Nano Material-modified Electrodes: Electrochemical Applications in Pharmaceutical, Biological, Environmental and Cosmetic Analysis

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AŞLIK	ALINTI YAPANLAR	YIL
ladonia rangiformis-mediated biosynthesis of ag–ZnO nanocomposites with enhanced ectrochemical performance for dye sensing applications P Turan, Z Kocakaya, DE Bayraktepe, K Polat, Z Yazan crochemical Journal, 117430		2026
Magnetite–Cerium Oxide Nanocomposite-Based Electrochemical DNA Biosensor for ighly Sensitive Detection of 4-Nonylphenol in Food Samples Yıldız, M Pekin Turan, D Eskiköy Bayraktepe, Z Yazan ectroanalysis 38 (1), e70102	1	2026

Alıntı yapanlar TÜMÜNÜ GÖ

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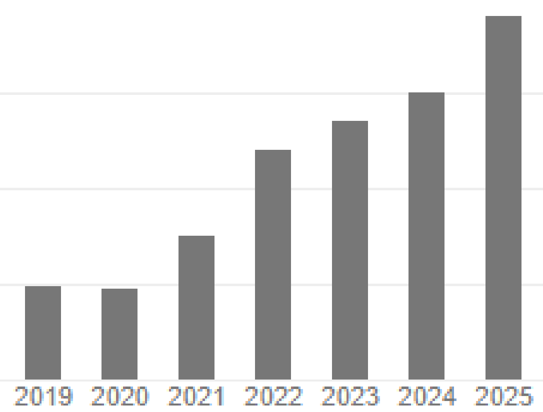












Our research groups

Our Research areas;

- Modified electrodes and their applications

Nano Material-modified Electrodes: Electrochemical Applications in Pharmaceutical, Biological, Environmental, Food and Cosmetic Analysis

- Heavy metal analysis with voltammetry
- Electrochemical drug-DNA interactions, DNA biosensors
- Voltammetric analysis of different groups of drugs

- Carbon paste electrode

- Pencil graphite electrode

- Screen printed carbon electrode

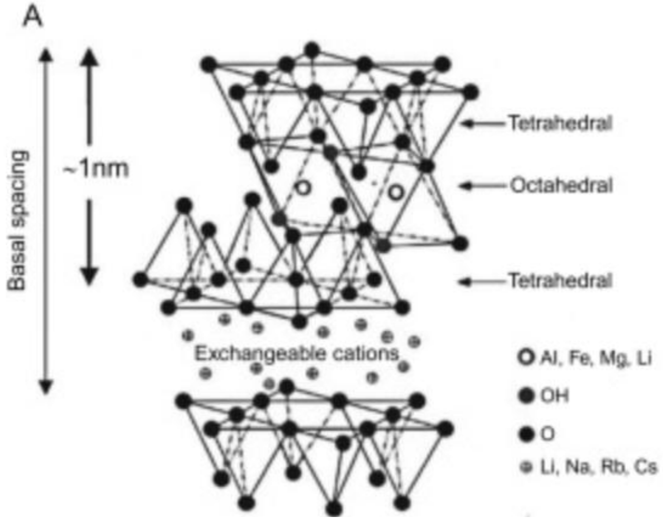
Nano Material-modified Electrodes: Electrochemical Applications in Pharmaceutical, Biological, Environmental Food and Cosmetic Analysis

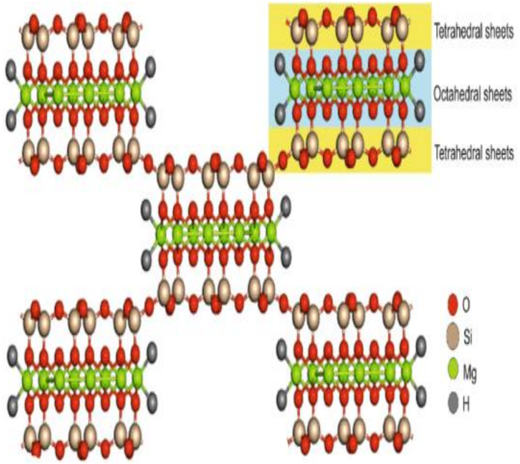
- Carbon nanomaterials (MWCNTs, etc.)
- Nanoclays, natural clays obtained from Türkiye
- Nanoparticles (TiO_2, Au, Ag, Bi, Hg, etc.)
- Conducting polymers

Nanoclay structures have been used to improve the electrical properties of the electrode surface due to their effective intercalation, flexible adsorption capacity, ion exchange capacity, and relatively high surface area

Montmorillonite nano clay nano

Sepiolite





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ELECTROANALYSIS

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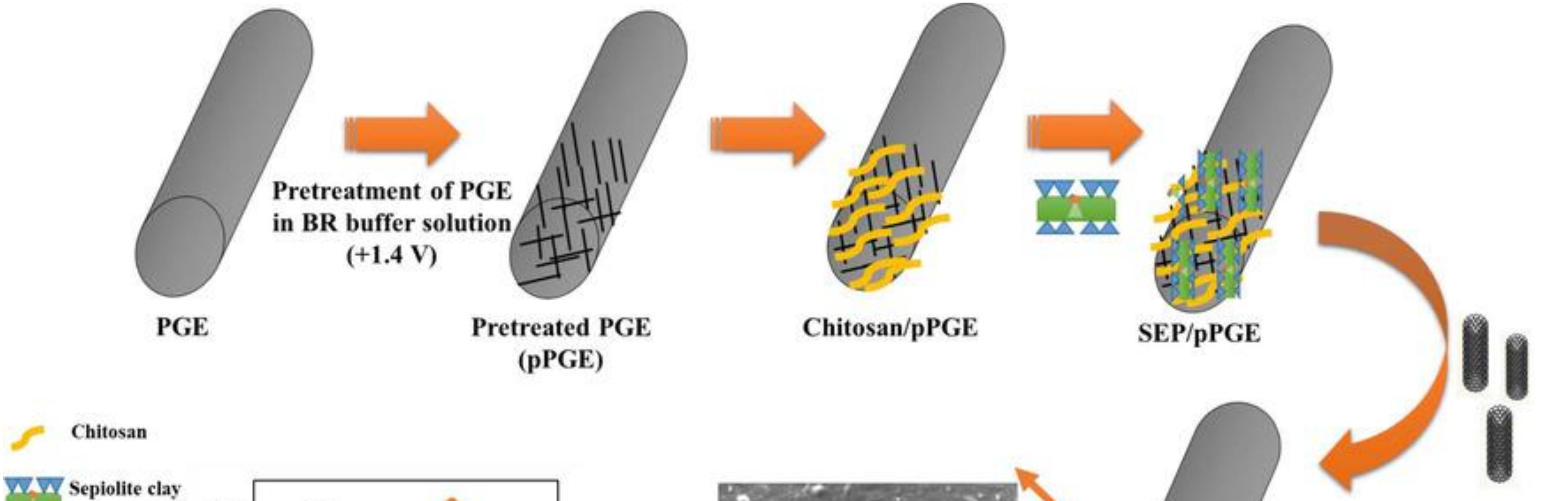
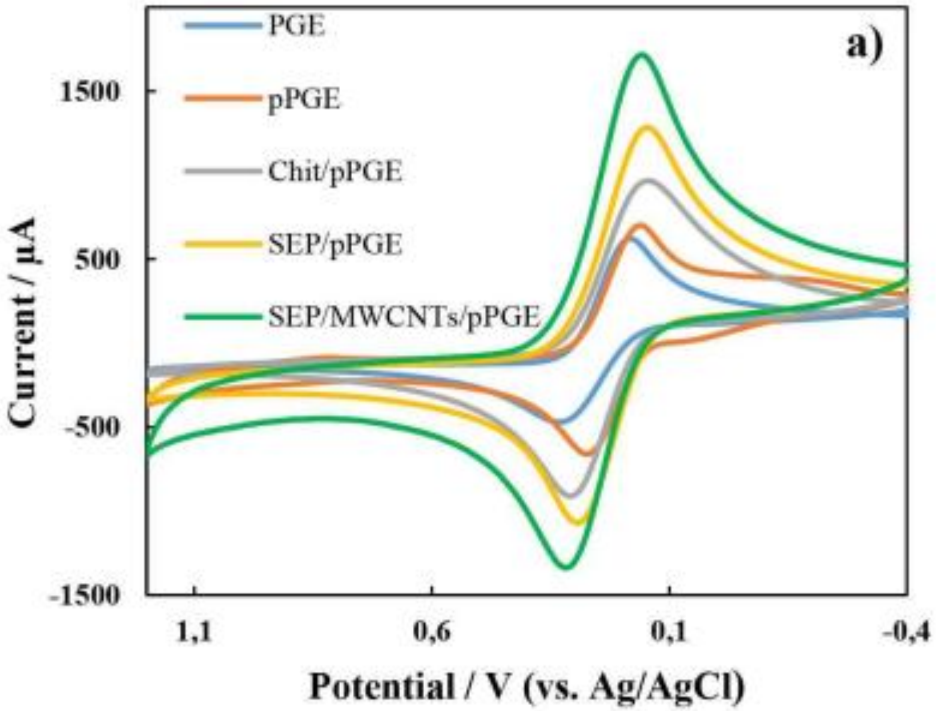
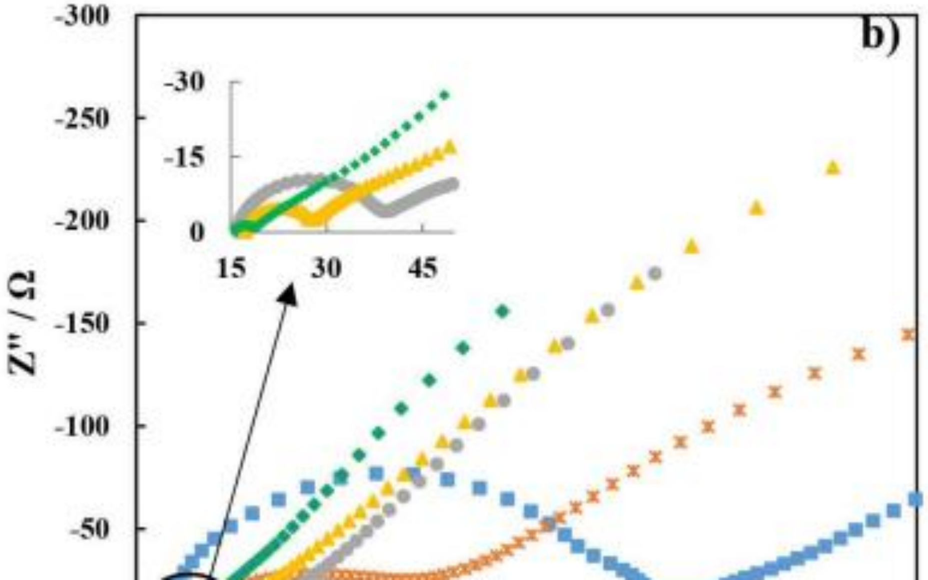
Application of Single-use Electrode Based on Nano-clay and MWCNT for Simultaneous Determination of Acetaminophen, Ascorbic Acid and Acetylsalicylic Acid in Pharmaceutical Dosage

Dilek Eskiköy Bayraktepe[a] and Zehra Yazan*[a]







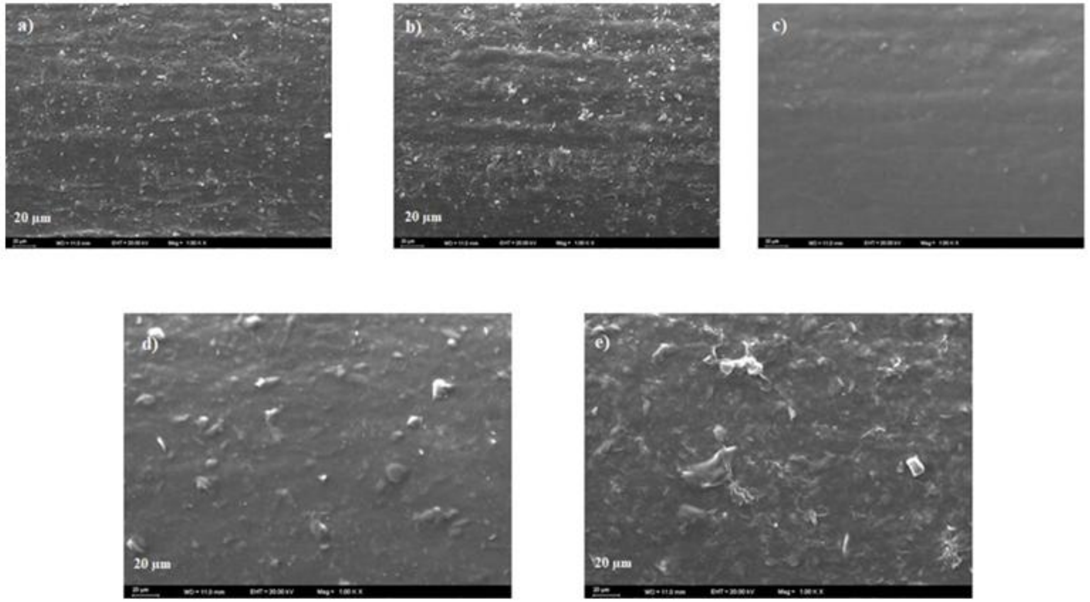
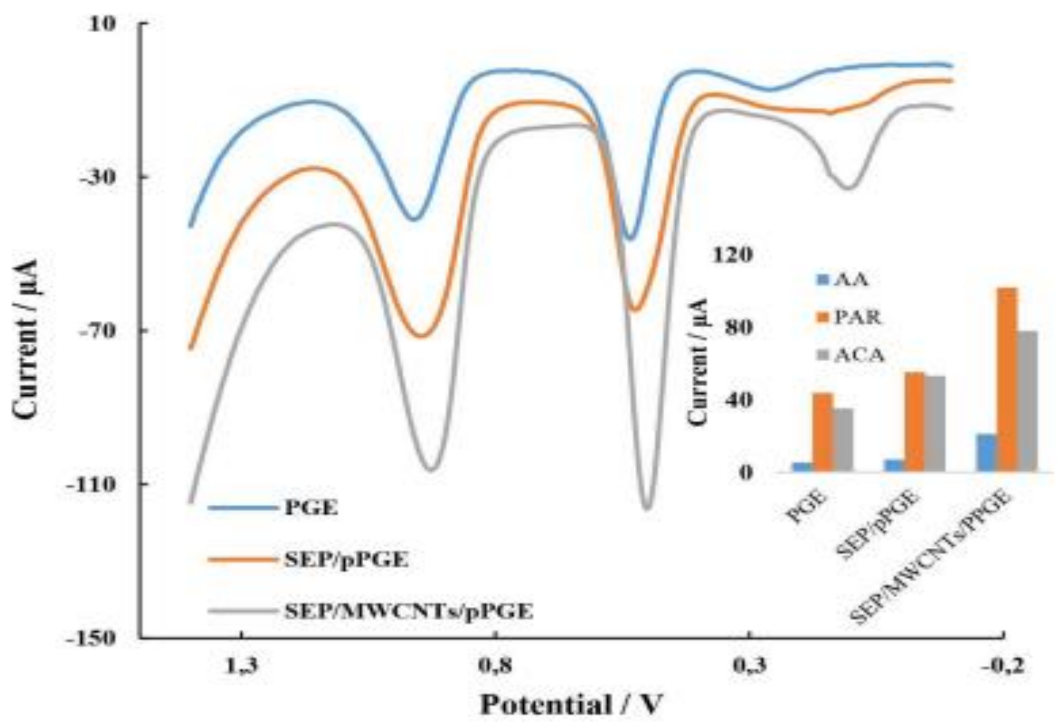


Fig.S1. SEM photographs of **a)** PGE, **b)** pPGE, **c)** Chit/pPGE, **d)** SEP/pPGE and **e)** SEP/MWCNTs/pPGE



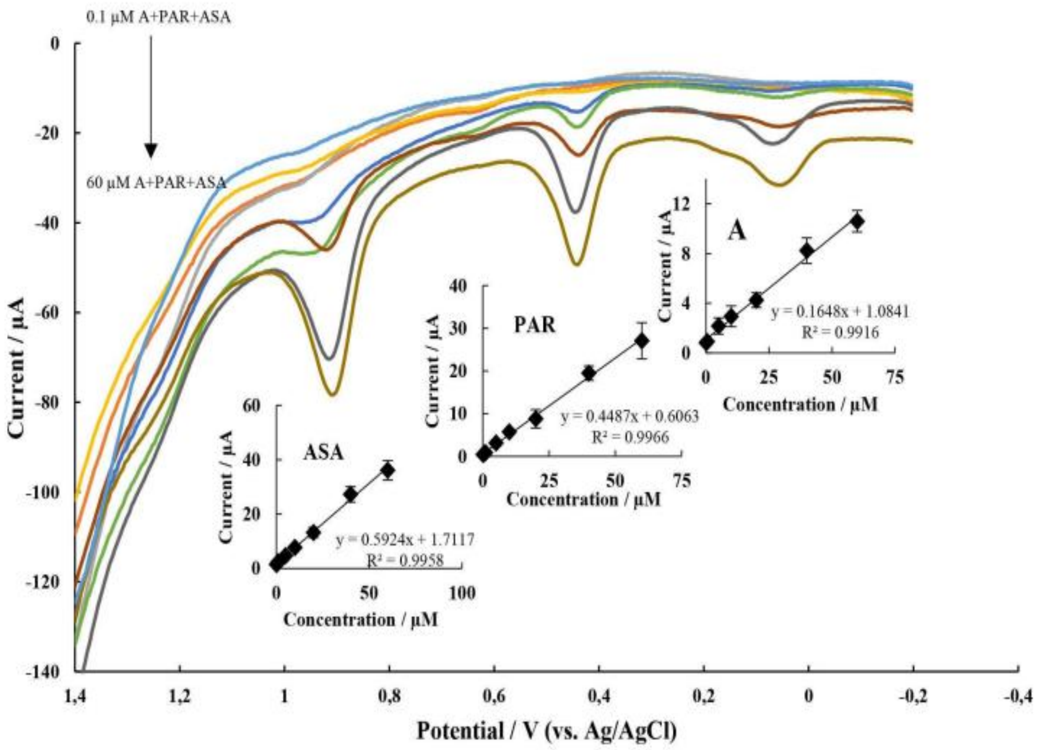


Fig. 5. The AdsDPV voltammograms with increasing concentrations of PAR, A, and ASA. **Insets:** Calibration graphs of A, PAR and ASA.

	Found amount, g					
Sample	New method	Average recovery, %	*RSD, %	Literature method [1]	*RSD, %	*t*
A (0.300 g)	0.297 (±0.008)	99.21	2.82	0.299 (±0.0003)	0.1	1.12
PAR (0.200 g)	0.202 (±0.006)	101.07	3.11	0.200 (±0.0006)	0.3	1.48
ASA (0.300 g)	0.303 (±0.010)	101.02	3.40	0.302 (±0.0006)	0.2	0.45

* Each value was obtained via average of 5 experiments. At 95 % confidence level, $t_{critical}$ value is 2.31.

Table 2. Comparison of the proficiency of previous studies for PAR, A, and ASA analysis.

Working Electrode	Method	Analyte	Detection Limit, μM	Working Range, μM	Sample	Literature
GO/$TmPO_4$/GCE	DPV	**A** DA UA	39.0	100–1000	Human urine	[37]
3D-MoS2/rGO/Au/GCE	DPV	**A** DA UA	0.93	2–5400	Human serum	[38]
GO/MWCNTs/CPE	SWV	**A** **PAR** GU	18 27	66–618 96–928	Pharmaceutical formulation	[39]
AuNPs/Cysteic acid/GCE	SWV	**PAR** TRA	0.03	0.1–10.7	Human serum	[40]
3DCuxO–ZnO NPs/Ppy/RGO	DPV	**A** **PAR** DA TRP	0.024 0.010	0.08–475 0.033–400	Human serum	[41]
ISSM-CNT-PE	AdsDPV	**PAR** **ASA**	0.026 0.085	0.3–63 0.3–63	Pharmaceutical formulations, Human urine, Human serum	[42]
GR-NF/GCE	SWV	**PAR** **ASA** CAF	0.001 0.065	0.008–0.51 0.87–17	Pharmaceutical formulations	[43]
BDD	AdsSWV	**PAR** **ASA** CAF	3.94 7.27	33–826 28–693	Pharmaceutical formulations	[44]
P4VP–MWCNT/GCE	DPV	**ASA** CAF	0.004	0.04–350	Pharmaceutical formulations	[45]
PNBMGCE	DPV	**PAR** TRA CAF	0.08	2.0–16.2	Pharmaceutical formulations	[46]
MOF-199/GCE	DPV	CAF **PAR**	 1.26	 20.0–300	Pharmaceutical formulations	[47]
ErGO	DP-ASV	**A**	0.36	0.2–4.4	Pharmaceutical	[48]

Heavy metal ions and Applications of Nanoclays

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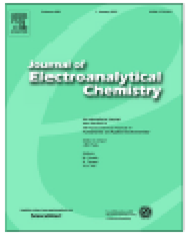

ELSEVIER

Bismuth nanoparticles decorated on Na-montmorillonite-multiwall carbon nanotube for simultaneous determination of heavy metal ions-electrochemical methods

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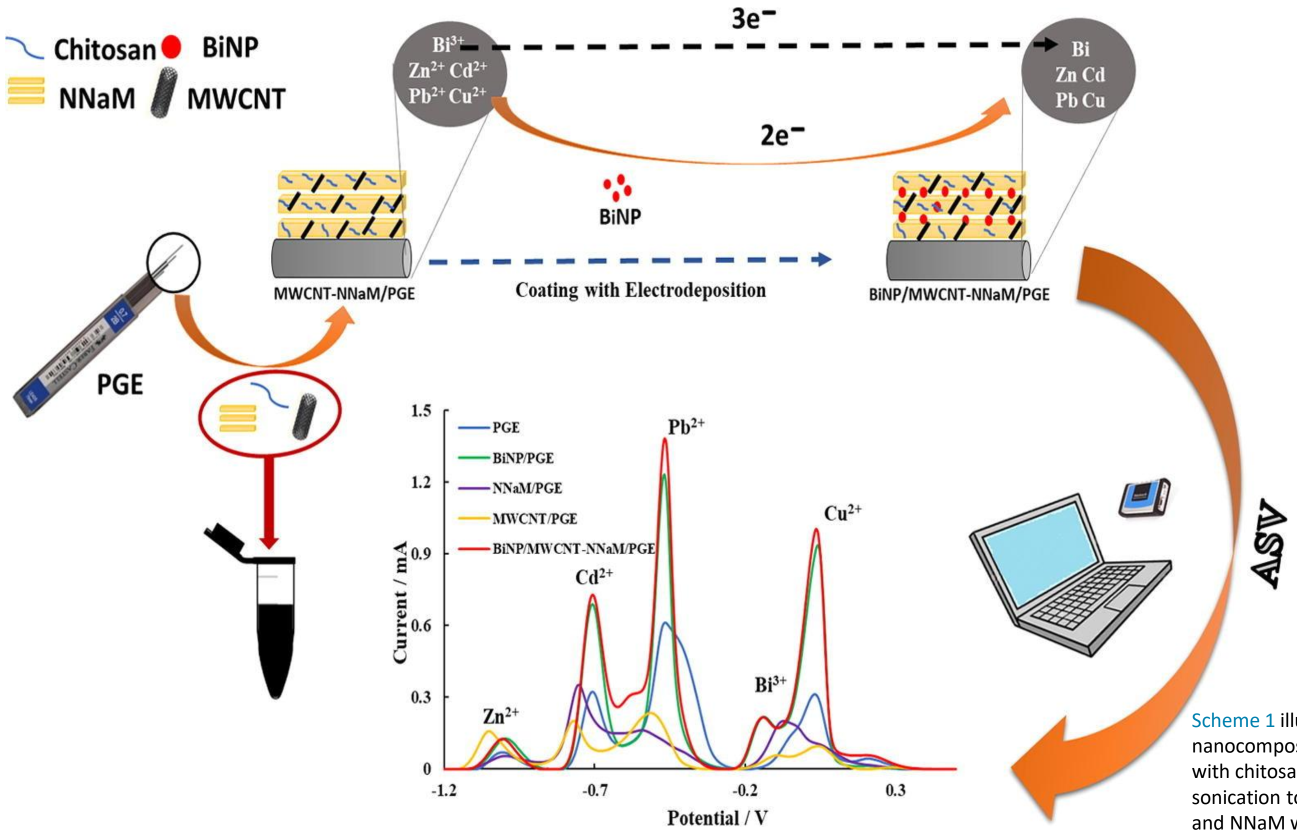

Scheme 1 illustrates preparing the BiNP/MWCNT-NNaM/PGE nanocomposite material. 0.1 % of MWCNT and NNaM were dispersed with chitosan (2 % (m/v) dispersed in acetic acid solution 2 % (v/v) by sonication to obtain a homogeneously distributed mixture. MWCNT and NNaM were coated by dipping the PGE into a vial containing the composite mixture and left to dry in the open air in the upsidedown position. Then, the bismuth film was deposited in situ on the MWCNT-NNaM/PGE electrode by electrodeposition of the standard solution of 5.0×10^{-6} M Bi (III) in 1.0 M acetate buffer (pH 4.5) with constant stirring; while deposition of the analytes, Zn (II), Cd (II), Pb (II), and Cu (II), was occurring. The measurements were repeated five times. For comparison, electrodes representing several stages of the modification procedure were also prepared to test the benefit of each stage. In this regard, BiNP/PGE, MWCNT/PGE, and NNaM/PGE electrodes were manufactured using 0.1 % MWCNT, 0.1 % NNaM, and 5.0×10^{-6} M Bi (III) for coating

Electrochemical properties of modified electrodes

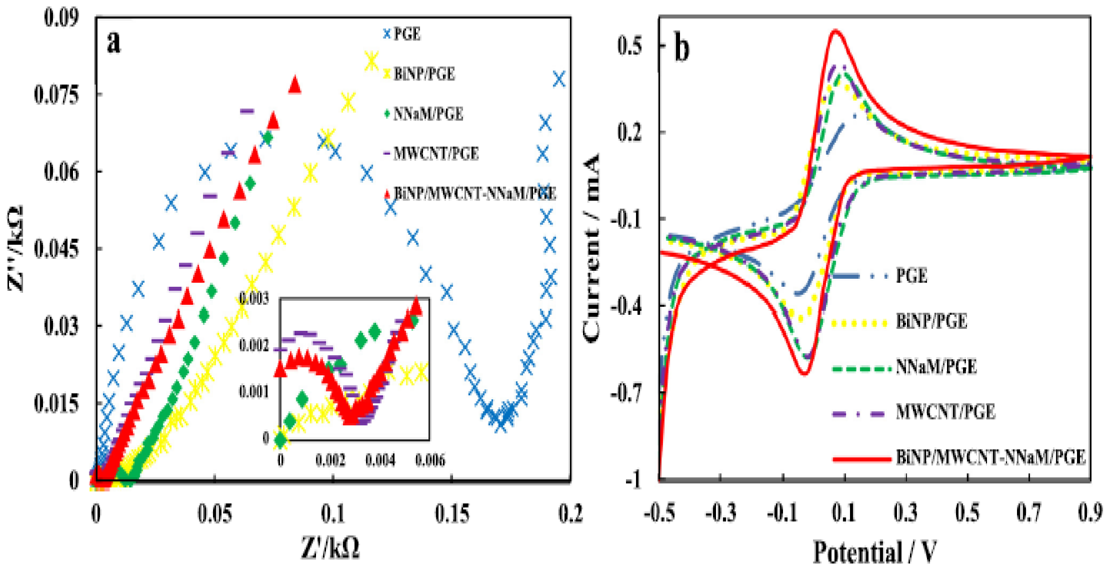

Fig. 1. **a)** Nyquist diagrams **b)** Cyclic voltammograms of PGE (blue), BiNP/PGE (yellow), NNaM/PGE (green), MWCNT/PGE (purple), and BiNP/MWCNT-NNaM/PGE electrodes (red) in 0.1 M KCl solution containing 5.0 mM of $[Fe(CN)_6]^{3-/4-}$ at a scan rate of 0.05 Vs^{-1}.

pH effect

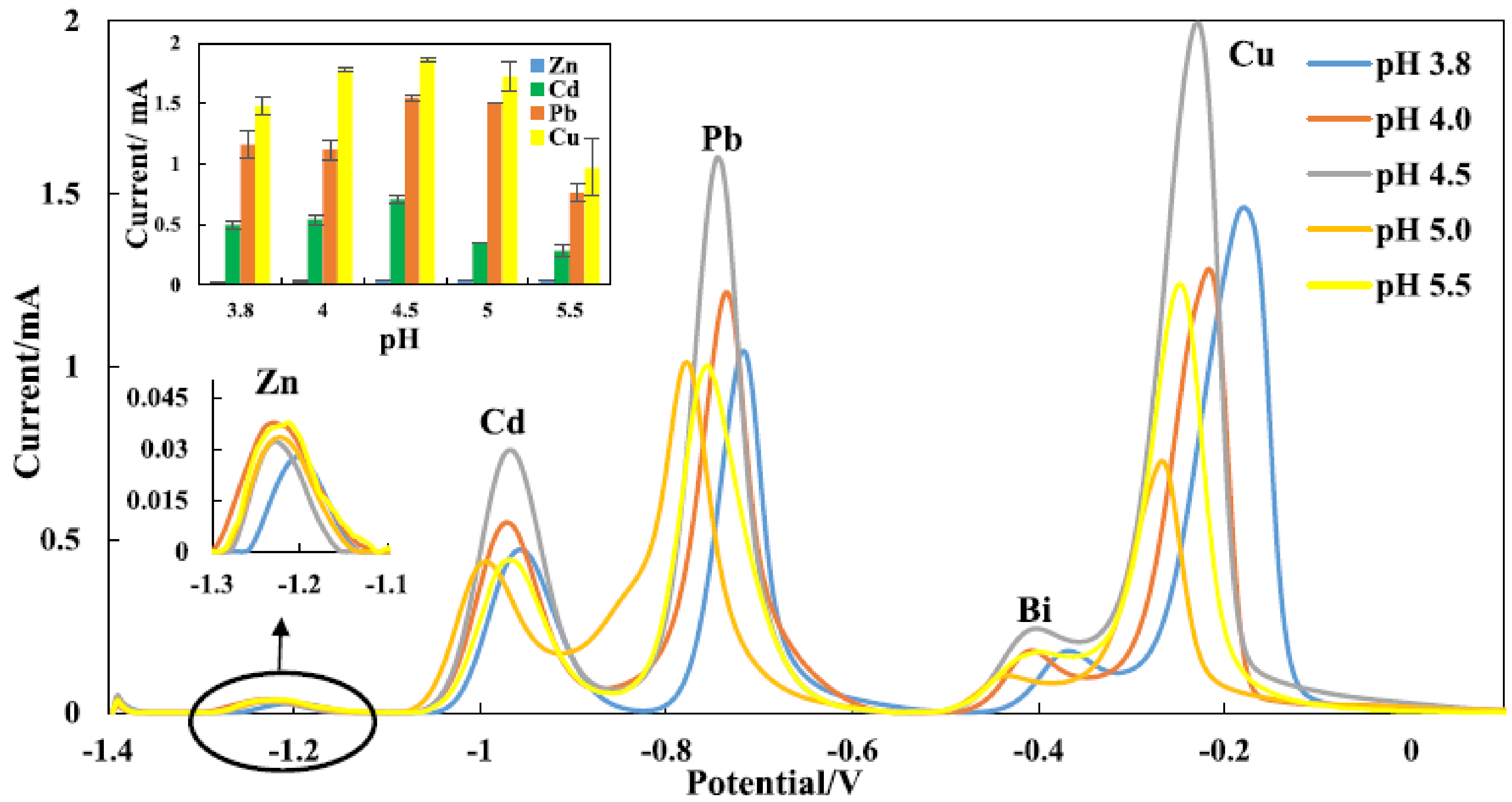

Fig. 3. SWASV voltammograms of 50.0 μM Zn (II), 5.0 μM Pb (II), 10.0 μM Cd (II) and 10.0 μM Cu (II) at different pH values in acetate buffer solution at BiNP/MWCNT-NNaM/PGE. Inset: The plot of i_p of pH on the BiNP/MWCNT-NNaM/PGE.

The other optimization parameters:

To obtain the best SWV signal for the simultaneous determination of the metal ions, the effect of deposition potential on peak currents was investigated in the potential range (–1.2 V) - (–2.0 V) (Fig. S4a). The peak currents for Zn (II), Pb (II), Cd (II), and Cu (II) began to rise at –1.2 V and reached their maximum value at –1.80 V. Hence; we selected –1.80 V as the optimal deposition potential for the best peak shape and the highest peak currents. Optimizing the deposition time was also achieved. For this purpose, by setting the Edep to the optimum value found, the effect of deposition time on peak currents was examined within the range 0–480 s with increments of the 60 s (Fig. S4b), and the highest peak currents were achieved at a tdep of 180 s.

Table 1

Regression and validation parameters of the simultaneous calibration lines of Zn (II), Pb (II), Cd (II), and Cu (II) ions.

Regression parameters	Zn	Cd	Pb	Cu
Linear working range, µM	2.36–40.0	0.32–2.0	0.03–5.0	0.52–10.0
	40.0–180.0	2.0–240.0	5.0–80.0	10.0–40.0
Slope, mA/µM	0.003 (±0.0002)	0.1741 (±0.04)	0.2674(±0.012)	
	0.0014 (0.00042)	0.0053(±0.001)	0.0128(±0.0013)	0.1349(±0.01
				0.0348(±0.00
Limit of detection (LOD), µM	0.707	0.097	0.008	0.157
Limit of quantification (LOQ), µM	2.36	0.32	0.03	0.52
Regression coefficient (R^2)	0.9872	0.9986	0.9708	0.995
	0.9966	0.9958	0.956	0.9832
Repeatability of peak potential, RSD%[a] (intra-day)	0.06	1.96	3.53	5.71
Repeatability of peak current, RSD%[a] (intra-day)	9.31	0.30	3.83	5.73
Reproducibility of peak potential, RSD%[a]	0.35	1.16	1.14	6.35
Reproducibility of peak current, RSD%[a]	7.89	5.76	2.07	0.43

[a] RSD is the relative standard deviation of 5 replications (95% Confidence Level).

Table 2

Comparison of analytical performance at the BiNP/MWCNT-NNaM/PGE electrode with previously reported modified PGE sensors.

Electrode	Method	Analyzed metals	Working ranges, µM	LOD, µM	Sample	Lit.
Nafion-covered pencil-lead BFEs	SWASV	Zn	0.153–1.530	0.006	Tap Water	[38]
		Cd	0.088–0.889	0.003		
		Pb	0.048–0.483	0.02		
Pencil-lead graphite BiFE	SWASV	Zn	0.01–0.12	0.012		[39]
		Cd	0.01–0.12	0.003		
		Pb	0.01–0.12	0.002		
Bi/PL-Es	DPASV	Cd	0–0.89	0.178	Drinking and tap water, wastewater reference, soil sample	[40]
		Pb	0–0.48	0.009		
ERGO-PG-BiE	SWASV	Zn	0.03–0.30	0.004	Tap Water	[41]
		Cd	0.018–0.178	0.0009		
		Pb	0.009–0.096	0.0006		
NG-PG-BiE	SWASV	Zn	0.153–1.529	0.003	Tap water	[42]
		Cd	0.089–0.889	0.0008		
		Pb	0.048–0.483	0.001		
sol–gel-DIIP/PGE	DPASV	Cd	1.11×10^{-9}–5.29×10^{-8}	4.48×10^{-10}	Human hood serum, Cow's milk, Lake water samples	[43]
		Cu	1.97×10^{-9}–2.83×10^{-8}	5.35×10^{-10}		
6B PDE	ASV	Cd	0.872–3.356	0.872		[44]
		Pb	0.048–0.724	0.048		
EP-PGE	SWASV	Cd	0.089–0.356	0.0099	Standard reference water sample	[45]
		Pb	0.024–0.217	0.002		
BiFE	DPASV	Cd	0.429–2.073	0.098	Wastewater sample	[46]
		Pb	0.233–1.124	0.056		
AgNP/Bi/Nafion/PGE	ASV	Cd	0.889–8.896	0.002	Wastewater sample	[47]
		Pb	0.482–4.826	0.0014		
BiNP/Nafion modified PGE	ASV	Cd	0.088–1.334	0.065	Cow's milk samples	[48]
		Pb	0.0483–0.724	0.149		
G/Bi-PGE	SWASV	Cd	0.044–0.889	0.0011	Canadian-certified reference water, Tap water samples	[49]
		Pb	0.024–0.483	0.0014		
HF-PGE	DPV	Zn	0.014–7.312	0.004	Mineral, tap and river water samples	[50]
		Cu	0.011–7.868	0.003		
BiNP/MWCNT-NNaM/PGE	*SWASV*	*Zn*	*2.36–40.0; 40.0–180.0*	*0.707*	*Tap Water*	*Present work*
		Cd	*0.32–2.0; 2.0–240.0*	*0.097*		
		Pb	*0.03–5.0; 5.0–80.0*	*0.008*		
		Cu	*0.52–10.0; 10.0–40.0*	*0.157*		

Interference studies:

The selective determination of heavy metals was investigated in0.1 M acetate buffer using SWASV. Fig S6 shows SWASV response to heavy metals over possible interference metals (Mn2+, Al3+, Ni2+,Sb3+ Co2+, Fe3+, Cr3+, Ca2+, Mg2+ and Na3PO4). The response currents were compared with peak currents in the absence of interfering agents (Fig. S6). Considering the low concentration of heavy metals, (in the order of µg/L) in water [51], all interfering agents were kept at a 10:1 ratio (analyte: interfering metal). The result shows that the ions tested have no significant interference (all below 4.5 %). Then, the practical application of the modified sensor was investigated in the real sample.

to demonstrate the analytical applicability of the proposed sensor, tap water was directly analyzed using BiNP/MWCNT-NNaM/PGE electrode. Recovery studies were carried out with the standard addition method in which known amounts of the standard solutions of the analyte are added to the tap water sample

Table 3. The determination of Zn (II), Cd (II), Pb (II), and Cu (II) in tap water sample mean recovery results and the relative standard deviation.

Method	Sample	Claimed amount, µM	Found amount, µM	Average recovery, %	RSD[a], %
SWASV	Zn	20.0	20.111±0.6415	99.5±3.12	3.13
	Cd	20.0	20.195±0.8775	99.2±4.20	4.23
	Pb	20.0	20.873±0.7453	95.9±3.49	3.64
	Cu	20.0	20.487±0.3719	97.6±1.76	1.79

a

Each value is the mean of three experiments (95% Confidence Level).