirring condition. Insert: the expansion circle section (A), the calibration linear graph of wide concentration range from 0 to 7940 μM glucose with sensitivity of 3753.78 μA$mM^{-1}cm^{-2}$, coefficient of correlation R^2=0.995 and detection limit of 0.3 μM (B).

Several non-enzymatic glucose sensors based on nickel nanoparticles are collected in Table 1 to compare with Ni/NPC/GCE. From the Table 1 evidently clear that Ni/NPC/GCE demonstrate very high sensitivity, low detection limit and wide linear range compare with other nanoparticles, which is promising for future glucose sensor development.

Table 1. Sensitivity, linear range and detection limit of Ni/NPC/GCE towards glucose oxidation in comparison with some other electrodes based on Ni nanoparticles.

Electrodes	Sensitivity $mAmM^{-1}cm^{-2}$	Linear range μM	Detection limit μM	References
Bi/Ni/GCE	33.96	0-5800	590	[22]
Ni-rGO	813	1-110	1	[45]
Ni/ATP/RGO	1414.4	1-710	0.37	[48]
NiO	43.9	1-110	0.16	[54]
NiO /MWCNTs	1770	10-7000	2	[55]
NiNP/SMWNTs	1438	1-1000	0.5	[56]
Ni/NPC/GCE	3753.78	1-7940	0.3	Current study

There are six electrodes (Ni/NPC/GCE) were prepared and kept at room temperature that weren't in performance used to study the stability and reproducibility factor of Ni/NPC/GCE. After 15 and 30 days the relative standard deviation (ΔIpa) of 98.2% and 97.1% by amperometric responses of varying glucose concentration comparing with new prepared electrodes investigated, but in 8 days of storage no any changing of peak current observed. The reproducibility and long-term stability of Ni/NPC/GCE was confirmed by current data result.

Another significant electrode factor is anti-interference investigation, because some molecules such as: dopamine (DA), uric acid (UA) and ascorbic acid (AA) together with glucose co-exist in human's blood. The glucose level of human's blood in millimole unit but DA, UA and AA in micromole degree physiologically normal life, so glucose and interfering substrates with the mol ratio of 5:1 were selected to investigate anti-interference study by using amperometric test of Ni/NPC/GCE with addition of 0.5 mM standard glucose, 0.1 mM DA, 0.1 mM UA, 0.1 mM AA and another 0.5 mM standard glucose in 0.1 M KOH with selected potential of +0.6 V is displayed in Fig. 7. It could be seen from the Fig. 7. that amperometric response of Ni/NPC/GCE to DA and UA didn't shows any current stage but against AA performed very low current which for glucose detection can't interfere. During addition of interfering substances the negligible current responses have mentioned than glucose, this could be refer to the rough surface of Ni/NPC/GCE, which the rough surface electrode favors kinetically controlled the glucose electro-oxidation reaction, when the electro-oxidation of the

interfering suspicious being diffusion-controlled doesn't related significantly on the electrode rudeness[57]. So the confirmation result was mentioned and well knows from some Ni nanoparticles based modified electrodes[43,58]. By investigated test can infer that the Ni/NPC/GCE has the best anti-interference capability against detected substrates and it offers as-prepared electrode could be selected as non-enzymatic glucose biosensor in human's blood and biological real samples.

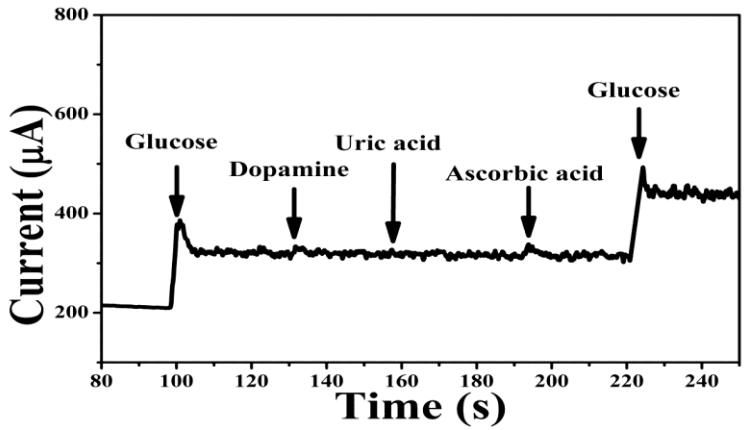


Figure 7. Amperometric test of Ni/NPC/GCE upon successive addition of 0.5 mM standard glucose, 0.1 mM dopamine, 0.1 mM uric acid, 0.1 mM ascorbic acid and another 0.5 mM standard glucose with optimum potential of +0.6 V in 0.1 M KOH under magnetic stirring condition.

3.5. Glucose determination in human's blood serum samples

Amperometric responses of Ni/NPC/GCE upon successive addition of serum samples: (a, b, c, d) 10 µL, (a_1, b_1, c_1, d_1) 50 µL, (a_2, b_2, c_2, d_2) 100 µL and from 100 mM standard glucose (e) 5 µL, (e_1) 25 µL, (e_2) 50 µL is demonstrating in Fig. 8. Due to the current result non-enzymatic sensor based on Ni/NPC/GCE was suggested for glucose determination in real blood's serum samples. Discovery value ranges of 98.2-104.3% proved the novelty of fabricated non-enzymatic biosensor for future development and glucose determination in real blood samples and biological fluids.

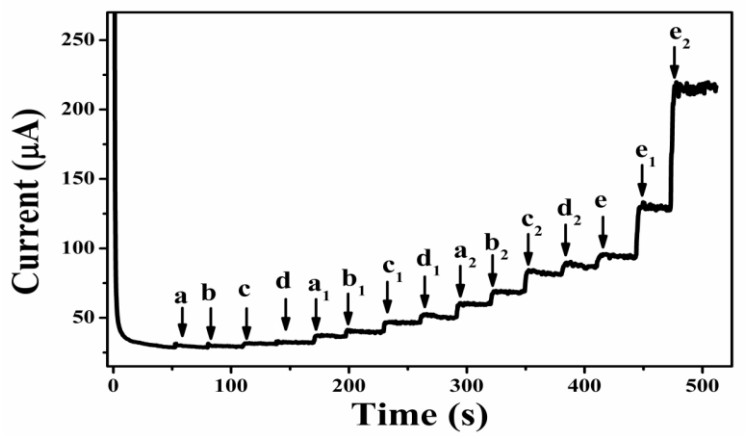


Figure 8. Amperometric test's result of Ni/NPC/GCE upon subsequent addition of serum samples for glucose determination in human's blood serum samples (a, b, c, d) 10µL, (a_1, b_1, c_1, d_1) 50µL, (a_2, b_2, c_2, d_2) 100 µL and standard glucose (e) 0.05 mM, (e_1) 0.25 mM and (e_2) 0.5 mM.

At the optimum potential of 0.6 V in 0.1 M KOH by addition subsequent varying glucose concentration and human's blood serum samples were recorded in Fig. 8. According the enzymatic method's data glucose concentration was tested to be 5.7 mM, 5.5 mM, 9.9 mM and 9.7 mM which were delivered from the local hospital. In comparison with enzymatic method, according this result glucose concentration in serum samples were calculated as 5.6 mM, 5.42 mM, 10.4 mM and 9.6 mM. The average result of glucose determination in human's blood serum samples in comparison with medical (enzymatic) method is collected in Table 2.

Table 2. Glucose determination in human's blood serum samples by using non-enzymatic method based on Ni/NPC/GCE in comparison with medical method.

Samples	Enzymatic method (mM)	Added (µM)	Found (µM)	Recovery (%)
		-	-	-
Serum		5.7	5.6	98.2
sample 1	5.7	28.5	28	98.2
		57	57.3	100.5
		-	-	-
Serum		5.5	5.42	98.5
sample 2	5.5	27.7	28.1	101.4
		55	54.2	98.5
		-	-	-
Serum		9.9	10.4	105
sample 3	9.9	49.5	51.2	103.4
		99	103.3	104.3
		-	-	-
Serum		9.7	9.6	99
sample 4	9.7	48.5	48.1	99.1
		97	95.9	98.9

4. CONCLUSION

The current work performed the novelty of Ni/NPC/GCE as non-enzymatic glucose biosensor that nickel nanoparticles happily were deposited on NPC modified GCE. Some positive characteristics such as: high sensitivity, magnificent stability and reproducibility, low working voltage and very fast amperometric response against glucose oxidation, relates to Ni/NPC/GCE. Therefore, the Ni/NPC/GCE was compared with some other non-enzymatic glucose sensors, at the optimum potential of +0.6 V demonstrated high sensitivity of 3753.78 $\mu AmM^{-1}cm^{-2}$ towards glucose oxidation with coefficient of correlation R^2=0.995, from 1-7940 µM linear range with low detection limit of 0.3 µM (S/N=3), were performed. Also the manufactured electrode has excellent anti-interference ability towards co-existence substances and according magnificent performance of Ni/NPC/GCE it could be used as suitable device for the glucose determination in human's blood and real biological samples.

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