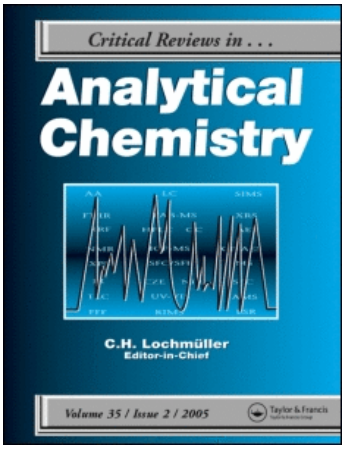

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Recent Advances in Electroanalysis of Organic Compounds at Carbon Paste Electrodes

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Recent Advances in Electroanalysis of Organic Compounds at Carbon Paste Electrodes

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In this review (with 223 refs), electroanalysis of organic compounds with carbon paste-based electrodes, sensors, and detectors is discussed. The individual methods, covering the period of 2004–2008, are summarized in tables with accompanying commentaries, attention being paid to environmental pollutants, pharmaceutical formulations and drugs, as well as other biologically active organic compounds. Recent achievements and trends are discussed, critically evaluated, and some future prospects are outlined.

Keywords Carbon paste electrodes, electroanalysis, sensors, organic pollutants, pharmaceuticals, drugs, biologically active compounds, review

INTRODUCTION

In 2009, we commemorate the 50th anniversary of the Nobel Prize for polarography (1) and, coincidentally, last year we celebrated the 50th anniversary of the introduction of carbon paste electrodes (CPEs) (2). Polarography with the dropping mercury electrode (DME) and electroanalysis with CPEs also share similar fates with respect to their more-or-less accidental discovery and later-achieved position. Whereas direct current polarography (DCP) was invented during investigations of electrocapillary phenomena at DME, carbon paste was a "side-product," coming from Ralph Adams with unsuccessful experiments with the so-called dropping carbon electrode [DCE (3,4)]. Both DME and CPE spread over the globe and touched almost every area of theoretical and applied electrochemistry. Since their introduction, CPEs underwent a lengthy and impressive development (5–13). In this paper we pay attention to the period of 2004–2008, not covered by the most up-dated review (8). Because a full overview of electroanalysis with CPEs was beyond the scope of this dedicated issue, it was decided to focus on electroanalysis of organic compounds taking into account recently prepared extensive review on inorganic compounds (13). Last, but not least, an "organic" orientation of this paper reflects the legacy of Heyrovský's polarography, which is now more frequently used in organic electrochemistry.

The following general trends concerning CPEs can be observed:

1. New types of carbon paste mixtures are developed, tested, and applied. Traditional CPEs are being replaced by alternate materials. Classical forms of graphite moiety are replaced by new carbon materials like fullerenes "C-60," hollow carbon fibers, or carbon nanotubes (12) and traditional pasting liquids are substituted by room-temperature ionic liquids (RTILs) or other recently synthesized organic liquids (13).
2. New approaches to chemical and biological modification of CPEs are investigated.
3. Methodologies based on the use of various nanoparticles (e.g., nanosized metals, synthetic zeolites and silicas, inorganic/organic hybrids of *Dawson* type) or newly synthetised polymers (with immobilized functional active groups or encapsulating some enzymes and mediators) are extensively tested.

Research in the field of organic compounds can be divided into the four following categories:

1. Qualitative and quantitative analysis of organic substances with particular emphasis on environmental pollutants such as electroactive derivatives of polyaromatic hydrocarbons (PAHs), various pesticides, organic dyes, or industrial

Dedicated to the Memory of Professor Jaroslav Heyrovský on the occasion of the 50th Anniversary of the Nobel Prize for polarography

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surfactants (8). Typically, the respective electrochemical characterization has to precede the proper determination;
2. Carbon paste biosensors utilizing advantageous properties of carbon paste for its modification with various enzymes or enzyme-containing tissues, together with the corresponding mediators (9);
3. Pharmaceutical and clinical analysis with CPEs is represented by hundreds of papers resulting in methodical procedures for more than 150 different pharmaceuticals and drugs in real samples (2,8);
4. Qualitative and quantitative analysis of biologically active compounds (BAC) such as purines, amino acids, peptides lipids, enzymes, hormones, biological co-factors, neurotransmitters (catechols and dopamin), nucleic acids (DNA, RNA), sugars, vitamins, antioxidants, or even some microorganisms like bacteria and viruses. Most of these substances can be analyzed with CP biosensors, but not necessarily because there are other carbon paste-based configurations available for these purposes (8).

Both unmodified and modified CPEs are both widely applicable in organic analysis, whereas in inorganic analysis bare CPEs are only rarely used (13). Unmodified CPEs are still very popular in pharmaceutical analysis, where a hydrophobic binder acts as a certain type of modifier that attracts highly lipophilic molecules of pharmaceuticals and drugs. Due to a complex character of many organic samples, a pre-separation step (HPLC, CZE, SPE, LLE, etc.) is often required prior to electrochemical detection.

RECENT TRENDS IN ANALYSIS OF ORGANIC SUBSTANCES

Modern electroanalytical methods using classical three electrode systems critically depend on the working electrode as the choice of a reference and an auxiliary electrode is usually just a routine task. Therefore, there is an effort to prepare tailor-made so-called "designer CPEs," with lower overpotential of the redox reaction, better selectivity, or higher sensitivity (e.g., via the appearance of the catalytic currents). But it is necessary to keep in mind that the broad range of various CPEs could be disadvantageous, too. There are so many papers on glucose determination (14–30), hydrogen peroxide (31–46), or NADH (47–51), with each author stressing the advantages of a new electrode or new electrode material; even for scientists working in the field of electroanalysis utilizing paste electrode it is quite difficult to choose the best electrode type for the problem to be solved. Moreover, amperometric or voltamperometric methods are linked with an inherent problem of electrode passivation or fouling which limits the practical applications.

The promising properties of RTILs (thermal stability, nonvolatility, designability, ion conductivity, composition variability, polarity adjustability, etc.) have not yet been fully utilized in the world of CPEs. High ion density and ion conductivity seems to be an especially limited factor. We can see an increasing number of papers dealing with DNA, protein, or gene sequence analysis (52–66). The use of polymerase chain reactions (PCR) in DNA hybridization and the study of dsDNA-modified CP sensors or biosensors are very promising and, due to the involved PCR, also extremely sensitive. A bright future could be forecast for specific DNA or protein biosensors coupled with PCR.

The development of new methods of using bare CPEs is justified, especially in the field of pharmaceutical analysis of relatively simple matrices (tablets, injections, syrups) where the new methods are usually very simple, fast, non-expensive, and present an independent alternative for more frequently used spectrophotometric or separation methods. Any type of modification of the CPEs composition is connected with a desirable increase in either selectivity or sensitivity. The gains must prevail over the more complicated and labor-intensive preparation of the electrode, easier passivation, or electrode fouling, and usually more fixed electrochemical protocol.

DETERMINATION OF ORGANIC COMPOUNDS USING CARBON PASTE ELECTRODES

CPEs can be used as classical working electrodes in batch methods or in flowing systems (HPLC-ED, CZE-ED, FIA-ED). A simple configuration of the carbon paste based wall-jet type detector is depicted in Figure 1. Batch methods are usually very sensitive because of the possibility to accumulate the analyte from the solution on the surface of the working electrode. On the other hand, the adsorption, co-reduction, or co-oxidation of interferents can obscure the electrode process under study or passivate the electrode so that either relatively simple matrices or a preliminary separation is necessary. Therefore, voltammetry at CPEs is suited for analysis of various pharmaceutical products because the analyzed matrices are relatively simple with usually only one electrochemically active analyte present, while other substances present are usually electrochemically inactive. Surprisingly, the developed batch methods are often also usable on biological fluids like human serum or urine where the concentration of the pharmaceutical or its metabolite is markedly higher than of other components. Table 1 surveys recent selected applications of bare, chemically modified, and biologically modified CPEs in the analysis of organic compounds important from the point of view of human health and environmental protection. The type of analyte was chosen as the main classifier and the analytes are arranged in an alphabetical order although it must be kept in mind that the analyzed species, in fact, could be different. The claimed linear dynamic range consists sometimes from two linear parts, typically in a higher concentration range for, e.g., DPV or SWW, and in the lower concentration range for AdSV. The widespread use of CPEs in this field is connected with the ease of their modification and thus with the ease of tailoring their properties with regard to selectivity and sensitivity. Nevertheless, bare CPEs are still frequently used in this field, constituting up to about 20% of the published papers. Without analyte accumulation on the surface of the working electrode, LOD is usually around 1×10^{-7} to 1×10^{-6} M; AdSV typically

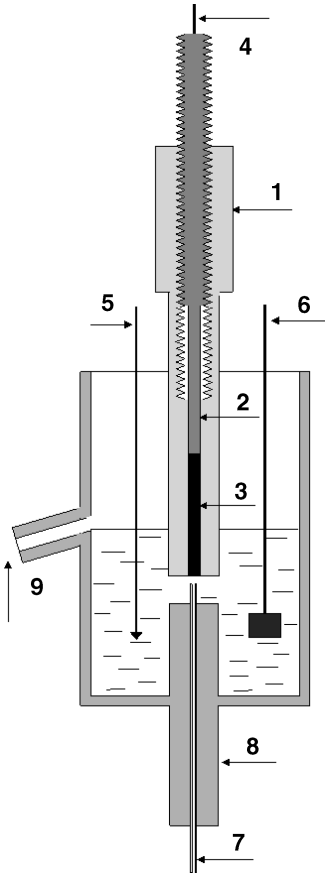

FIG. 1. Scheme of the CPE wall-jet type detector. 1—Teflon body, 2—stainless steel piston, 3—carbon paste working electrode, 4—electric contact, 5—reference electrode, 6—auxiliary electrode, 7—inlet capillary, 8—glass vessel, 9—mobile phase overflow.

decreases LOD to 1×10^{-8}– 1×10^{-9} M. LOD can be further decreased with either special techniques like electrode transfer to different supporting electrolyte, following the accumulation in another electrolyte, analyte multiplication reactions, use of catalytic reactions, or new modifiers with special properties as will be discussed below.

Recently published methods are frequently based on the oxidation of amino group (67–83, 85–87, 89–94) or hydroxy group (69, 75, 80, 81, 89, 95–128) on aromatic, heteroaromatic, or heterocyclic rings. LOD are typically around $(0.1–10) \times 10^{-7}$ M (68, 71, 72, 75, 80, 81, 88, 112, 122, 126, 129–131). LOD of the anti-arrythmic agent amiodarone (132) on bare CPE below 10^{-9} M is enabled by a catalytic wave in the presence of potassium peroxodisulphate oxidation agent and enhancing surfactant Triton X-100. The catalytic peak also enabled determination of anthraquinone derivative emodin (109) using the dissolved oxygen as oxidizing agent. AdSV of another anthraquinone derivative physcion (116) on bare CPE based on catalytic principle with re-oxidation by dissolved oxygen gives LOD 8×10^{-11} M. Reactivation of CPE surface by scanning the potential between 0.4 and 1.3 V enabled the determination of sub-nanomolar concentrations of tamoxifen (133).

Modification of the CPE involves nanomaterials like single or multiple wall carbon nanotubes or metals like silver, gold, platinum, or palladium, or nanocrystalline metal oxides or formation of bismuth or platinum films on the electrode surface. These nanomaterials play an important role as either catalysts or homogenizing components for other paste components. Inorganic modifiers such as montmorrilonite, sepiolite, fluoroapatite, hydroxyapatite, and zeolites serve for selective accumulation of the analyte on the electrode surface which is reflected by peak current increase and lower limits of detection. The well known catalytic properties of carbon nanotubes can substantially decrease LOD (74, 89, 94, 97, 119–121, 134–139). Nevertheless, nanomolar LOD was reported only for easily oxidizable flavonoid quercetin (121) or easily reducible methylparathion (87) for which catalytic properties of single wall carbon nanotubes (SWCNT) were supported by the use of RTIL 1-butyl-3-methylimidazolium hexafluorophosphate, which reportedly enhances the adsorption of methylparathion on the electrode surface. RTILs were recently tested as modifiers or substitutes of pasting liquids with some encouraging results already published. However, according to our opinion, the disadvantages connected with too high conductivity and very different properties coming from their structural differences makes RTILs application rather complicated. When using paraffin, mineral, or silicone oil together with "any type" of carbon powder, the prepared CPE usually works very well, which is not the case with "any type" of ionic liquid. In some papers, the beneficial contribution of RTILs is clearly cited (69, 87, 101, 102, 105, 114, 139), but it may be difficult to distinguish whether the beneficial effect comes from carbon nanotubes or from RTIL (87, 139). CPE can be used for determination of both oxidizable and reducible group in the same analyte (75), which increases the reliability of the determination.

A very useful combination is CPEs combined with high separation power of either CZE (140–143) or HPLC (93, 126, 144). The resulting methods are then not only highly sensitive but could be used for complicated matrices (biological fluids, food and drinks, environmental samples) (Fig. 2). Cu(I) cations (supported by multi wall carbon nanotubes [MWCNT]) (140) play an important role in capillary zone electrophoresis with electrochemical detection (CZE-ED) of several amino acids; the same is valid for the determination of glucose, sucrose, fructose, and ascorbic acid [Cu(I) cations supported by PEG] (141). Nineteen essential amino acids gave oxidation peaks at CPE (140). Carbohydrate or AA can be adsorbed at CPE modified by PEG, the oxidation is then triggered by the deprotonation of the analyte and its isomerization to enediol form followed with the oxidation by Cu(I), Cu(II), and Cu(III) surface states (141). Nano-nickel oxide was utilized to catalyze the oxidation of glucose, sucrose, and fructose (143). The role of nNiO laid the facilitation of the carbohydrate dehydrogenation/oxidation which is reflected in better reproducibility and sensitivity of the CZE-ED in honey samples.

TABLE 1
Determination of organic compounds using carbon paste electrodes

Analyte	Type of CPE	Technique	LDR (LOD)	Remarks	Ref(s)
N-Acetylcysteine	CNT, CoSal	CV, DPV	1×10^{-7}–1×10^{-4} M (5×10^{-8} M)	0.1 M PhB pH 7, pharmaceutical and clinical samples	(150)
Amino acids	MWCNT, Cu_2O	CZE-AMP +0.75 V vs. SCE	1×10^{-4}–5×10^{-6} M (1×10^{-8}–1×10^{-7} M)	Alkaline buffers pH 12.5, t_{anal} 20 min	(140)
p-Aminobenzoic acid	Crown ethers	DPV	0.4–500 μg/mL (0.1 μg/mL)	BRB pH 2, pharmaceuticals, yeast	(67)
3-Amino-fluoranthene	Bare	AdSDPV	2×10^{-8}–1×10^{-4} M (2×10^{-8} M)	0.04 M BRB pH 4, model samples	(68)
p-Aminophenol	IL	CV, DPV	2×10^{-6}–3×10^{-4} M (6×10^{-7} M)	0.1 M PhB pH 7, model waste waters	(69)
Aminophylline	Pt film	CV, DPV	8–40 mg/L (1 mg/L)	0.1 M PhB pH 3.2–6.6, cosmetic creams	(70)
8-Aminoquinoline	Bare	AdSDPV	2×10^{-7}–1×10^{-4} M (2×10^{-7} M)	0.1 M NaOH, model quinolines mixtures	(71)
Aminoquinolines	Bare	DPV, AdSDPV	1×10^{-7}–1×10^{-4} M (1×10^{-7} M)	0.1 M H_3PO_4, model samples	(72)
Amiodarone	Bare	AdSV	2×10^{-10}–2.3×10^{-8} M (1.5×10^{-10} M)	0.2 M AcB pH 5.3. $K_2S_2O_8$, Triton X-100, t_{acc} 30 s	(132)
Amitrole	MWCNT	AdSV	0.8–7 μM (0.6 μM)	0.05 M PhB pH 7.4, t_{acc} 5 min, spiked river water	(73)
Amoxicillin	VO(Salen)	CV, DPV, SWV, LSW	(8.5 μM for SWV)	tablets	(95)
Ascorbic acid, sugars	PEG, Cu_2O	CZE-AMP +0.3 to +0.6 V vs. SCE	1×10^{-6}–5×10^{-5} M ($\sim 5 \times 10^{-7}$ M)	30 mM NaOH, t_{anal} 22 min, simultaneous determ. in beverages	(141)
Ascorbic acid	Fe(III) Y zeolite	SWV	4×10^{-7}–1.2×10^{-3} M (2×10^{-8} M)	PhB pH 5, citrus fruits samples	(96)
Avidin, biotin	Avidin	AdSSWV, FIA	(3×10^{-15} M)	0.1 M AcB pH 4, transgenic maize extract, pharmaceiticals	(146)
Azobenzene dyes	Bare	AdSDPV	1×10^{-4}–2×10^{-7} M (2×10^{-8} M)	BRB pH 3 and 4, model mixtures	(75)
Benorilate	nAg	DPV	1×10^{-7}–2.5×10^{-4} M (1×10^{-8} M)	0.001 M PhB pH 6.88, pharmaceuticals	(76)
Bergenin	MWCNT	CV, DPV	6×10^{-7}–1×10^{-5} M (7×10^{-8} M)	PhB pH 7, tablets	(97)
Bisphenol A	CTAB	VOL	2.5×10^{-8}–1×10^{-6} M (7.5×10^{-9} M)	Waste plastic samples	(98)
Bromadiolone	Bare	DPV	(0.5 ng/mL)	0.2 M AcB pH 4.2, animal tissue	(77)
Caffeine	Q	CV, SWV	0.3×10^{-6}–8×10^{-3} (0.3×10^{-6} M)	PhB pH 6, coffee samples	(151)
Carbamates	Polyamide	CZE-AMP +1 V vs. SCE	1×10^{-7}–2×10^{-5} M (3×10^{-8} M)	Borate buffer pH 11, t_{anal} 23 min, sprayed vegetables samples	(142)
Carbidopa	PbO_2, resin	DPV	4.2×10^{-5}–1.5×10^{-4} M (3.7×10^{-6} M)	0.1 M $HClO_4$, pharmaceuticals, simult. with L-dopa	(99)

(Continued on next page)

TABLE 1
Determination of organic compounds using carbon paste electrodes (Continued)

Analyte	Type of CPE	Technique	LDR (LOD)	Remarks	Ref(s)
Carbohydrates	nNiO	CZE-AMP +0.55 V vs. SCE	1×10^{-6}–1×10^{-3} M (3×10^{-7} M)	0.05 M NaOH, t_{anal} 20 min, honey samples	(143)
Catechin	$\beta-$ CD	SWV	2–70 μg/mL (1.34 μg/mL)	0.05 M PhB pH 7, tea samples	(100)
Catechol	IL	CV	1×10^{-6}–8×10^{-4} M (6×10^{-7} M)	PhB pH 3, synthetic samples	(101)
Catecholamines	IL	CV	$\sim 3 \times 10^{-7}$–1×10^{-4} M ($\sim 1 \times 10^{-7}$ M)	0.1 M H_2SO_4+ 0.01 M KCl, pharmaceuticals	(102)
Cephalosporins	Co(Salophen)	DPV	1×10^{-5}–1×10^{-3} M (1×10^{-6} M)	0.1 M PhB pH 3, human synthetic serum	(152)
Chlorophenol	Montmorilonite, CTAB	SWV	5×10^{-8}–1×10^{-5} M (2×10^{-8} M)	0.1 M PhB pH 8, t_{acc} 2 min, water samples	(103)
Chloroquine	dsDNA	CV, DPV	1×10^{-7}–1×10^{-5} M (3×10^{-8} M)	0.02 M AcB, pH 4, serum	(74)
Chlorpyrifos	Sepiolite	AdSDPV	0.0001–2 ppm (8×10^{-5} ppm)	BRB pH 2, t_{acc} 80 s, water, juice, soil samples	(153)
Ciprofloxacin	SDBS	VOL	8×10^{-8}–5×10^{-6} M (2×10^{-8} M)	PhB pH 4, t_{acc} 2 min, drugs	(154)
Ciprofloxacin	CTAB	CV, DPV, LSV	1×10^{-7}–2×10^{-5} M (5×10^{-8} M)	0.1 M PhB pH 7, t_{acc} 3 min, drugs	(155)
Cisapride	CNT	AdSDPV	4×10^{-8}–2×10^{-5} M (1×10^{-8} M)	BRB pH 6.1, tablets	(78)
Clozapine	dsDNA	AdSDPV	7×10^{-9}–1.2×10^{-6} M (1.5×10^{-9} M)	0.5 M AcB pH 4.3, t_{acc} 3 min, human serum	(79)
Coumarins, psoralens	Bare	VOL	(0.06 and 0.20 mg/L, resp.)	PhB pH 2 and 7, citrus oils	(156)
L-Cysteine	FDCM	CV, DPV	1.5×10^{-5}–3.2×10^{-3} M (1.4×10^{-6} M)	0.1 M PhB pH 8, plasma, pharmaceuticals	(157)
Cysteine	Bi powder	SWCSV	1×10^{-6}–5×10^{-5} M (3×10^{-7} M)	0.1 M AcB pH 4.7, t_{acc} 100–600 s	(158)
Dipyridamole	CTAB	EIS, DPV	0.03–12 μg/mL (0.01 μg/mL)	0.5 M PhB pH 8, t_{acc} 2 min, tablets	(159)
Dipyrone	VO(Salen)	CV	9.9×10^{-6}–2.8×10^{-3} M (7.2×10^{-6} M)	0.1 M KCl pH 5–8, pharmaceuticals	(160)
Diquat	Fluoroapatite	CV, SWV	3.1×10^{-8} M	0.1 M K_2SO_4, river water	(161)
Dobesilate	$La(OH)_3$ nanowires	LSV	3×10^{-10}–1×10^{-8} M (5×10^{-11} M)	model samples	(104)
Dobesilate	IL	DPV	8×10^{-7}–1×10^{-4} M (4×10^{-7} M)	0.5 M H_2SO_4, capsules, urine	(105)
Dopamine	Ti phosphate, SiO_2	DPV	2×10^{-7}–5×10^{-5} M (4.3×10^{-8} M)	0.1 M PhB pH 7.5, injections	(106)
Dopamine	SDBS	CV, DPV	5×10^{-7}–8×10^{-4} M (5×10^{-8} M)	0.1 M PhB pH 7.4, injections, model biol. samples	(107)
Dopamine	SDS	DPV	0.01–0.2 mM (5 μM)	0.1 M NaCl, AA masking, pharmaceuticals	(108)
Emodin	Bare	AdSV	3×10^{-10}–4×10^{-8} M (1×10^{-10} M)	AmB pH 8.2, t_{acc} 30 and 90 s, plant	(109)
Endosulfan	C18 modifier, Cu(II)	DPASV	0.001–0.011 mg/L (40 ng/L)	0.2 M BRB pH 4, model samples	(162)

TABLE 1
Determination of organic compounds using carbon paste electrodes (Continued)

Analyte	Type of CPE	Technique	LDR (LOD)	Remarks	Ref(s)
Estrone	CTAB	VOL	9×10^{-8}–8×10^{-6} M (4×10^{-8} M)	t_{acc} 3 min, tablets	(110)
Ethinylestradiol	CPB	LSV	5×10^{-8}–2×10^{-5} M (3×10^{-8} M)	0.07 M PhB pH 8, t_{acc} 3 min, tablets	(111)
Etoposide	Bare	CV, LSV, DPV	2.5×10^{-7}–2.5×10^{-5} M (1×10^{-7} M)	0.04 M BRB pH 3, human serum	(112)
Flavonoids	Bare	SWV	0.15–5 (200) μM (in nM region)	0.1 M PhB pH 7, body liquids	(129)
Flavonols	diphenylether	AdSV	30–1000 μg/L (9 μg/L)	0.04 M BRB pH 5, food products	(113)
Fluoren-9-ol, acetamidofluorene	Bare	SWV, AdSDPV	0.01–300 μM (1 μM and 0.04 μM, resp.)	0.1 M H_2SO_4 and BRB pH 7, resp.	(80)
Fluoroquinolones	Bare	CV, AdSDPV	2×10^{-7}–6×10^{-5} M ($\sim 4 \times 10^{-7}$ M)	0.05 M AcB pH 5, urine, dosage forms	(130)
Fluoroquinolones	CD	DPV	3.2×10^{-8}–2×10^{-5} M (2.4×10^{-8} M)	0.04 M BRB pH 4, t_{acc} 160 s, pharmaceuticals, urine	(163)
Guanine	Montmorillonite	CV, DPV	5×10^{-8}–2×10^{-5} M (2×10^{-8} M)	0.1 M PhB pH 7, t_{acc} 4 min, urine samples	(164)
Guanine	ssDNA	SWV	0.025–100 μM (12.5 nM)	PhB pH 7.4, oligonucleotides analysis	(165)
Heroin	Ru complex, zeolite	ECL	2–80 μM (1.1 μM)	0.1 M PhB pH 6.3	(147)
Homocysteine et al.	nAu, cysteamine	CV, HPLC-AMP, +0.8 V	0.1–1 μM (30 nM)	AcN – 0.05 M PhB pH 2, serum samples	(144)
Hydroquinone	IL	CV	5×10^{-6}–5×10^{-3} M (2.5×10^{-6} M)	PhB pH 2.5, waste waters	(114)
Inosine	$La(OH)_3$ nanowires	LSV	4×10^{-9}–2×10^{-8} M (8.3×10^{-10} M)	0.1 M PhB + 6×10^{-6} M Cu(II) + 6×10^{-6} M $K_2S_2O_8$, pharmaceuticals, human serum	(145)
Isoniazid	MWCNT	CV, DPV	1×10^{-6}–1×10^{-3} M (5×10^{-7} M)	0.1 M AcB pH 4, clinical, pharmaceutical samples	(134)
Leucoindigo	Bare	CV, ACV, AdSV	1×10^{-6}–7.5×10^{-9} M (7.4 nM)	0.1 M Tris-HCl pH 7.2, t_{acc} 2 min	(81)
Malachite green	SDBS	CV, DPV	8×10^{-9}–5×10^{-7} M (4×10^{-9} M)	0.1 M PhB pH 6.5, t_{acc} 5 min, fish samples	(82)
Mefenamic acid	$La(OH)_3$ nanowires	LSV	2×10^{-11}–4×10^{-9} M (6×10^{-12} M)	0.1 M PhB pH 5.8, drug samples	(83)
Metamitron	Bi film	SWV, DPAmp	10–200 μM (2 μM)	0.1 M AcB pH 4.5, model samples	(84)
Metformine	Cu(II) complex wires, MWCNT	LSV	9×10^{-7}–5×10^{-5} M (6.5×10^{-7})	0.04 M BRB pH 7.2, tablets	(135)
Metformine	Cu(II), MWCNT	CV, SWV	2×10^{-7}–1×10^{-5} M (6.7×10^{-8} M)	0.1 M AmB pH 8.9, pharmaceuticals	(136)
Methimazole	Co complex	CV, DPV	1×10^{-6}–1×10^{-4} M (5×10^{-7} M)	0.1 M PhB pH 7, pharmaceutical and clinical samples (serum)	(166)

(*Continued on next page*)

TABLE 1
Determination of organic compounds using carbon paste electrodes (Continued)

Analyte	Type of CPE	Technique	LDR (LOD)	Remarks	Ref(s)
Methotrexate	CD	CV, SWV	(∼1.3 ng/mL), 0.1% D-Mtx (m/m in LMtx)	0.05 M PhB pH 6.4, enantioseparation, tablets, injections	(85)
Metoclopramide	Bare	CV, SWASV	0.07–0.34 ng/mL (0.007 ng/mL)	0.4 M AcB pH 6 + 0.2 M KCl, t_{acc} 1 to 1.5 min, pharmaceuticals, spiked urine	(86)
Methylparathion	IL, SWCNT	CV, LSV	2×10^{-9}–4×10^{-6} M (1×10^{-9} M)	0.1 M PhB pH 7, t_{acc} 3 min, lake water, fruit samples	(87)
MPCA	MnO_2	CV, AMP +0.1 V vs. SCE	3.8×10^{-6}–1×10^{-5} M (0.2 ppm)	0.1 M KCl, commercial product	(167)
Naphthoquinones	Bare	DPV, FIA	1–50 μg/mL, (to ng/mL)	0.2 M PhB, biological samples	(168)
Natamycin	Bare	CV, DPV	2×10^{-6}–8×10^{-5} M (1.5×10^{-6} M)	0.5 M H_2SO_4 pH 1.8, capsules	(169)
Nicotinamide	Crown ethers	CV, DPV	0.1–500 μg/mL (0.03 μg/mL)	0.001 M CH_3COOH, pharmaceuticals	(170)
Oxalic acid	nPd	DCV, CV	1×10^{-2}–2×10^{-5} M (2×10^{-5} M)	0.01 M H_2SO_4, model solutions	(171)
Paraquat	Phosphate	SWV	2.3×10^{-8}–3×10^{-6} M (7.8×10^{-10} M)	0.1 M K_2SO_4, water samples	(172)
Paraquat	Hydroxyapatite	SWV	8×10^{-8}–2×10^{-5} M (1.8×10^{-8} M)	0.1 M K_2SO_4, river waters	(173)
Paraquat	Fluoroapatite	SWV	5×10^{-8}–7×10^{-5} M (3.5×10^{-9} M)	0.1 M K_2SO_4, model spiked food samples	(174)
Pefloxacin	dsDNA	AdSDPV	1×10^{-7}–1×10^{-5} M (3×10^{-8} M)	0.02 M AcB pH 5, urine samples	(175)
D-Penicillamine	FDCA	CV, DPV	6.5×10^{-1}–1×10^{-4} M (6×10^{-6} M)	0.1 M PhB pH 7, capsules	(176)
D-Penicillamine	FEPE	CV, DPV	7×10^{-6}–2.3×10^{-4} M (3.9×10^{-6} M)	0.1 M PhB pH 7, capsules, human serum	(177)
Phenazopyridine	Bare	SWV	2.5×10^{-8}–2.5×10^{-6} M (7.5×10^{-9} M)	0.5 M H_2SO_4, urine, tablets	(88)
Piroxicam	MWCNT	CV, DPV	0.15–5 μg/mL (0.1 μg/mL)	0.1 M AcB pH 6, t_{acc} 5 min, dosage forms	(89)
Phenol	Ppy, PVP	CV, ASV	1×10^{-6}–1×10^{-3} M (1×10^{-7} M)	PhB pH 10, t_{acc} 10 min, waste waters	(115)
Physcion	Bare	AdSV	2×10^{-10}–2×10^{-8} M (8×10^{-11} M)	0.4 M AmB pH 10.5, t_{acc} 1–2 min, catalytic current, plant extract	(116)
Propylthiouracil	CoClSal	CV, DPV	7.6×10^{-6}–7.5×10^{-4} M (2×10^{-6} M)	0.1 M AcB pH 4, pharmaceutical, clinical preparations	(90)
Pyridoxine	Crown ethers	CV, DPV	0.6–100 μM (0.2 μM)	0.05 M Tris pH 10.3, multivitamin pharmaceuticals	(117)
Quercetin	Bare	SWASV	68–338 ppb (6.8 ppb)	0.04 M PhB pH 4 + 0.1 M KCl, t_{acc} 15 s, spiked urine	(118)
Quercetin	CNT	AdSV, ChP	0.1–1 μM (3×10^{-8} M)	AcB pH 5.5, flavonoids samples	(119)

(*Continued on next page*)

TABLE 1
Determination of organic compounds using carbon paste electrodes (Continued)

Analyte	Type of CPE	Technique	LDR (LOD)	Remarks	Ref(s)
Quercetin, rutin	MWCNT	CV, DPV, RDPV	0.05–5 μM and 0.1–10 μM, resp. (2×10^{-8} M and 4×10^{-8} M, resp.)	0.04 M BRB pH 7, plant, serum samples	(120)
Quercetin	MWCNT	CV, COU	2×10^{-9}–2×10^{-5} M ($\sim 1 \times 10^{-9}$ M)	0.1 M PhB pH 4, rutin hydrolysates	(121)
Repaglinide	Bare	DPV	8×10^{-7}–3.2×10^{-6} M (1.3×10^{-7} M)	0.04 M BRB, tablets, human serum	(131)
Resveratrol	Bare	CV, SWV	5×10^{-9}–1.6×10^{-7} M (in nM)	0.001 M KCl + 0.1 M HNO_3 pH 1, urine, pharmaceuticals dosage forms	(122)
Riboflavin	Crown ethers	CV, DPV, SWASV	0.5 ng/mL–70 μg/mL (0.2 ng/mL)	0.04 M BRB pH 1.5, pharmaceuticals, food	(91)
Rutin	PVP	CV, LSV	3.9×10^{-7}–1.3×10^{-5} M (1.5×10^{-7} M)	0.1 M PhB pH 6, t_{acc} 10 min, pharmaceuticals	(123)
Streptavidin	Bare	SWV	3–60 zmol/5 μl (0.3 aM)	0.2 M AcB pH 4, t_{acc} 10 min, electrode transfer	(92)
SDBS	Butylrhodamine B	ECL	2×10^{-6}–8×10^{-3} M (5×10^{-7} M)	0.1 M NaOH	(148)
Sudan I	Montmorillonite	CV, SWV	2×10^{-7}–4×10^{-6} M (8×10^{-8} M)	0.1 M PhB pH 7, t_{acc} 2 min, food samples	(124)
Tamoxifen	Bare	LSV	7×10^{-10}–3×10^{-8} M (1×10^{-10} M)	AcB pH 4.1, tablets	(133)
Tanshinone II A	Bare	VOL	1.2×10^{-8}–2.1×10^{-6} M (4.1×10^{-9} M)	0.2 M BRB pH 2.4 + EtOH, tablets	(178)
TEA, TPrA	Bare, heating 39°C	CZE, ECL, Ru complex	$\sim 0.01 - 40$ μM (0.002 μM)	0.02 M PhB pH 8, model mixtures	(149)
Tetracycline et al.	Cu(II), dsDNA	VOL	1×10^{-9} M	0.2 M AcB + 0.02 M NaCl pH 4.7	(125)
Theophylline	K_2PtCl_6	HPLC-AMP	50–3200 ng/mL (1.1 ng/mL)	MeOH-PhB pH 5.5, serum, purines detection	(93)
Thymol	Bare	HPLC-AMP, +1.1 V vs. Ag/AgCl	2×10^{-7}–1×10^{-7} M (2.9×10^{-7} M)	0.004 M BRB pH 7 – MeOH (1:9), pharmaceuticals	(126)
Tocopherol	CNT, dsDNA	CV, SWV	0.5–160 μg/L (1.3×10^{-10} M)	0.1 M PhB, food, pharmaceuticals	(127)
Troponin I	Molecular sieve	ASV	0.8–5.0 ng/mL (0.5 ng/mL)	0.1 M HNO_3, real myocardial samples, immunoreaction	(179)
Troponin I	Molecular sieve	ASV	0.5–5.0 ng/mL (0.2 ng/mL)	0.1 M HNO_3, real myocardial samples, immunoreaction	(180)
Troxerutin	PVP	CV, COU	1×10^{-4}–1×10^{-8} M (5×10^{-9} M)	0.1 M KCl, t_{acc} 5 min, pharmaceuticals	(128)
Tryptophan	MWCNT, CoSal	CV, DPV	5×10^{-5}–5×10^{-7} M (1×10^{-7} M)	0.1 M AcB pH 4, pharmaceutical, clinical preparations	(137)
Tryptophan	FEPE	CV, ChrADPV	8.5×10^{-7}–6.3×10^{-6} M (5.6×10^{-7} M)	0.1 M PhB pH 7, human serum	(181)
Urapidil	MWCNT	CV, DPV	5×10^{-8}–2×10^{-6} M (3.8×10^{-8} M)	0.04 M BRB pH 6.8, t_{acc} 1 min, tablets	(94)
Uric acid, ascorbic acid	MWCNT, CoNSal, nafion	CV, DPV	1×10^{-7}–1×10^{-4} M ($\sim 6 \times 10^{-8}$ M)	0.1 M AcB pH 4, model AA and UA samples	(138)

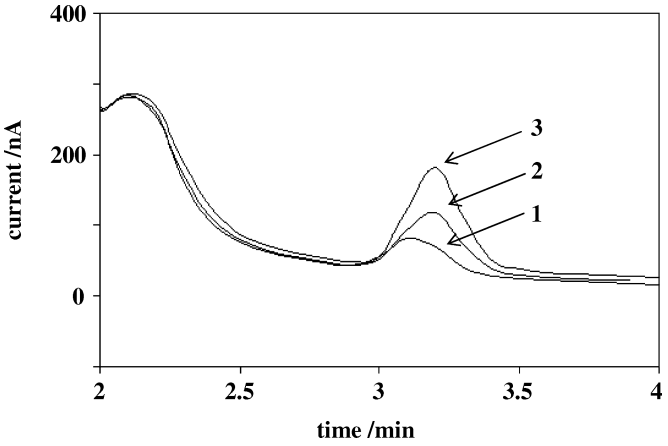

FIG. 2. The details of the chromatograms of thymol determination in thyme syrup (0.5 mL syrup diluted to 10 mL by 90% methanol in water), amperometric detection at CPE at +1, 1 V vs. Ag/AgCl reference electrode, mobile phase Britton-Robinson buffer pH 7 - methanol 1:9 (V/V), 0.5 mL/min, column Lichrospher® RP – 18, 100 – 5 μm, 125 × 4 mm, injected 20 μL, 1—thymol peak in the syrup, 2—added 100 μL of 1×10^{-3} mol/L thymol in methanol, 3—added 200 μL of 1×10^{-3} mol/L thymol in methanol.

Elemental gold (144) and platinum (93) nanoparticles were used for HPLC-ED of homocysteine (144) and theophylline (93) based on enhanced electron transfer connected with gold nanoparticles or with electrocatalytic activity of platinum nanoparticles towards the oxidation of the purine ring in theophylline and its metabolites. Taking into account that the CPE prepared from spherical microparticles of glassy carbon can be successfully used even in media with a high content of organic mobile phase modifiers like methanol or acetonitrile (126) it is possible to state that separation methods with detection at CPEs have a bright future.

The most sensitive recently published methods are based either on modification of CPE by lanthanum hydroxide nanowires (83, 104, 145) or on electrode transfer after a long time of analyte accumulation (92, 146). To get the inosine oxidation peak, the presence of Cu(II) ions and potassium disulphate was needed (145). The high sensitivity of the lanthanum hydroxide nanowires-modified CPE is reportedly connected with the formation of "porous layer" on the surface of CPE, thus markedly increasing its surface. The approach chosen for the determination of avidin and biotin (146) or streptavidin (92) is different. Here, the method is based on the oxidative signal resulting from the presence of tryptophan and tyrosine in the avidin protein molecule and very strong binding of avidin on the surface of the electrode so that transfer of the electrode to the washing solution and proper electrolyte is enabled. When streptavidin is used instead of avidin, the sensitivity of adsorptive transfer stripping voltammetry (AdTSV) is about one hundred times higher when working with only 5 μL drops (92).

Last but not least, sensitive electroluminescent methods at CPEs (147–149) should also be mentioned. LOD of heroine (147) (based on electrocatalytic response of ruthenium complex) and of sodium dodecylbenzene sulphonate (based on oxidation of butyl-rhodamine B) (148) is around 1 μM. LOD around 2 nM were reported for TEA and TPrA determination (149) with electrical heating of the CPE by 100 kHz alternating current. Here, tris(2,2′-bipyridyl)ruthenium(II) complex was added to the separation buffer for CZE. Surprisingly, the temperature elevation did not worsen the CPE performance but improved the peak shape, increased its reproducibility, and lowered the detectability of TEA and TPrA.

CARBON PASTE-BASED SENSORS AND BIOSENSORS

Fascinating possibilities of CPEs in this field are documented in Table 2. CPEs-based sensors or biosensors are typically used in the analysis of biogenic amines where electrochemistry successfully competes with separation methods. All published papers (182–185) utilize enzyme modification of CPE either by polyphenol oxidase (183–185) or horseradish peroxidase (182). Mainly, amperometry is used with quite low detection potentials. Ascorbic acid (AA) (186, 187) and uric acid (UA) (187–189) are also frequently targeted analytes. The method (187) utilizing incorporated thionone-nafion ion pair system as an electron mediator is able to simultaneously determine 500 nM AA and 50 nM UA, even in complex biological and clinical matrices. Even nanomolar limits of detection are reported for UA determination (188), with paste comprising multi-walled carbon nanotubes and ionic liquid 1-butyl-3-methylimidazolium hexafluorophosphate. No enzyme was needed in contrast to similarly sensitive methods (189) where uricase together with electron transfer mediator tetracyanoquinodimethane were used. Amperometric sensors for D-lactic acid (190) depends on the biorecognition element of D-lactate cytochrome c oxidoreductase bound by glutaraldehyde in combination with methosulphate—Reinecke's salt as mediator. A similar principle was used for detection of D-amino acids (191) when fatty acid modification of flavin adenin dinucleotide redox cofactor was employed.

CP sensors are quite often also used for phenols (43, 192–204), which is based on their easy oxidation and/or easy enzymatic reactions. The use of immobilized bacteria or microbial cells expressing hydrolases and degrading organophosphorous (194), of tyrosinase (202, 203), and of either magnetic particles (202) or gold nanoparticles (203) was described. By far, the largest number of papers is devoted to the analysis of sugars (14–30, 205), glucose being the favorite analyte (14–30). The majority of methods utilizes glucose oxidase together with a broad range of metal complexes, metal nanomaterials, polymers, ionic liquids, etc. A very sensitive method for simultaneous determination of glucose and insulin (30) is based on a needle type of an integrated chemically and biologically modified carbon paste where the glucose signal relies on the catalytic activity of glucose oxidase and the insulin signal relies on the electrocatalytic activity of ruthenium oxide. The glucose sensor

TABLE 2
Determination of organic compounds using carbon paste electrode-based sensors

Analyte	Type of CPE	Technique	LDR (LOD)	Remarks	Ref(s)
D-Amino acids	DAAOX, ferrocene, modified FAD	AMP, +0.7 V vs. Ag/AgCl	3×10^{-3}–1×10^{-4} M (1×10^{-4} M)	0.05 M PhB, pH 9.2	(191)
Ascorbic acid	FePC	POT	1×10^{-2}–1×10^{-6} M (5×10^{-7} M)	0.05 M PhB, pH 6, catalytic AA oxidation, response time <10 s, vitamin praparations	(186)
Ascorbic acid, uric acid	Thionine, nafion	DPV, CV	1×10^{-4}–1×10^{-6} M (5×10^{-7} M AA, 5×10^{-8} M UA)	0.1 M AcB, pH 5, ion pairing, pharmaceuticals, urine, serum	(187)
Benzoyl peroxide	CuTerpy	AMP, −0.05 V vs. SCE	0.9–5 μg/mL (0.2 μg/mL)	0.1 M PhB, pH 7, pharmaceuticals, RT 0.5 s	(208)
Biogenic amines	HRP	AMP, −50 mV vs. SCE	40–470 ng/mL, (17 ng/mL)	0.1 M PhB, pH 7, 10 μM H_2O_2, blood samples, RT 0.5 s	(182)
*CA125	nAu, thionine, anti-CA125	AMP, DPV, EIA	10–30 U/mL (1.8 U/mL)	AcB, pH 7, human serum immunosensor	(57)
*CA19-9	nAu, HRP, CA19-9 antibody	DPV, CV, EIA	2–30 U/mL (1.37 U/mL)	PhB, pH 7, immunosensor	(58)
*CEA	nAg and nFe_3O_4	CV, POT, ACI, EIA	1.5–200 ng/mL (0.5 ng/mL)	PhB pH 7.4, CEA antigen attachment, immunosensor	(59)
*CEA	nAu, thionine, nFe_3O_4	DPV	1.5–60 ng/mL (0.3 ng/mL)	AcB, pH 6.8, immunoassay system	(60)
*CEA	nAu, nFe_3O_4, HRP, MPTMS	DPV	1–55 ng/mL (0.13 ng/mL)	PhB, pH 7, 1.3 mM OPD, 0.8 nM H_2O_2, immunosensor, protein diagnostics	(61)
Clozapine	HRP, MMPs, GA	AMP, 0.0 V vs. Ag/AgCl	2×10^{-4}–3×10^{-5} M (5 μM)	PhB pH 7.4, 0.1 mM H_2O_2, batch samples	(209)
Clozapine, thiols	HRP, MMPs	CV, AMP, 0.0 V vs. Ag/AgCl	10–220 μM GSH (5 μM)	PhB pH 7.4, 0.1 mM H_2O_2	(210)
Cysteine, GSH	Tyrosinase	AMP, FIA, -0.05 V vs. Ag/AgCl	1–8 μM, (0.1 μM AMP, 1 μM FIA)	pH 6.5, minimum AA and UA interferences	(211)
Cysteine	CoSal	AMP, POT, DPV	2×10^{-6}–1×10^{-2} M (1×10^{-6} M)	0.05 M PhB or AcB, catalytic cysteine oxidation	(212)
Cysteine	(VO)O-Salen	CV, AMP, 0.65 V vs. SCE	2.4×10^{-4}–2.3×10^{-3} M (1.7×10^{-4} M)	0.1 M KCl, pH 5, possibly pharmaceuticals	(213)
Cysteine	NPN	AMP, +0.33 V vs. Ag/AgCl	0.8×10^{-6}–13.2×10^{-6} M (2.5×10^{-7} M)	0.1 M PhB, pH 7, food samples	(214)
*DNA sequence	Chitosan, MB	DPV	1.5×10^{-9}–1.5×10^{-7} M (3×10^{-10} M)	20 mM TRIS, pH 7, PCR, hepatitis B virus sequences, MB peak decrease measurement	(52)
*DNA sequence	HRP, ssDNA, nAu	DPV	9.5×10^{-9}–1.5×10^{-10} M (5×10^{-11} M)	0.1 M PhB pH 7, 0.5 M H_2O_2, test DNA samples, HRP inhibition by dsDNA	(53)
*DNA sequence	PP, ssDNA, EB, MWCNT	DPV	1×10^{-8}–1×10^{-10} M (8.5×10^{-11} M)	0.1 M PhB pH 7, differential EB current measurements	(54)
*DNA	IL, ssDNA	CV	10–110 μg/mL (1.5 μg/mL)	PhB, pH 7, t_{acc} 160s at +0.35 V, guanine peak, model samples	(55)

(*Continued on next page*)

TABLE 2
Determination of organic compounds using carbon paste electrode-based sensors (Continued)

Analyte	Type of CPE	Technique	LDR (LOD)	Remarks	Ref(s)
*DNA sequence	nPbSe, CTAB, chitosan	DPV	5×10^{-11}–5×10^{-6} M (1.6×10^{-11} M)	Methylene violet indicator, plant samples	(56)
Dopamine	PPO, TCNQ	AMP, FIA, 0.1 V vs. Ag/AgCl	2×10^{-2}–2×10^{-4} M (1.5×10^{-4} M)	0.3 M PhB, pH 7.8, pharmaceuticals	(183)
Dopamine	PPO, albumin, nAu	AMP, -0.1 V vs. Ag/AgCl	1×10^{-3}–2×10^{-7} M (2×10^{-7} M)	0.05 M PhB pH 7.4, in presence of AA	(184)
Dopamine	Apple tissue (PPO)	DPV	0.4–25.2 μM (2×10^{-7} M)	Injections, synthetic samples	(185)
Enalapril	LAAO	SIA/AMP, 0.65 V vs Ag/AgCl	0.08–1.5 μM (4.3 nM)	0.1 M NaCl, raw materials, pharmaceuticals, enantioanalysis	(215)
EPN	CNT, DNA	SWV, CV	10–210 ng/L (8×10^{-12} M)	0.1 M $NH_4H_2PO_4$, fruit tissue, fish brain cells	(206)
Ethanol, NADH	Ru complex, Zr phosphate	AMP, CV	10–80 mM	0.1 M PhB, pH 8, NADH oxidation in presence of yeast	(216)
α-1-Fetoprotein	nAu and nFe_2O_3, anti-AFP	POT, EIA	1–80 ng AFT (0.5 ng AFT)	0.1 M PhB pH 7, immunosensor	(62)
*Gene sequence	DNA, SA/Al film	CV, DPV	not found	BRB	(63)
*Gene sequence	DNA, SA/Al film	CV, DPV	2×10 nM	BRR, plant extracts	(64)
*Gene sequence	CTAB, ssDNA, MB	CV, DPV	(1×10^{-8} M)	Hybridization detection	(65)
*Gene sequence	CNT, pLys film	CV	1×10^{-12}–1×10^{-7} M (3.1×10^{-13} M)	5.0 mM $[Fe(CN)_6]^{3-/4-}$ (1:1) + 0.1 M KCl electrostatic adsorption, PCR amplification	(66)
Glucose	GOX, nAu	AMP, CV	4×10^{-5}–2.8×10^{-4} M (1×10^{-5} M)	0.1 M PhB, pH 5, no AA and UA interferences	(14)
Glucose	Cu, GOX	AMP, −0.1 V vs. Ag/AgCl	1.5×10^{-4}–6×10^{-3} M (1.5×10^{-4} M)	0.05 M PhB, pH 7.4, no interferences from common interferents, serum samples	(15)
Glucose	GOX, MnO_2	AMP, FIA,+0.48 V vs. Ag/AgCl	20–500 mg/L (10.5 mg/L)	0.2 M PhB, pH 7.5	(16)
Glucose	GOX, RL	AMP, LSV	2–20×10^{-3} M, (8×10^{-4} M)	0.1 M KPF_6, RL oxidation monitoring, blood samples	(17)
Glucose	GOX, Cu, Ir, CNT	AMP, -0.1 vs. Ag/AgCl	1.2×10^{-2}–2×10^{-5} M, (2×10^{-5} M)	0.05 M PhB pH 7.4, H_2O_2 reduction	(18)
Glucose	Pt, GOX	CV, AMP, 0 V vs. Ag/AgCl	6×10^{-5}–1.2×10^{-2} M, (2×10^{-5} M)	0.05 M PhB pH 7.4, model samples, 20–30 s RT	(19)
Glucose	GDH, DI, NAD(+) CNT, Os polymer	AMP, +0.2 V vs. Ag/AgCl	1×10^{-5}–8×10^{-4} M, (1×10^{-5} M)	0.1 M PhB, pH 7, sweet wines samples	(20)
Glucose	$La(OH)_3$, Cu(II)	VOL, −0.17 V vs. CSE	2×10^{-5}–8×10^{-7} M, (3.5×10^{-7} M)	AmB pH 9.8, model samples	(21)
Glucose, phenol	CNT, Os complex, microbial cells	AMP, +0.3 V vs. Ag/AgCl	0.05–2.0 mM	0.05 M PhB pH 7, RT 35 s, artificial waste waters (for phenol)	(22)
Glucose	PQQ-GDH, CNT, $K_3Fe(CN)_6$	AMP, CV, +0.5 V vs. Ag/AgCl	1×10^{-3}–35×10^{-3} M (0.15 mM)	citrate buffer, pH 6, 2 μl samples, RT 20 s	(23)

TABLE 2
Determination of organic compounds using carbon paste electrode-based sensors (Continued)

Analyte	Type of CPE	Technique	LDR (LOD)	Remarks	Ref(s)
Glucose	PP, GOX, PTY, Pt	AMP	1×10^{-5}–1.8×10^{-2} M, (5×10^{-6} M)	2 months stability, almost no interferences, RT 10 s	(24)
Glucose	GOX, IL	AMP, VOL, +0.9 V vs. SCE	1–20 mM	0.05 M PhB, pH 7.5, RT 5 s	(25)
Glucose	nFe_3O_4-SiO2, GOX, chitosan	AMP, FIA, +0.35 V vs. Ag/AgCl	1×10^{-5}–4×10^{-3} M, (3.2×10^{-6} M)	0.1 PhB, pH 7.3, RT 10 s	(26)
Glucose	GOX, IL	DPV	1×10^{-7}–8×10^{-4} M, (3×10^{-8} M)	0.067 M PhB, pH 7, human plasma, no mediator	(27)
Glucose	nNdHCF	SWV	5.0–100.0 μM (3 μM)	0.5 M KCl, no interferences	(28)
Glucose	GOX, MCP	AMP, +0.4 V vs. Ag/AgCl	7.2×10^{-5}–1.5×10^{-2} M, (7.2×10^{-5} M)	0.05 M PhB, pH 7.4	(29)
Glucose, insulin	GOX, RuO_2	AMP, FIA, +0.6 V vs. Ag/AgCl	0.1–1 μM and 2–14 mM (23 nM and 500 nM), resp.	0.1 M NaCl/0.05 M PhB, pH 7.4, simultaneous determination	(30)
L-Glutamate	GluOx, TTF-TCNQ, BSA	AMP, +0.05 V vs. Ag/AgCl	sigmoidal shape (5×10^{-5} M)	0.05 M NaCl or KCl, pH 7, tomato foods	(31)
H_2O_2	Mn oxides	AMP, +0.3 V vs. Ag/AgCl	1.0×10^{-4}–6.9×10^{-4} (2 μM)	0.01 M PhB pH 7.4, model samples	(32)
H_2O_2	HRP, MB, SiO_2, NbO	AMP, −0.05 M vs. SCE	1–700 μM, (5×10^{-7} M)	0.1 M PhB pH 6.8, RT 1 s, model samples	(33)
H_2O_2	CNT, GOx	AMP, −0.1 V vs. Ag/AgCl	1–50 mM	0.05 M PhB pH 7.4, model samples	(34)
H_2O_2	CNT	CV, AMP, −0.1 V vs. Ag/AgCl	2–20 mM	0.05 M PhB pH 7.4, RT 10 s	(35)
H_2O_2	Coconut tissue	AMP, CV, −0.15 V	2×10^{-4}–3.4×10^{-3} M (4×10^{-5} M)	pH 5.2, pharmaceuticals, 3 months lifetime	(36)
H_2O_2	GaHCF	AMP, +0.15 V vs. SCE	4.9×10^{-6}–4×10^{-4} M (1×10^{-6} M)	0.05 M PhB, pH 6.8, model samples	(37)
H_2O_2	HRP,nFe_3O_4, GA	AMP	1.2×10^{-7}–8.3×10^{-5} M (4.5×10^{-8} M)	Magnetic microparticles	(38)
H_2O_2	nAu, cytochrome c	CV, 0 or -0,1 V vs. Ag/AgCl	10 μM–5 mM (1×10^{-5} M)	0.1 M PhB pH 7, pseudo peroxidase acivity	(39)
H_2O_2	HRP, nAu, chitosan	CV, AMP -0.3 V vs. SCE	1.2×0^{-5}–2.4×10^{-3} M (6.3×10^{-6} M)	0.067 M PhB, HQ mediator, real samples	(40)
H_2O_2	HRP, nAu	CV, AMP, 0 to −0.4 V vs. SCE	2×10–$7\text{-}5 \times 10^{-5}$ M (2.1×10^{-7} M)	0.1 M PhB, pH 7, no mediator	(41)
H_2O_2	RuO_2	CV, AMP +0.6 V vs. SCE	0.029 –0.1 mM (7 μM)	0.1 M PhB, pH 7.4, H_2O_2 consumption monitoring, catalase activity measur.	(42)
H_2O_2, hydroquinone	nAu, HRP	AMP, -0.25 V vs. Ag/AgCl	5×10^{-7}–1.3×10^{-4} M (4×10^{-7} M)	0.1 M PhB pH 6.8, thiols inhibition study	(43)
H_2O_2	MB, NaX zeolite	AMP, CV, -0.4 V vs. Ag/AgCl	1×10^{-5}–1×10^{-3} M (1.4×10^{-4} M)	PhB, pH 6	(44)
H_2O_2	nAu, HRP, PTH	AMP, 0.05 V vs. SCE	9.6×10^{-6}–1.2×10^{-3} M (7.5×10^{-7} M)	0.1 M AcB pH 6.5, multiporous PTH	(45)
H_2O_2	Heme proteins, IL	AMP, -0.45 V vs. Ag/AgCl	7.6×10^{-5}–1×10^{-3} M (2.3×10^{-5} M)	0.1 M PhB pH 7, environmental samples, 3 months storage	(46)

(*Continued on next page*)

TABLE 2
Determination of organic compounds using carbon paste electrode-based sensors (Continued)

Analyte	Type of CPE	Technique	LDR (LOD)	Remarks	Ref(s)
Hydroquinone	Chitosan, plant extracts	DPV	(2.5×10^{-5} M)	0.1 M PhB, pH 7, waste waters	(192)
Hydroquinone	Chitosan, gilo peroxidase, GA	SWV	(2 μM)	0.1 M PhB, pH 7, 6 months lifetime	(193)
Hypoxanthine	nAu, GA, BSA	AMP, 0 and +0.6 V vs. Ag/AgCl	0.5–10.0 μM (2×10^{-7} M)	0.1 M PhB, pH 7.4, sardines, chicken meal	(217)
Hypoxanthine	XOD, luminol	Electrochemi-luminescence	0.6–120 μM (0.1 μM)	0.2 M PhB pH 7, electrically heated CP, 35°C	(218)
*IgG	nFe_3O_4, cystein, IgG antibody, GA	POT	0.1–1.2 ng/mL (0.023 ng/mL)	0.067 M PhB pH 7.4, immunosensor	(207)
Lactic acid	LCCOXR, mediator, GA	AMP, 0 V vs SCE	1.5×10^{-5}–1×10^{-1} M (5.6×10^{-5} M)	0.05 M PhB, pH 7, biological samples	(190)
LOX inhibiting drugs	LOX	DPV, +0.9 V vs. Ag/AgCl	5.5×10^{-5}–1.5×10^{-4} M	0.1 M Sorensen b., pH 9, linoleic acid as substrate	(219)
Metronidazole	Porfyrine	AMP, −0.4 vs. SCE	2.9×10^{-3}–5.8×10^{-8} M (5.8×10^{-8} M)	BRB pH 4.3, pharmaceutical preparations	(220)
NADH	Coumestan	CV, ChA, DPV	1–400 μM (1×10^{-7} M)	0.1 M PhB, pH 7, in uric acid presence	(47)
NADH	Hematoxylin	CV, ChA, DPV	0.4–600 μM (8×10^{-8} M)	0.1 M PhB, pH 7	(48)
NADH	MB, zeolite	AMP, 0 V vs. Ag/AgCl	3×10^{-5}–1×10^{-7} M (8×10^{-7} M)	Ca^{2+} fortified zeolite	(49)
NADH, PHEA	NAD(x), PDH, uricase, DHB	CV	0.5–10 mM (0.5×10^{-3} M)	PhB pH 9, phenylketonuria sensor, human urine	(50)
NADH	CNF	AMP, DPV, +0.45 vs. Ag/AgCl	2×10^{-8}–11.5×10^{-6} M (2×10^{-8} M)	0.1 M PhB pH 7, mediatorless sensor	(51)
Nicotine	ChOX, Q, BSA, GA	AMP, +0,45 V vs. SCE	2×10^{-5}–9.2×10^{-4} M (1×10^{-5} M)	0.067 M PhB, pH 7.4, inhibition biosensor	(221)
p-Nitrophenyl-	OPH immob. cells	AMP, +0.6 V vs. Ag/AgCl	1 nM–2 μM (1 nM)	50 mM citrate b., pH 7.5, 50 μM $CoCl_2$, organophospohorous nerve agents	(194)
p-Nitrophenol	Microb. cells	AMP, +0.3 V vs. Ag/AgCl	20 nM–20 μM (20 nM)	20 mM PhB, pH 7.5, microbial bios.	(195)
p-Nitrophenol (insectisides)	OPH, albumin, nylon net	AMP, +0.85 V vs. Ag/AgCl	2–40 nM (15 nM)	0.1 M PhB pH 7, OP insecticides	(196)
p-Nitrophenol (pesticides)	Bacteria, OPH	AMP, +0.6 V vs. Ag/AgCl	(1.4 ppb)	50 mM citrate b., PhB, pH 7.5, 50 μM $CoCl_2$, lake water	(197)
p-Nitrophenol (pesticides)	Bacteria, OPH	AMP, +0.9 V vs. Ag/AgCl	0.2–175 μM (0.2 to 1μM)	pH 8.5, microbial biosensor, nerve agents	(198)
p-Nitrophenol	Nafion, bacteria	AMP, +0.4 V vs. Ag/AgCl	5 μM–5 nM (5 nM)	50 mM citrate b., pH 7.5, water samples	(199)
Pesticides	FePC, AChE, ChOx	AMP, +0,35 V vs. Ag/AgCl	1×10^{-5}–1×10^{-9} M (10 nM)	0.05 M PhB pH 7.5, H_2O_2 detection	(200)
Phenols	HRP, Fc	AMP	3×10^{-7}–1.5×10^{-5} M (3×10^{-7} M)	wine, tea samples	(201)
Phenol	Tyrosinase, magnetic particles	AMP, -0.15 V vs. SCE	1×10^{-6}–2.5×10^{-4} M (6×10^{-7} M)	0.1 M PhB + 0.1 M KCl, pH 7, final quinone determination	(202)

TABLE 2
Determination of organic compounds using carbon paste electrode-based sensors (Continued)

Analyte	Type of CPE	Technique	LDR (LOD)	Remarks	Ref(s)
Phenol	nAu, tyrosinase	AMP, −0.15 vs. SCE	4×10^{-6}–4.8×10^{-5} M (6×10^{-9} M)	0.1 M PhB, pH 7, RT 5 s	(203)
Phenol	Tyrosinase, MPMS	AMP, −0.15 vs. Ag/AgCl	0.025–50 μM (25 nM)	0.05 M PhB+0.1 M NaCl, pH 7, biological fluids, marker of exposure to OPC	(204)
Psicose	DTE, DFDH	AMP, +0.4 V vs. Ag/AgCl	8×10^{-5}–50×10^{-3} M (8×10^{-5} M)	citrate b.+ PhB, food, environment samples, microflow cell	(205)
Rutin	GP, chitosan, ECH, GA	SWV, +0.124 V vs. Ag/AgCl	3.4×10^{-7}–7.2×10^{-6} M (2×10^{-8} M)	0.1 M PhB, pH 7, 8 months lifetime	(193)
Uracil	$La(OH)_3$, Cu(II)	AMP, +0.22 V	3×10^{-8}–4×10^{-9} M (2×10^{-10} M)	0.1 M PhB pH 6.4, pharmaceuticals	(222)
Uric acid	MWCNT-IL	VOL, +0.49 V vs. SCE	1×10^{-8}–1×10^{-6} M (5×10^{-9} M)	PhB, pH 4, urine samples, t_{acc} 3min	(188)
Uric acid	Uricase, tetracyanoquinodimethane	AMP, FIA, +0.34 V vs. Ag/AgCl	1–100 μM (0.19 μM)	TRIS-HCL buffer pH 8.6, RT 50 s, biological fluids	(189)
Vitamin B-12	DBCH	SWV	2×10^{-9}–2×10^{-7} M (8.5×10^{-10} M)	0.2 M PhB pH 2.5, reduction of Co(III), reoxidation to Co(II), pharmaceuticals, biological matrices	(223)

*oligonucleotides confirmation or hybridization proof.

is reportedly not affected by injections of insulin samples while the insulin one is not responding to the large excess of glucose. Direct mediatorless determination of glucose utilizing glucose oxidase and ionic liquid as carbon paste binder was reported (27). Glucose oxidase was immobilized on hydrophobic ionic liquid 1-butylpyridinium hexafluorophosphate, with no other supporting films or mediators needed while retaining stability, repeatability, and reproducibility of performance even in real samples of human plasma.

Biosensors for hydrogen peroxide (32–46) incorporate either horseradish peroxidase and other peroxidases or glucose oxidase. As electron transfer mediators between immobilized enzyme and the electrode surface organic dyes or metal nanoparticles like gold nanoparticles, colloidal gold particles, or metal oxide particles are used. The medium pH for these sensors is almost exclusively around pH 7, with potentials for amperometric detection varying roughly from −0.5 to +0.5 V. The sensitivity is around 1 μL/mol; the highest sensitivity reported (38) (4.5×10^{-8} M) was achieved after covalent immobilization of horseradish peroxidase using 3-(aminopropyl)triethoxysilane and glutaraldehyde on magnetic iron oxide particles used for analyte pre-concentration. Gold nanoparticles together with horseradish peroxidase (40, 41, 43, 45) are successful modifiers of CPE, helping the incorporated enzyme stability and showing electrocatalytic properties.

Reduced nicotinamide adenine dinucleotide is another important analyte (47–51). Its direct oxidation takes place at potentials above +1 V; moreover, it is accompanied by electrode passivation and fouling due to the radical intermediates' formation and their subsequent polymerization. Again, electrode surface modification or electron transfer mediation is the solution. Hematoxylin-modified CE enabled electrocatalytic oxidation of in neutral media at the potential below +0.2 V, with LOD 8×10^{-8} M. Even lower LOD (2×10^{-8} M) is claimed for mediatorless CPE modified by carbon nanofibers produced by electrospinning technique. The applied potential is a little bit higher (+0.45 V) but still reasonably low and no mediator is needed.

By far the most sensitive methods are connected with DNA (gene)- or protein-based sensors (52–56, 62–66, 206, 207). Methods based on guanine oxidation are not so sensitive (55), although CV with a 3-minute accumulation time enabled determination of DNA concentrations of 1.5 μg/mL. Immunosensors with antigen attachments allow the detection of proper antigen at the concentration as low as 0.5 ng/mL (59–61). PCR can further decrease LOD of specific oligonucleotides. PCR-amplified short DNA sequences related to hepatitis B virus were determined using methylen blue and chitosan-modified CPE (52). Here, the decrease in electroactive label meldola blue current measured by DPV was measured when evaluating the hybridization of the probe with the target (52). LOD of 3.1×10^{-13} M for genes, for phosphinothricin acetyltransferase (PAT) was recently reported (66). Modified CPE was prepared by the dripping of well-dispersed carboxylic group-functionalized single-walled carbon nanotubes on the CPE surface followed by formation of poly-l-lysine films. The DNA probes were immobilized by

electrostatic adsorption. Hybridization was monitored by electrochemical impedance spectroscopy using $[Fe(CN)_6]^{3-/4-}$ as an indicator. LDR of this DNA electrochemical sensor is 1×10^{-12}–1×10^{-7} M.

CONCLUSIONS

As documented above, various types of CPEs, CMCPEs, and CP-biosensors still belong among the most popular laboratory-made configurations. Their wide-spread applicability reflects specific properties of carbon pastes, as well as the versatility of this electrode material in combinations with new technologies. Such adaptability is then apparently the most distinct feature of the present day's electrochemistry with carbon paste-based electrodes compared to previous periods.

Regarding the area of electroanalysis of organic pollutants, pharmaceuticals, and biologically important organic compounds, the following trends can be highlighted, most of them also representing probable future activities in the field (2, 8, 13):

1. More frequent use of new carbon pastes made of alternate materials that simulate the function of some modifiers (e.g., electrocatalytic properties of carbon nanotubes and some ionic liquids) or stabilize the carbon paste mixture for its application in atypical media;
2. Combination of traditional electrochemical principles with other detection techniques such as spectroelectrochemistry, electrochemiluminiscence, or modern microscopy (particularly useful for initial characterisations of newly synthesized modifiers);
3. Further miniaturization of selected CPE configurations for detection in flowing streams;
4. Testing and applications of new pre-concentration principles of non-electrochemical character, effective for improvement of the overall electroanalytical performance;
5. Practical preference of methods with favorable ecological parameters (the so-called environmentally friendly procedures connected with "green analytical chemistry"). In this respect, nearly harmless and non-toxic carbon pastes may be a significant advantage;
6. Adaptations of already existing methods and procedures in terms of the above-mentioned features; i.e., the improved electroanalytical performance (sensitivity and selectivity), capability to combine with other techniques, compatibility with analyzers of new generations, plus acceptability given by the actual economical demands. In view of the latter, carbon paste mixtures had always been in the foreground as a cheap and easy-to-prepare material and the same can be expected for the up-coming years.

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ABBREVIATIONS AND SYMBOLS

AA	Ascorbic acid
accum.	Accumulation (pre-concentration)
AcB	Acetate buffer
AChE	Acetylcholin esterase
ACV	Alternating current voltammetry
ADH	Alcohol dehydrogenase
AdSV	Adsorptive stripping voltammetry
AdTSV	Adsorptive transfer stripping voltammetry
AFT	Alpha-1-fetoprotein
AmB	Ammonia buffer
ASV	Anodic stripping voltammetry
BRB	Britton-Robinson buffer
BSA	Bovine serum albumin
C	Carbon (graphite)
CA	Chronoamperometry
CA125	Carcinoma antigen 125
CA19-9	Carbohydrate antigen 19-9
CD	Cyclodextrine
CEA	Carcinoembryonic antigen
ChOx	Choline oxidase
CMCPE(s)	Chemically modified carbon paste electrode(s)
CNF	Carbon nanofibres
CoSal	N,N'-bis(salicylidene)-1,2-phenylenediaminocobalt (II)
CoClSal	Cobalt(II)-4-chlorosalophen
CoNSal	Cobalt(II)-5-nitrosalophen
COU	Coulometry
CP	Carbon paste
CPB	Cetylpyridinium bromide
CPE(s)	Carbon paste electrode(s)
CTAB	Cetyl-trimethyl-ammonium bromide
CuTerpy	(2,2′:6′,2″-terpyridyl)copper(II) chloride
CV	Cyclic voltammetry
CZE	Capillary zone electrophoresis
DAAOx	D-amino acid oxidase
DBCH	1,2-dibromocyclohexane
DCE	Dropping carbon electrode
DFDH	D-fructose dehadrogenase
DHB	3,4-dihydroxybenzaldehyde
DI	Diaphorase
DME	Dropping mercury electrode
DNA	Deoxyribonucleic acid
DPV	Differential pulse voltammetry
DPA(C)SV	Differential pulse anodic (cathodic) stripping voltammetry
DTE	D-tagatose 3-epimerase
EB	Ethidium bromide
ECH	Epichlorhydrin
ECL	Electrochemiluminescence (signal) detection
EIS	Electrochemical impedance spectroscopy
EPN	O-ethyl-O-4-(nitrophenyl)phenyl phosphonothioate

EtOH Ethanol
Fc Ferrocene
FAD Flavinadenin dinucleotide
FDCA Ferrocenedicarboxylic acid
FePc Iron(II) phthalocyanine
FePC Ferrophthalocyanone
FEPE 1-[4-ferrocenylethynyl)-phenyl]-1-ethanone
FIA Flow injection analysis
GA Glutaraldehyde
GaHCF Gallium hexacyanoferrate
GDH Glucose dehydrogenase
GluOX Glutamate oxidase
GOX Glucose oxidase
GP Gilo peroxidase
GSH Glutathione
Hb Hemoglobin
HPLC High performance liquid chromatography
HRP Horse radish peroxidase
IgG Immunoglubulin G
IL Ionic liquid
LAAO L-amino acid oxidase
LDR Linear dynamic range
LOX Lipoxygenase
LSV Linear scan (sweep) voltammetry
LOD Limit of detection
LOQ Limit of quantification
M Molar concentration [mol L^{-1}]
MB Methylene blue
MCP Mesoporous carbon powder
MeOH Methanol
MMPs Magnetised silica-based microparticles
modif. Modifier, modified
MPCA Monochlorophenoxyacetic acid
MPMS 1-methoxyphenazine methosulfate
MPTMS 3-mercaptopropyl trimethoxysilane
Mtx Methotrexate
NAD(H) Nicotinamide dinucleotide (reduced form)
NdHCF Neodymium(III) hexacyanoferrate
NPN 4-nitrophthalonitrile
OPH Organophosphorus hydrolase
OPD O-phenylenediamine
Pc Phthalocyanine
PCR Polymerase chain reaction
PDH Phenylalanine dehydrogenase
PEG Polyethylen glycol
PhB Phosphate buffer
PHEA Phenylalanine
pNP p-nitrophenol
POT Potentiometry
PP Polypyrrol
PPO Polyphenol oxidase
PQQ-GDH Pyrrole quinoline quinone glucose dehadrogenase
PTH Polythionine
PTY Polytyramine
PVP Polyvinylpyrrolidone
PyOX Pyranose oxidase
Q/HQ Quinone/hydroquinone
RSD Relative standard deviation [%]
RT Response time
RTIL Room temperature ionic liquid
SA Stearic acid
SDBS Sodium dodecylbenzene sulphonate
SDS Sodium dodecylsulphate
SV Stripping voltammetry
SWV Square-wave voltammetry
t_{acc} Accumulation time (period)
t_{anal} Analysis time
TCNQ Tetracyanoquinodimethane
TEA Triethylamine
TPrA Tri-n-propylamine
t_R Response time
TRIS Buffer (commercial formulation)
TTF-TCNQ Tetrafulvalene-tetracyanoquinodimethane
U Enzyme activity unit
UA Uric acid
VO(Salen) N,N'-ethylenebis(salicylideneamino)oxo-vanadium (IV)
v/v Volume ratio
XOD Xanthin oxidase.

REFERENCES

1. P. Zuman, Electrolysis with a dropping mercury electrode: J. Heyrovský's contribution to electrochemistry. *Critical Reviews in Analytical Chemistry* 31 (2001):281–289.
2. I. Švancara, K. Vytřas, K. Kalcher, A. Walcarius, and J. Wang, Carbon paste electrodes in facts, numbers, and notes: A retrospective review on the occasion of the 50-years jubilee of carbon paste in electrochemistry and electroanalysis. *Electroanalysis* 21 (2009):7–28.
3. R. N. Adams, Carbon paste electrodes. *Analytical Chemistry* 30 (1958):1576–1576.
4. R. N. Adams, *Electrochemistry at Solid Electrodes* (M. Dekker, New York, 1969).
5. K. Kalcher, Chemically modified carbon paste electrodes in voltammetric analysis. *Electroanalysis* 2 (1990):419–433.
6. K. Kalcher, J. M. Kauffmann, J. Wang, I. Švancara, K. Vytřas, C. Neuhold, and Z. Yang, Sensors based on carbon paste in electrochemical analysis: A Review with particular emphasis on the period 1990–1993. *Electroanalysis* 7 (1995):5–22.
7. I. Švancara, K. Vytřas, J. Barek, and J. Zima, Carbon paste electrodes in modern electroanalysis. *Critical Reviews in Analytical Chemistry* 31 (2001):311–345.
8. K. Kalcher, I. Švancara, R. Metelka, K. Vytřas, and A. Walcarius, Heterogeneous electrochemical carbon sensors, in *The Encyclopedia of Sensors, Vol. 4* eds. C. A. Grimes, E. C. Dickey, and M. V. Pishko (American Scientific Publishers, Stevenson Ranch, CA, USA, 2006), Ch. 4, 283–429.
9. L. Gorton, Carbon paste electrodes modified with enzymes, tissues, and cells (A Review). *Electroanalysis* 7 (1995):23–45.

10. K. Brainina and M. B. Vydrevich: Stripping analysis of solids. *Journal of Electroanalytical Chemistry and Interfacial Electrochemistry* 121 (1981):1–28.
11. R. D. O'Neill, Sensor–tissue interactions in neurochemical analysis with carbon paste electrodes in vivo. *Analyst (UK)* 118 (1993):433–438.
12. G. A. Rivas, M. D. Rubianes, M. L. Pedano, N. F. Ferreyra, G. L. Luque, M. C. Rodriguez, and S. A. Miscoria, Carbon nanotubes paste electrodes: A New alternative for the development of electrochemical sensors. *Electroanalysis* 19 (2007):823–831.
13. I. Švancara, A. Walcarius, and K. Vytřas, Carbon paste electrodes in the new millennium and their applications in electroanalysis of inorganic ions and molecules. *Central European Journal of Chemistry*, submitted paper.
14. S. Q. Liu and H. X. Ju, Reagentless glucose biosensor based on direct electron transfer of glucose oxidase immobilized on colloidal gold modified carbon paste electrode. *Biosensors & Bioelectronics* 19 (2003):177–183.
15. M. C. Rodriguez and G. A. Rivas, Highly selective first generation glucose biosensor based on carbon paste containing copper and glucose oxidase. *Electroanalysis* 13 (2001):1179–1184.
16. K. Schachl, E. Turkusic, A. Komersova, M. Bartos, H. Moderegger, I. Svancara, H. Alemu, K. Vytras, M. Jimenez-Castro, and K. Kalcher, Amperometric determination of glucose with a carbon paste biosensor. *Collection of Czechoslovak Chemical Communications* 67 (2002):302–313.
17. R. G. Evans, C. E. Banks, and R. G. Compton, Amperometric detection of glucose using self-catalytic carbon paste electrodes. *Analyst* 129 (2004):428–431.
18. G. L. Luque, N. F. Ferreyra, and G. A. Rivas, Glucose biosensor based on the use of a carbon nanotube paste electrode modified with metallic particles. *Microchimica Acta* 152 (2006):277–283.
19. L. Ming, X. Xi, and J. Liu, Electrochemically platinized carbon paste enzyme electrodes: A new design of amperometric glucose biosensors. *Biotechnology Letters* 28 (2006):1341–1345.
20. R. Antiochia and L. Gorton, Development of a carbon nanotube paste electrode osmium polymer-mediated biosensor for determination of glucose in alcoholic beverages. *Biosensors & Bioelectronics* 22 (2007):2611–2617.
21. L. Liu, J. F. Song, P. F. Yu, and B. Cui, Voltammetric determination of glucose based on reduction of copper(II)-glucose complex at lanthanum hydroxide nanowire modified carbon paste electrodes. *Talanta* 71 (2007):1842–1848.
22. S. Timur, U. Anik, D. Odaci, and L. Lo Gorton, Development of a microbial biosensor based on carbon nanotube (CNT) modified electrodes. *Electrochemistry Communications* 9 (2007):1810–1815.
23. G. Li, H. Xu, W. J. Huang, Y. Wang, Y. S. Wu, and R. Parajuli, A pyrrole quinoline quinone glucose dehydrogenase biosensor based on screen-printed carbon paste electrodes modified by carbon nanotubes. *Measurement Science & Technology* 19 (2008):1–7.
24. M. Q. Liu, J. H. Jiang, Y. L. Feng, G. L. Shen, and R. Q. Yu, Glucose biosensor based on immobilization of glucose oxidase in electrochemically polymerized polytyramine film and overoxidised polypyrrole film on platinized carbon paste electrode. *Chinese Journal of Analytical Chemistry* 35 (2007):1435–1438.
25. M. M. Musameh, R. T. Kachoosangi, L. Xiao, A. Russell, and R. G. Compton, Ionic liquid-carbon composite glucose biosensor. *Biosensors & Bioelectronics* 24 (2008):87–92.
26. H. Qiu, H. Peng, and R. Liang, Ferrocene-modified Fe_3O_4@SiO_2 magnetic nanoparticles as building blocks for construction of reagentless enzyme-based biosensors. *Electrochemistry Communications* 9 (2007):2734–2738.
27. X. Shangguan, H. F. Zhang, and J. B. Zheng, Direct electrochemistry of glucose oxidase based on its direct immobilization on carbon ionic liquid electrode and glucose sensing. *Electrochemistry Communications* 10 (2008):1140–1143.
28. Q. L. Sheng, Y. Shen, H. F. Zhang, and J. B. Zheng, Neodymium (III) hexacyanoferrate (II) nanoparticles induced by enzymatic reaction and their use in biosensing of glucose. *Electrochimica Acta* 53 (2008):4687–4692.
29. L. Zhu, C. Tian, D. Zhu, and R. Yang, Ordered mesoporous carbon paste electrodes for electrochemical sensing and biosensing. *Electroanalysis* 20 (2008):1128–1134.
30. J. Wang and X. J. Zhang, Needle-type dual microsensor for the simultaneous monitoring of glucose and insulin. *Analytical Chemistry* 73 (2001):844–847.
31. R. Pauliukaite, G. Zhylyak, D. Citterio, and U. E. Spichiger-Keller, L-glutamate biosensor for estimation of the taste of tomato specimens. *Analytical and Bioanalytical Chemistry* 386 (2006):220–227.
32. Y. H. Lin, X. L. Cui, and L. Y. Li, Low-potential amperometric determination of hydrogen peroxide with a carbon paste electrode modified with nanostructured cryptomelane-type manganese oxides. *Electrochemistry Communications* 7 (2005):166–172.
33. A. S. Santos, N. Duran, and L. T. Kubota, Biosensor for H_2O_2 response based on horseradish peroxidase: Effect of different mediators adsorbed on silica gel modified with niobium oxide. *Electroanalysis* 17 (2005):1103–1111.
34. F. Kurusu, S. Koide, I. Karube, and M. Gotoh, Electrocatalytic activity of bamboo-structured carbon nanotubes paste electrode toward hydrogen peroxide. *Analytical Letters* 39 (2006):903–911.
35. F. Kurusu, H. Tsunoda, A. Saito, A. Tomita, A. Kadota, N. Kayahara, I. Karube, and M. Gotoh, The advantage of using carbon nanotubes compared with edge plane pyrolytic graphite as an electrode material for oxidase-based biosensors. *Analyst* 131 (2006):1292–1298.
36. J. V. B. Kozan, R. P. Silva, S. H. P. Serrano, A. W. O. Lima, and L. Angnes, Biosensing hydrogen peroxide utilizing carbon paste electrodes containing peroxidases naturally immobilized on coconut (Cocus nucifera L.) fibers. *Analytica Chimica Acta* 591 (2007):200–207.
37. H. Yu, Q. L. Sheng, and J. Bin Zheng, Preparation, electrochemical behavior and performance of gallium hexacyanoferrate as electrocatalyst of H_2O_2. *Electrochimica Acta*, 52 (2007):4403–4410.
38. Y. H. Yuan and J. P. Li, A biosensor based on immobilizing horseradish peroxidase on Fe_3O_4 nanoparticles. *Chinese Journal of Analytical Chemistry* 35 (2007):1078–1082.
39. H. X. Ju, S. Q. Liu, B. X. Ge, F. Lisdat, and F. W. Scheller, Electrochemistry of cytochrome c immobilized on colloidal gold modified carbon paste electrodes and its electrocatalytic activity. *Electroanalysis* 14 (2002):141–147.

40. C. X. Lei, S. Q. Hu, G. L. Shen, and R. Q. Yu, Immobilization of horseradish peroxidase to a nano-Au monolayer modified chitosan-entrapped carbon paste electrode for the detection of hydrogen peroxide. *Talanta* 59 (2003):981–988.
41. S. Q. Liu and H. X. Ju, Renewable reagentless hydrogen peroxide sensor based on direct electron transfer of horseradish peroxidase immobilized on colloidal gold-modified electrode. *Analytical Biochemistry* 307 (2002):110–116.
42. M. F. Dousikou, M. A. Koupparis, and C. E. Efstathiou, Determination of catalase-like activity in plants based on the amperometric monitoring of hydrogen peroxide consumption using a carbon paste electrode modified with ruthenium(IV) oxide. *Phytochemical Analysis* 17 (2006):255–261.
43. A. Elyacoubi, S. I. M. Zayed, B. Blankert, and J. M. Kauffmann, Development of an amperometric enzymatic biosensor based on gold modified magnetic nanoporous microparticles. *Electroanalysis* 18 (2006):345–350.
44. C. Varodi, D. Gligor, and L. M. Muresan, Carbon paste electrodes modified with methylene blue immobilized on a synthetic zeolite. *Revue Roumaine De Chimie* 52 (2007):81–88.
45. F. C. Wang, R. Yuan, and Y. Q. Chai, A new amperometric biosensor for hydrogen peroxide determination based on HRP-nanogold-PTH-nanogold-modified carbon paste electrodes. *European Food Research and Technology* 225 (2007):95–104.
46. S. F. Wang, H. Y. Xiong, and Q. X. Zeng, Design of carbon paste biosensors based on the mixture of ionic liquid and paraffin oil as a binder for high performance and stabilization. *Electrochemistry Communications* 9 (2007):807–812.
47. H. R. Zare, N. Nasirizadeh, S. M. Golabi, M. Namazian, M. Mazloum-Ardakani, and D. Nematollahi, Electrochemical evaluation of coumestan modified carbon paste electrode: Study on its application as a NADH biosensor in presence of uric acid. *Sensors and Actuators B-Chemical* 114 (2006):610–617.
48. H. R. Zare, N. Nasirizadeh, M. Mazloum-Ardakani, and M. Namazian, Electrochemical properties and electrocatalytic activity of hematoxylin modified carbon paste electrode toward the oxidation of reduced nicotinamide adenine dinucleotide (NADH). *Sensors and Actuators B-Chemical* 120 (2006):288–294.
49. C. Varodi, D. Gligor, A. Maicaneanu, and L. M. Muresan, Carbon paste electrode incorporating calcium-exchanged zeolite modified with Methylene Blue for amperometric detection of NADH. *Revista De Chimie* 58 (2007):890–894.
50. D. J. Weiss, M. Dorris, A. Loh, and L. Peterson, Dehydrogenase based reagentless biosensor for monitoring phenylketonuria. *Biosensors & Bioelectronics* 22 (2007):2436–2441.
51. X. Mao, M. Baloda, A. S. Gurung, Y. H. Lin, and G. D. Liu, Multiplex electrochemical immunoassay using gold nanoparticle probes and immunochromatographic strips. *Electrochemistry Communications* 10 (2008):1636–1640.
52. M. D. Guo, Y. Q. Li, H. X. Guo, X. Q. Wu, and L. F. Fan, Electrochemical detection of short sequences related to the hepatitis B virus using MB on chitosan-modified CPE. *Bioelectrochemistry* 70 (2007):245–249.
53. J. Pan, Voltammetric detection of DNA hybridization using a non-competitive enzyme linked assay. *Biochemical Engineering Journal* 35 (2007):183–190.
54. H. Qi, X. X. Li, P. Chen, and C. X. Zhang, Electrochemical detection of DNA hybridization based on polypyrrole/ss-DNA/multi-wall carbon nanotubes paste electrode. *Talanta* 72 (2007):1030–1035.
55. C. Phanthong and M. Somasundrum, Enhanced sensitivity of 4-chlorophenol detection by use of nitrobenzene as a liquid membrane over a carbon nanotube-modified glassy carbon electrode. *Electroanalysis* 20 (2008):1024–1027.
56. J. K. Xie, K. Jiao, H. Liu, Q. X. Wang, S. F. Liu, and X. Fu, DNA electrochemical sensor based on PbSe nanoparticle for the sensitive detection of CaMV35S transgene gene sequence. *Chinese Journal of Analytical Chemistry* 36 (2008):874–878.
57. D. P. Tang, R. Yuan, and Y. Q. Chai, Electrochemical immunobioanalysis for carcinoma antigen 125 based on thionine and gold nanoparticles-modified carbon paste interface. *Analytica Chimica Acta* 564 (2006):158–165.
58. D. Du, X. X. Xu, S. F. Wang, and A. D. Zhang, Reagentless amperometric carbohydrate antigen 19–9 immunosensor based on direct electrochemistry of immobilized horseradish peroxidase. *Talanta* 71 (2007):1257–1262.
59. D. P. Tang, R. Yuan, and Y. Q. Chai, Magnetic core-shell Fe_3O_4@Ag nanoparticles coated carbon paste interface for studies of carcinoembryonic antigen in clinical immunoassay. *Journal of Physical Chemistry B* 110 (2006):11640–11646.
60. D. P. Tang, R. Yuan, and Y. Q. Chai, Magneto-controlled bioelectronics for the antigen-antibody interaction based on magnetic-core/gold-shell nanoparticles functionalized biomimetic interface. *Bioprocess and Biosystems Engineering* 31 (2008):55–61.
61. D. Y. Tang and B. Y. Xia, Electrochemical immunosensor and biochemical analysis for carcinoembryonic antigen in clinical diagnosis. *Microchimica Acta* 163 (2008):41–48.
62. D. P. Tang, R. Yuan, and Y. Q. Chai, Direct electrochemical immunoassay based on immobilization of protein-magnetic nanoparticle composites on to magnetic electrode surfaces by sterically enhanced magnetic field force. *Biotechnology Letters* 28 (2006):559–565.
63. K. Jiao, Y. Ren, G. Y. Xu, and X. Z. Zhang, Voltammetric study on deoxyribonucleic acid immobilization and hybridization on stearic acid/aluminum ion films and the detection of specific gene related to phosphinothricin acethyltransferase gene from bacillus amyloliquefaciens gene. *Chinese Journal of Analytical Chemistry* 33 (2005):1381–1384.
64. K. Jiao, X. Z. Zhang, G. Y. Xu, and W. Sun, Fabrication and voltammetric characteristics of carbon paste electrode modified by ssDNA/stearic acid. *Acta Chimica Sinica* 63 (2005):1100–1104.
65. G. Y. Xu, K. Jiao, J. S. Fan, and B. Zhang, Immobilizing DNA on cetyltrimethyl ammonium bromide cationic membrane for the detection of specific gene related to NPT II. *Asian Journal of Chemistry* 19 (2007):4161–4172.
66. C. Jiang, T. Yang, K. Jiao, and H. W. Gao, A DNA electrochemical sensor with poly-L-lysine/single-walled carbon nanotubes films and its application for the highly sensitive EIS detection of PAT gene fragment and PCR amplification of NOS gene. *Electrochimica Acta* 53 (2008):2917–2924.
67. R. M. Kotkar and A. K. Srivastava, Voltammetric determination of para-aminobenzoic acid using carbon paste electrode modified with macrocyclic compounds. *Sensors and Actuators B-Chemical* 119 (2006):524–530.

68. K. Cizek, J. Barek, S. Kuecuekkolbasi, M. Ersoez, and J. Zima, Voltammetric determination of 3-aminofluoranthene at different types of carbon electrodes. *Chemia Analityczna* 52 (2007):1003–1013.
69. Y. Zhang and J. B. Zheng, An ionic liquid bulk-modified carbon paste electrode and its electrocatalytic activity toward p-aminophenol. *Chinese Journal of Chemistry* 25 (2007):1652–1657.
70. L. H. Wang and C. C. Wang, Electrochemical oxidation of aminophylline at film platinum electrodes, and its determination in cosmetic and pharmaceutical products. *Microchimica Acta* 153 (2006):95–100.
71. A. I. Stoica, J. Zima, and J. Barek, Differential pulse voltammetric determination of 8-aminoquinoline using carbon paste electrode. *Analytical Letters* 38 (2005):149–156.
72. J. Zima, A. I. Stoica, A. Zitova, and J. Barek, Voltammetric determination of selected aminoquinolines using carbon paste electrode. *Electroanalysis* 18 (2006):158–162.
73. M. Chicharro, E. Bermejo, M. Moreno, A. S. Sanchez, A. Zapardiel, and G. Rivas, Adsorptive stripping voltammetric determination of amitrole at a multi-wall carbon nanotubes paste electdrode. *Electroanalysis* 17 (2005):476–482.
74. A. Radi, Accumulation and trace measurement of chloroquine drug at DNA-modified carbon paste electrode. *Talanta* 65 (2005):271–275.
75. A. I. Stoica, J. Zima, and J. Barek, Voltammetric determination of N,N-dimethyl-4-amino-4′-hydroxyazobenzene at a glassy carbon paste electrode in the presence of N,N-dimethyl-4-aminoazobenzene. *Chemia Analityczna* 52 (2007):201–212.
76. C. Y. Wang and X. Y. Hu, Determination of benorilate in pharmaceutical formulations and its metabolite in urine at carbon paste electrode modified by silver nanoparticles. *Talanta* 67 (2005):625–633.
77. M. Beklova, S. Krizkova, V. Supalkova, R. Mikelova, V. Adam, J. Pikula, and R. Kizek, Determination of bromadiolone in pheasants and foxes by differential pulse voltammetry. *International Journal of Environmental Analytical Chemistry* 87 (2007):459–469.
78. L. Zheng and J. F. Song, Adsorptive voltammetric determination of cisapride on carbon nanotubes paste electrode. *Chinese Journal of Analytical Chemistry* 35 (2007):1018–1020.
79. K. Farhadi, R. H. Yamchi, and R. Sabzi, Electrochemical study of interaction between clozapine and DNA and its analytical application. *Analytical Letters* 40 (2007):1750–1762.
80. N. German, S. Armalis, J. Zima, and J. Barek, Voltammetric determination of fluoren-9-ol and 2-acetamidofluorene using carbon paste electrodes. *Collection of Czechoslovak Chemical Communications* 70 (2005):292–304.
81. P. Fanjul-Bolado, M. B. G. Gonzalez-Garcia, and A. Costa-Garcia, Voltammetric determination of leucoindigo adsorbed on pretreated carbon paste electrodes: Its application in a flow system. *Electroanalysis* 17 (2005):148–154.
82. W. S. Huang, C. H. Yang, W. Y. Qu, and S. H. Zhang, Voltammetric determination of malachite green in fish samples based on the enhancement effect of anionic surfactant. *Russian Journal of Electrochemistry* 44 (2008):946–951.
83. L. Liu and J. F. Song, Voltammetric determination of mefenamic acid at lanthanum hydroxide nanowires modified carbon paste electrodes. *Analytical Biochemistry* 354 (2006):22–27.
84. A. S. Arribas, E. Bermejo, M. Chicharro, and A. Zapardiel, Voltammetric detection of the herbicide metamitron at a bismuth film electrode in nondeaerated solution. *Electroanalysis* 18 (2006):2331–2336.
85. D. Abd El-Hady, M. M. Seliem, R. Gotti, and N. A. El-Maali, Novel voltammetric method for enantioseparation of racemic methotrexate—Determination of its enantiomeric purity in some pharmaceuticals. *Sensors and Actuators B-Chemical* 113 (2006):978–988.
86. O. A. Farghaly, M. A. Taher, A. H. Naggar, and A. Y. El-Sayed, Square wave anodic stripping voltammetric determination of metoclopramide in tablet and urine at carbon paste electrode. *Journal of Pharmaceutical and Biomedical Analysis* 38 (2005):14–20.
87. S. S. Fan, F. Xiao, L. Q. Liu, F. Q. Zhao, and B. Z. Zeng, Sensitive voltammetric response of methylparathion on single-walled carbon nanotube paste coated electrodes using ionic liquid as binder. *Sensors and Actuators B-Chemical* 132 (2008):34–39.
88. M. Citak, S. Yilmaz, Y. Dilgin, G. Turker, S. Yagmur, H. Erdugan, and N. Erdugan, Osteryoung square wave voltammetric determination of phenazopyridine hydrochloride in human urine and tablet dosage forms based on electrochemical reduction at carbon paste electrode. *Current Pharmaceutical Analysis* 3 (2007):141–145.
89. A. Abbaspour and R. Mirzajani, Electrochemical monitoring of piroxicam in different pharmaceutical forms with multi-walled carbon nanotubes paste electrode. *Journal of Pharmaceutical and Biomedical Analysis* 44 (2007):41–48.
90. S. Shahrokhian and M. J. Jannat-Rezvani, Voltammetric studies of propylthiouracil at a carbon-paste electrode modified with cobalt(II)-4-chlorosalophen: Application to voltammetric determination in pharmaceutical and clinical preparations. *Microchimica Acta* 151 (2005):73–79.
91. R. M. Kotkar, P. B. Desai, and A. K. Srivastava, Behavior of riboflavin on plain carbon paste and aza macrocycles based chemically modified electrodes. *Sensors and Actuators B-Chemical* 124 (2007):90–98.
92. J. Petrlova, M. Masarik, D. Potesil, V. Adam, L. Trnkova, and R. Kizek, Zeptomole detection of streptavidin using carbon paste electrode and square-wave voltammetry. *Electroanalysis* 19 (2007):1177–1182.
93. L. H. Wang, H. J. Tien, and C. Y. Tai, Use of a disposable modified carbon paste electrode for liquid chromatography-amperometric detection of theophylline and three metabolites in human serum. *Journal of the Chinese Chemical Society* 53 (2006):1523–1530.
94. L. Zheng and J. F. Song, Voltammetric behavior of urapidil and its determination at multi-wall carbon nanotube paste electrode. *Talanta* 73 (2007):943–947.
95. M. F. Bergamini, M. F. S. Teixeira, E. R. Dockal, N. Bocchi, and E. T. G. Cavalheiro, Evaluation of different voltammetric techniques in the determination of amoxicillin using a carbon paste electrode modified with [N,N′-ethylenebis(salicylideneaminato)] oxovanadium(IV). *Journal of the Electrochemical Society* 153 (2006):E94–E98.
96. A. Nezamzadeh, M. K. Amini, and H. Faghihian, Square-wave voltammetric determination of ascorbic acid based on its

electrocatalytic oxidation at zeolite-modified carbon-paste electrodes. *International Journal of Electrochemical Science* 2 (2007):583–594.
97. Q. Zhuang, J. H. Chen, J. Chen, and X. H. Lin, Electrocatalytical properties of bergenin on a multi-wall carbon nanotubes modified carbon paste electrode and its determination in tablets. *Sensors and Actuators B-Chemical* 128 (2008):500–506.
98. W. S. Huang, Voltammetric determination of bisphenol a using a carbon paste electrode based on the enhancement effect of cetyltrimethylammonium bromide (CTAB). *Bulletin of the Korean Chemical Society* 26 (2005):1560–1564.
99. H. C. de Melo, A. P. D. Seleghim, W. L. Polito, O. Fatibello-Filho, and I. C. Vieira, Simultaneous differential pulse voltammetric determination of l-dopa and Carbidopa in pharmaceuticals using a carbon paste electrode modified with lead dioxide immobilized in a polyester resin. *Journal of the Brazilian Chemical Society* 18 (2007):797–803.
100. D. El-Hady and N. El-Maal, Selective square wave voltammetric determination of (+)-catechin in commercial tea samples using beta-cyclodextrin modified carbon paste electrode. *Microchimica Acta* 161 (2008):225–231.
101. W. Sun, Y. Z. Li, M. X. Yang, J. Li, and K. Jiao, Application of carbon ionic liquid electrode for the electrooxidative determination of catechol. *Sensors and Actuators B-Chemical* 133 (2008):387–392.
102. D. V. Chernyshov, N. V. Shuedene, E. R. Antipova, and I. V. Pletnev, Ionic liquid-based miniature electrochemical sensors for the voltammetric determination of catecholamines. *Analytica Chimica Acta* 621 (2008):178–184.
103. H. Y. Yang, X. J. Zheng, W. S. Huang, and K. B. Wu, Modification of montmorillonite with cationic surfactant and application in electrochemical determination of 4-chlorophenol. *Colloids and Surfaces B-Biointerfaces* 65 (2008):281–284.
104. L. Liu, J. F. Song, Y. Peng-Fei, and B. Cui, Enhancement action of lanthanum hydroxide nanowire towards voltammetric response of Dobesilate and its application. *Chinese Journal of Chemistry* 26 (2008):220–224.
105. J. B. Zheng, Y. Zhang, and P. P. Yang, An ionic liquid-type carbon paste electrode for electrochemical investigation and determination of calcium dobesilate. *Talanta* 73 (2007):920–925.
106. M. Kooshki and E. Shams, Selective response of dopamine in the presence of ascorbic acid on carbon paste electrode modified with titanium phosphated silica gel. *Analytica Chimica Acta* 587 (2007):110–115.
107. J. B. Zheng and X. L. Zhou, Sodium dodecyl sulfate-modified carbon paste electrodes for selective determination of dopamine in the presence of ascorbic acid. *Bioelectrochemistry* 70 (2007):408–415.
108. G. Alarcon-Angeles, S. Corona-Avendano, M. Palomar-Pardave, A. Rojas-Hernandez, M. Romero-Romo, and M. Ramirez-Silva, Selective electrochemical determination of dopamine in the presence of ascorbic acid using sodium dodecyl sulfate micelles as masking agent. *Electrochimica Acta* 53 (2008):3013–3020.
109. Z. H. Yan, J. N. Li, J. J. Fei, X. Mao, P. Gao, and Y. L. Ding, Study on the adsorptive catalytic voltammetry of emodin at a carbon paste electrode. *Analytical Letters* 38 (2005):1641–1650.
110. C. Yang and P. Xie, Studies on enhanced oxidation of estrone and its voltammetric determination at carbon paste electrode in the presence of cetyltrimethylammonium bromide. *Bulletin of the Korean Chemical Society* 28 (2007):1729–1734.
111. C. Y. Li, Voltammetric determination of ethinylestradiol at a carbon paste electrode in the presence of cetyl pyridine bromine. *Bioelectrochemistry* 70 (2007):263–268.
112. A. E. Radi, N. Abd-Elghany, and T. Wahdan, Electrochemical study of the antineoplastic agent etoposide at carbon paste electrode and its determination in spiked human serum by differential pulse voltammetry. *Chemical & Pharmaceutical Bulletin* 55 (2007):1379–1382.
113. G. J. Volikakis and C. E. Efstathiou, Fast screening of total flavonols in wines, tea-infusions and tomato juice by flow injection/adsorptive stripping voltammetry. *Analytica Chimica Acta* 551 (2005):124–131.
114. W. Sun, Q. Jiang, M. X. Yang, and K. Jiao, Electrochemical behaviors of hydroquinone on a carbon paste electrode with ionic liquid as binder. *Bulletin of the Korean Chemical Society* 29 (2008):915–920.
115. Z. D. Chen and M. Hojo, Determination of phenol using a carbon paste electrode modified with overoxidized polypyrrole/polyvinylpyrrolidone films. *Bunseki Kagaku* 56 (2007):669–673.
116. Y. L. Ding, J. Li, and J. Fei, Adsorptive catalytic voltammetry of physcion in the presence of dissolved oxygen at a carbon paste electrode. *Microchimica Acta* 150 (2005):125–130.
117. P. B. Desai, R. M. Kotkar, and A. K. Srivastava, Electrochemical behaviour of pyridoxine hydrochloride (vitamin B-6) at carbon paste electrode modified with crown ethers. *Journal of Solid State Electrochemistry* 12 (2008):1067–1075.
118. O. A. Farghaly, Voltammetric determination of quercetin in urine at carbon paste electrode. *Analytical Letters* 38 (2005):2247–2258.
119. J. B. He, X. Q. Lin, and J. Pan, Multi-wall carbon nanotube paste electrode for adsorptive stripping determination of quercetin: A comparison with graphite paste electrode via voltammetry and chronopotentiometry. *Electroanalysis* 17 (2005):1681–1686.
120. X. Q. Lin, J. B. He, and Z. G. Zha, Simultaneous determination of quercetin and rutin at a multi-wall carbon-nanotube paste electrodes by reversing differential pulse voltammetry. *Sensors and Actuators B-Chemical* 119 (2006):608–614.
121. P. Xiao, F. Q. Zhao, and B. Z. Zeng, Voltammetric determination of quercetin at a multi-walled carbon nanotubes paste electrode. *Microchemical Journal* 85 (2007):244–249.
122. H. F. Zhang, L. F. Xu, and J. B. Zheng, Anodic voltammetric behavior of resveratrol and its electroanalytical determination in pharmaceutical dosage form and urine. *Talanta* 71 (2007):19–24.
123. A. C. Franzoi, A. Spinelli, and L. C. Vieira, Rutin determination in pharmaceutical formulations using a carbon paste electrode modified with poly(vinylpyrrolidone). *Journal of Pharmaceutical and Biomedical Analysis* 47 (2008):973–977.
124. H. G. Lin, G. Li, and K. B. Wu, Electrochemical determination of Sudan I using montmorillonite calcium modified carbon paste electrode. *Food Chemistry* 107 (2008):531–536.
125. A. G. Angelikaki and S. T. Girousi, Sensitive detection of tetracycline, oxytetracycline, and chlortetracycline in the presence of copper(II) ions using a DNA-modified carbon paste electrode. *Chemia Analityczna* 53 (2008):445–454.

126. J. Zima, M. Cienciala, J. Barek, and J. C. Moreira, Determination of thymol using HPLC-ED with glassy carbon paste electrode. *Chemia Analityczna* 52 (2007):1049–1057.
127. S. Y. Ly, Voltammetric analysis of DL-alpha-tocopherol with a paste electrode. *Journal of the Science of Food and Agriculture* 88 (2008):1272–1276.
128. X. F. Yang, F. Wang, and S. S. Hu, The electrochemical oxidation of troxerutin and its sensitive determination in pharmaceutical dosage forms at PVP modified carbon paste electrode. *Colloids and Surfaces B-Biointerfaces* 52 (2006):8–13.
129. V. Adam, R. Mikelova, J. Hubalek, P. Hanustiak, M. Beklova, P. Hodek, A. Horna, L. Trnkova, M. Stiborova, L. Zeman, and R. Kizek, Utilizing of square wave voltammetry to detect flavonoids in the presence of human urine. *Sensors* 7 (2007):2402–2418.
130. M. A. El Ries, A. A. Wassel, N. T. A. Ghani, and M. A. El-Shall, Electrochemical adsorptive behavior of some fluoroquinolones at carbon paste electrode. *Analytical Sciences* 21 (2005):1249–1254.
131. M. A. N. El-Ries, G. G. Mohamed, and A. K. Attia, Electrochemical determination of the antidiabetic drug repaglinide. *Yakugaku Zasshi-Journal of the Pharmaceutical Society of Japan* 128 (2008):171–177.
132. N. Liu, W. Gao, and J. F. Song, Catalytic adsorptive stripping voltammetry at a carbon paste electrode for the determination of amiodarone. *Chinese Journal of Chemistry* 24 (2006):1657–1661.
133. X. X. Guo, Z. J. Song, X. J. Tian, and J. F. Song, Single-sweep voltammetric determination of tamoxifen at carbon paste electrode. *Analytical Letters* 41 (2008):1225–1235.
134. S. Shahrokhian and M. Amiri, Multi-walled carbon nanotube paste electrode for selective voltammetric detection of isoniazid. *Microchimica Acta* 157 (2007):149–158.
135. X. J. Tian, J. F. Song, X. J. Luan, Y. Y. Wang, and Q. Z. Shi, Determination of metformin based on amplification of its voltammetric response by a combination of molecular wire and carbon nanotubes. *Analytical and Bioanalytical Chemistry* 386 (2006):2081–2086.
136. X. J. Tian and J. F. Song, Catalytic action of copper (II) ion on electrochemical oxidation of metformine and voltammetric determination of metformine in pharmaceuticals. *Journal of Pharmaceutical and Biomedical Analysis* 44 (2007):1192–1196.
137. S. Shahrokhian and L. Fotouhi, Carbon paste electrode incorporating multi-walled carbon nanotube/cobalt salophen for sensitive voltammetric determination of tryptophan. *Sensors and Actuators B-Chemical* 123 (2007):942–949.
138. S. Shahrokhian and H. R. Zare-Mehrjardi, Simultaneous voltammetric determination of uric acid and ascorbic acid using a carbon-paste electrode modified with malt-walled carbon Nanotubes/Nafion and Cobalt(II)-nitrosalophen. *Electroanalysis* 19 (2007):2234–2242.
139. F. Xiao, C. P. Ruan, J. W. Li, L. H. Liu, F. Q. Zhao, and B. Z. Zeng, Voltammetric determination of xanthine with a single-walled carbon nanotube-ionic liquid paste modified glassy carbon electrode. *Electroanalysis* 20 (2008):361–366.
140. S. Q. Dong, S. Zhang, L. Z. Chi, P. A. He, Q. J. Wang, and Y. Z. Fang, Electrochemical behaviors of amino acids at multiwall carbon nanotubes and Cu_2O modified carbon paste electrode. *Analytical Biochemistry* 381 (2008):199–204.
141. S. Q. Dong, S. Zhang, X. Cheng, P. G. He, Q. J. Wang, and Y. Z. Fang, Simultaneous determination of sugars and ascorbic acid by capillary zone electrophoresis with amperometric detection at a carbon paste electrode modified with polyethylene glycol and Cu_2O. *Journal of Chromatography A* 1161 (2007):327–333.
142. X. Cheng, Q. J. Wang, S. Zhang, W. D. Zhang, P. G. He, and Y. Z. Fang, Determination of four kinds of carbamate pesticides by capillary zone electrophoresis with amperometric detection at a polyamide-modified carbon paste electrode. *Talanta* 71 (2007):1083–1087.
143. X. Cheng, S. Zhang, H. Y. Zhang, Q. J. Wang, P. G. He, and Y. Z. Fang, Determination of carbohydrates by capillary zone electrophoresis with amperometric detection at a nano-nickel oxide modified carbon paste electrode. *Food Chemistry* 106 (2008):830–835.
144. L. Agui, C. Pena-Farfal, P. Yanez-Sedeno, and J. M. Pingarron, Electrochemical determination of homocysteine at a gold nanoparticle-modified electrode. *Talanta* 74 (2007):412–420.
145. L. Liu, J. F. Song, P. F. Yu, and B. Cui, A novel electrochemical sensing system for inosine and its application for inosine determination in pharmaceuticals and human serum. *Electrochemistry Communications* 8 (2006):1521–1526.
146. R. Kizek, M. Masarik, K. J. Kramer, D. Potesil, M. Bailey, J. A. Howard, B. Klejdus, R. Mikelova, V. Adam, L. Trnkova, and F. Jelen, An analysis of avidin, biotin and their interaction at attomole levels by voltammetric and chromatographic techniques. *Analytical and Bioanalytical Chemistry* 381 (2005):1167–1178.
147. Y. F. Zhuang, D. M. Zhang, and H. X. Ju, Sensitive determination of heroin based on electrogenerated chemiluminescence of tris(2,2′-bipyridyl)ruthenium(II) immobilized in zeolite Y modified carbon paste electrode. *Analyst* 130 (2005):534–540.
148. Y. Xue, X. W. Zheng, and K. G. Han, Electrogenerated chemiluminescence detecting sodium dodecyl benzene sulfonate based on its ion-associated complex effect. *Chinese Journal of Analytical Chemistry* 35 (2007):370–374.
149. Y. T. Chen, Z. Y. Lin, J. J. Sun, and G. N. Chen, A new electrochemiluminescent detection system equipped with an electrically heated carbon paste electrode for CE. *Electrophoresis* 28 (2007):3250–3259.
150. S. Shahrokhian, Z. Kamalzadeh, A. Bezzaatpour, and D. M. Boghaei, Differential pulse voltammetric determination of N-acetylcysteine by the electrocatalytic oxidation at the surface of carbon nanotube-paste electrode modified with cobalt salophen complexes. *Sensors and Actuators B-Chemical* 133 (2008):599–606.
151. M. Aklilu, M. Tessema, and M. Redi-Abshiro, Indirect voltammetric determination of caffeine content in coffee using 1,4-benzoquinone modified carbon paste electrode. *Talanta* 76 (2008):742–746.
152. E. S. Jamasbi, A. Rouhollahi, S. Shahrokhian, S. Haghgoo, and S. Aghajani, The electrocatalytic examination of cephalosporins at carbon paste electrode modified with CoSalophen. *Talanta* 71 (2007):1669–1674.
153. K. Sirisha, S. Mallipattu, and S. R. J. Reddy, Differential pulse adsorptive stripping voltammetric determination of chlorpyrifos at a sepiolite modified carbon paste electrode. *Analytical Letters* 40 (2007):1939–1950.

154. S. H. Zhang and S. Wei, Electrochemical determination of ciprofloxacin based on the enhancement effect of sodium dodecyl benzene sulfonate. *Bulletin of the Korean Chemical Society* 28 (2007):543–546.
155. H. Yi and C. Li, Voltammetric determination of ciprofloxacin based on the enhancement effect of cetyltrimethylammonium bromide (CTAB) at carbon paste electrode. *Russian Journal of Electrochemistry* 43 (2007):1377–1381.
156. L. H. Wang, S. Y. Jiang, and Y. Z. Lan, Voltammetric behavior of coumarins and psoralens at a carbon fiber ultramicroelectrode and their determination in citrus essential oils. *Bulletin of Electrochemistry* 20 (2004):445–451.
157. J. B. Raoof, R. Ojani, and H. Beitollahi, L-cysteine voltammetry at a carbon paste electrode bulk-modified with ferrocenedicarboxylic acid. *Electroanalysis* 19 (2007):1822–1830.
158. L. Baldrianova, P. Agrafiotou, I. Svancara, K. Vytras, and S. Sotiropouios, The determination of cysteine at Bi-powder carbon paste electrodes by cathodic stripping voltammetry. *Electrochemistry Communications* 10 (2008):918–921.
159. C. Y. Li, Electrochemical determination of dipyridamole at a carbon paste electrode using cetyltrimethylammonium bromide as enhancing element. *Colloids and Surfaces B-Biointerfaces* 55 (2007):77–83.
160. M. F. S. Teixeira, L. H. Marcolino-Junior, O. Fatibello, E. R. Dockal, and E. T. G. Cavalheiro, Voltammetric determination of dipyrone using a N,N′-ethylenebis-(salicylideneaminato)oxovanadium(IV) modified carbon-paste electrode. *Journal of the Brazilian Chemical Society* 15 (2004):803–808.
161. M. A. El Mhammedi, M. B. Akasse, and A. Chtaini, Investigation of square wave voltammetric detection of diquat at carbon paste electrode impregnated with Ca-10(PO4)(6)F-2: Application in natural water samples. *Materials Chemistry and Physics* 109 (2008):519–525.
162. H. El Bakouri, J. M. Palacios-Santander, L. Cubillana-Aguilera, A. Ouassini, I. Naranjo-Rodriguez, and J. de Cisneros, Electrochemical analysis of endosulfan using a C18-modified carbon-paste electrode. *Chemosphere* 60 (2005):1565–1571.
163. T. M. Reddy, K. Balaji, and S. J. Reddy, Voltammetric behavior of some fluorinated quinolone antibacterial agents and their differential pulse voltammetric determination in drug formulations and urine samples using a beta-cyclodextrin-modified carbon-paste electrode. *Journal of Analytical Chemistry* 62 (2007):168–175.
164. W. Huang, S. Zhang, and Y. Wu, Electrochemical behavior and detection of guanine using a sodium montmorillonite-modified carbon paste electrode. *Russian Journal of Electrochemistry* 42 (2006):153–156.
165. I. Stempkowska, M. Liga, J. Jasnowska, J. Langer, and M. Filipiak, Electrochemical response of oligonucleotides on carbon paste electrode. *Bioelectrochemistry* 70 (2007):488–494.
166. S. Shahrokhian and M. Ghalkhani, Voltammetric determination of methimazole using a carbon paste electrode modified with a Schiff base complex of cobalt. *Electroanalysis* 20 (2008):1061–1066.
167. N. Priyantha, A. Navaratne, S. Weliwegamage, and C. B. Ekanayake, Determination of MCPA through electrocatalysis by manganese species. *International Journal of Electrochemical Science* 2 (2007):433–443.
168. P. Babula, D. Huska, P. Hanustiak, J. Baloun, S. Krizkova, V. Adam, J. Hubalek, L. Havel, M. Zemlicka, A. Horna, M. Beklova, and R. Kizek, Flow injection analysis coupled with carbon electrodes as the tool for analysis of naphthoquinones with respect to their content and functions in biological samples. *Sensors* 6 (2006):1466–1482.
169. C. Aki, S. Yilmaz, Y. Dilgin, S. Yagmur, and E. Suren, Electrochemical study of natamycin—.analytical application to pharmaceutical dosage forms by differential pulse voltammetry. *Pharmazie* 60 (2005):747–750.
170. R. M. Kotkar and A. K. Srivastava, Electrochemical behavior of nicotinamide using carbon paste electrode modified with macrocyclic compounds. *Journal of Inclusion Phenomena and Macrocyclic Chemistry* 60 (2008):271–279.
171. L. G. Shaidarova, I. A. Chelnokova, A. V. Gedmina, G. K. Budnikov, S. A. Ziganshina, A. A. Mozhanova, and A. A. Bukharaev, Electrooxidation of oxalic acid at a carbon-paste electrode with deposited palladium nanoparticles. *Journal of Analytical Chemistry* 61 (2006):375–381.
172. M. A. El Mhammedi, M. Bakasse, and A. Chtaini, Electrochemical studies and square wave voltammetry of paraquat at natural phosphate modified carbon paste electrode. *Journal of Hazardous Materials* 145 (2007):1–7.
173. M. A. El Mhanunedi, M. Bakasse, and A. Chtaini, Square-wave voltammetric determination of paraquat at carbon paste electrode modified with hydroxyapatite. *Electroanalysis* 19 (2007):1727–1733.
174. M. A. El Mhammedi, M. Bakasse, R. Bachirat, and A. Chtaini, Square wave voltammetry for analytical determination of paraquat at carbon paste electrode modified with fluoroapatite. *Food Chemistry* 110 (2008):1001–1006.
175. A. Radi, M. A. El Ries, and S. Kandil, Spectroscopic and voltammetric studies of Pefloxacin bound to calf thymus double-stranded DNA. *Analytical and Bioanalytical Chemistry* 381 (2005):451–455.
176. J. B. Raoof, R. Ojani, and F. Chekin, Electrochemical analysis of D-penicillamine using a carbon paste electrode modified with ferrocene carboxylic acid. *Electroanalysis* 19 (2007):1883–1889.
177. J. B. Raoof, R. Ojani, F. Chekin, and R. Hossienzadeh, Carbon paste electrode incorporating 1-[4-(ferrocenyl ethynyl) phenyl]-1-ethanone for voltammetric determination of D-penicillamine. *International Journal of Electrochemical Science* 2 (2007):848–860.
178. X. J. Tian and J. F. Song, Voltammetric behavior and determination of tanshinone II A at carbon paste electrode. *Chinese Journal of Analytical Chemistry* 34 (2006):1283–1286.
179. H. S. Guo, N. Y. He, S. X. Ge, D. Yang, and J. N. Zhang, MCM-41 mesoporous material modified carbon paste electrode for the determination of cardiac troponin I by anodic stripping voltammetry. *Talanta* 68 (2005):61–66.
180. H. S. Guo, N. Y. He, S. X. Ge, D. Yang, and J. N. Zhang, Molecular sieves materials modified carbon paste electrodes for the determination of cardiac troponin I by anodic stripping voltammetry. *Microporous and Mesoporous Materials* 85 (2005):89–95.
181. J. B. Raoof, R. Ojani, and H. Karimi-Maleh, Carbon paste electrode incorporating 1-[4-(ferrocenyl ethynyl) phenyl]-1-ethanone for electrocatalytic and voltammetric determination of tryptophan. *Electroanalysis* 20 (2008):1259–1262.

182. T. J. Castilho, M. D. T. Sotomayor, and L. T. Kubota, Amperometric biosensor based on horseradish peroxidase for biogenic amine determinations in biological samples. *Journal of Pharmaceutical and Biomedical Analysis* 37 (2005):785–791.
183. V. S. Bezerra, J. L. De Lima, M. Montenegro, A. N. Araujo, and V. L. Da Silva, Flow-injection amperometric determination of dopamine in pharmaceuticals using a polyphenol oxidase biosensor obtained from soursop pulp. *Journal of Pharmaceutical and Biomedical Analysis* 33 (2003):1025–1031.
184. S. A. Miscoria, G. D. Barrera, and G. A. Rivas, Enzymatic biosensor based on carbon paste electrodes modified with gold nanoparticles and polyphenol oxidase. *Electroanalysis* 17 (2005):1578–1582.
185. J. B. Raoof, R. Ojani, and A. Kiani, Apple-modified carbon paste electrode: A biosensor for selective determination of dopamine in pharmaceutical formulations. *Bulletin of Electrochemistry* 21 (2005):223–228.
186. M. K. Amini, S. Shahrokhian, S. Tangestaninejad, and V. Mirkhani, Iron(II) phthalocyanine-modified carbon-paste electrode for potentiometric detection of ascorbic acid. *Analytical Biochemistry* 290 (2001):277–282.
187. S. Shahrokhian and M. Ghalkhani, Simultaneous voltammetric detection of ascorbic acid and uric acid at a carbon-paste modified electrode incorporating thionine-nafion ion-pair as an electron mediator. *Electrochimica Acta* 51 (2006):2599–2606.
188. Q. P. Yan, F. Q. Zhao, G. Z. Li, and B. Z. Zeng, Voltammetric determination of uric acid with a glassy carbon electrode coated by paste of multiwalled carbon nanotubes and ionic liquid. *Electroanalysis* 18 (2006):1075–1080.
189. R. F. Dutra, K. A. Moreira, M. I. P. Oliveira, A. N. Araujo, M. Montenegro, J. L. L. Filho, and V. L. Silva, An inexpensive biosensor for uric acid determination in human serum by flow-injection analysis. *Electroanalysis* 17 (2005):701–705.
190. M. Pohanka and P. Zboril, Amperometric biosensor for D-lactate assay. *Food Technology and Biotechnology* 46 (2008):107–110.
191. X. X. Wu, B. J. Van Wie, and D. A. Kidwell, An enzyme electrode for amperometric measurement of D-amino acid. *Biosensors & Bioelectronics* 20 (2004):879–886.
192. I. de Oliveira, I. C. Vieira, K. O. Lupetti, O. Fatibello-Filho, V. T. de Favere, and M. C. M. Laranjeira, Biosensor based on chitosan biopolymer and crude extract of ginger (Zingiber officinales rosc.) for the determination of hydroquinone in wastewater of photographic process. *Analytical Letters* 37 (2004):3111–3127.
193. I. de Oliveira, S. C. Fernandes, and I. C. Vieira, Development of a biosensor based on gilo peroxidase immobilized on chitosan chemically crosslinked with epichlorohydrin for determination of rutin. *Journal of Pharmaceutical and Biomedical Analysis* 41 (2006):366–372.
194. Y. Lei, P. Mulchandani, J. Wang, W. Chen, and A. Mulchandani, Highly sensitive and selective amperometric microbial biosensor for direct determination of p-nitrophenyl-substituted organophosphate nerve agents. *Environmental Science & Technology* 39 (2005):8853–8857.
195. P. Mulchandani, C. M. Hangarter, Y. Lei, W. Chen, and A. Mulchandani, Amperometric microbial biosensor for p-nitrophenol using Moraxella sp.-modified carbon paste electrode. *Biosensors & Bioelectronics* 21 (2005):523–527.
196. S. H. Chough, A. Mulchandani, P. Mulchandani, W. Chen, J. Wang, and K. R. Rogers, Organophosphorus hydrolase-based amperometric sensor: Modulation of sensitivity and substrate selectivity. *Electroanalysis* 14 (2002):273–276.
197. Y. Lei, P. Mulchandani, W. Chen, and A. Mulchandani, Biosensor for direct determination of fenitrothion and EPN using recombinant Pseudomonas putida JS444 with surface-expressed organophosphorous hydrolase. 2. Modified carbon paste electrode. *Applied Biochemistry and Biotechnology* 136 (2007):243–250.
198. P. Mulchandani, W. Chen, A. Mulchandani, J. Wang, and L. Chen, Amperometric microbial biosensor for direct determination of organophosphate pesticides using recombinant microorganism with surface expressed organophosphorus hydrolase. *Biosensors & Bioelectronics* 16 (2001):433–437.
199. Y. Lei, P. Mulchandani, W. Chen, J. Wang, and A. Mulchandani, Arthrobacter sp JS443-based whole cell amperometric biosensor for p-nitrophenol. *Electroanalysis* 16 (2004):2030–2034.
200. A. A. Ciucu, C. Negulescu, and R. P. Baldwin, Detection of pesticides using an amperometric biosensor based on ferophthalocyanine chemically modified carbon paste electrode and immobilized bienzymatic system. *Biosensors & Bioelectronics* 18 (2003):303–310.
201. Y. T. Kong, S. Imabayashi, K. Kano, T. Ikeda, and T. Kakiuchi, Peroxidase-based amperometric sensor for the determination of total phenols using two-stage peroxidase reactions. *American Journal of Enology and Viticulture* 52 (2001):381–385.
202. Z. M. Liu, Y. L. Liu, H. F. Yang, Y. Yang, G. L. Shen, and R. Q. Yu, A phenol biosensor based on immobilizing tyrosinase to modified core-shell magnetic nanoparticles supported at a carbon paste electrode. *Analytica Chimica Acta* 533 (2005):3–9.
203. S. Q. Liu, J. H. Yu, and H. X. Ju, Renewable phenol biosensor based on a tyrosinase-colloidal gold modified carbon paste electrode. *Journal of Electroanalytical Chemistry* 540 (2003):61–67.
204. L. G. Sokolovskaya, L. V. Sigolaeva, A. V. Eremenko, I. V. Gachok, G. F. Makhaeva, N. N. Strakhova, V. V. Malygin, R. J. Richardson, and I. N. Kurochkin, Improved electrochemical analysis of neuropathy target esterase activity by a tyrosinase carbon paste electrode modified by 1-methoxyphenazine methosulfate. *Biotechnology Letters* 27 (2005):1211–1218.
205. N. Miyanishi, N. Sato, S. I. Nakakita, W. Sumiyoshi, K. Morimoto, H. Okuma, M. Tokuda, K. Lzumori, E. Watanabe, and J. Hirabayashi, Development of an amperometric flow analysis sensor for specific detection of D-psicose. *Biosensors & Bioelectronics* 23 (2008):1347–1352.
206. S. Y. Ly, C. H. Lee, Y. S. Jung, O. M. Kwon, J. E. Lee, S. M. Baek, and K. J. Kwak, Simultaneous diagnostic assay of catechol and caffeine using an in vivo implanted neuro sensor. *Bulletin of the Korean Chemical Society* 29 (2008):1742–1746.
207. J. P. Li and H. D. Gao, A renewable potentiometric immunosensor based on Fe_3O_4 nanoparticles immobilized anti-IgG. *Electroanalysis* 20 (2008):881–887.
208. M. D. P. Sotomayor, I. L. T. Dias, G. D. Neto, and L. T. Kubota, Application of (2,2′: 6′,2′-terpyridyl) copper(II) chloride complex in sensor construction for benzoyl peroxide determination in pharmaceutical samples. *Analytica Chimica Acta* 494 (2003):199–205.

209. D. H. Yu, B. Blankert, E. Bodoki, S. Bollo, J. C. Vire, R. Sandulescu, A. Nomura, and J. M. Kauffmann, Amperometric biosensor based on horseradish peroxidase-immobilised magnetic microparticles. *Sensors and Actuators B-Chemical* 113 (2006):749–754.
210. D. H. Yu, B. Blankert, and J. M. Kauffmann, Development of amperometric horseradish peroxidase based biosensors for clozapine and for the screening of thiol compounds. *Biosensors & Bioelectronics* 22 (2007):2707–2711.
211. T. H. Huang, T. Kuwana, and A. Warsinke, Analysis of thiols with tyrosinase-modified carbon paste electrodes based on blocking of substrate recycling. *Biosensors & Bioelectronics* 17 (2002):1107–1113.
212. M. K. Amini, J. H. Khorasani, S. S. Khaloo, and S. Tangestaninejad, Cobalt(II) salophen-modified carbon-paste electrode for potentiometric and voltammetric determination of cysteine. *Analytical Biochemistry* 320 (2003):32–38.
213. M. F. S. Teixeira, E. R. Dockal, and E. T. G. Cavalheiro, Sensor for cysteine based on oxovanadium(IV) complex of Salen modified carbon paste electrode. *Sensors and Actuators B-Chemical* 106 (2005):619–625.
214. P. R. Lima, W. J. R. Santos, R. D. S. Luz, F. S. Damos, A. B. Oliveira, M. O. F. Goulart, and L. T. Kubota, An amperometric sensor based on electrochemically triggered reaction: Redox-active Ar-NO/Ar-NHOH from 4-nitrophthalonitrile-modified electrode for the low voltage cysteine detection. *Journal of Electroanalytical Chemistry* 612 (2008):87–96.
215. R. I. Stefan, J. F. van Staden, C. Bala, and H. Y. Aboul-Enein, Online assay of the S-enantiomers of enalapril, ramipril and pentopril using a sequential injection analysis/amperometric biosensor system. *Journal of Pharmaceutical and Biomedical Analysis* 36 (2004):889–892.
216. M. B. Santiago, M. M. Velez, S. Borrero, A. Diaz, C. A. Casillas, C. Hofmann, A. R. Guadalupe, and J. L. Colon, NADH electrooxidation using bis(1,10-phenanthroline-5,6-dione) (2,2′-bipyridine) ruthenium(II)-exchanged zirconium phosphate modified carbon paste electrodes. *Electroanalysis* 18 (2006):559–572.
217. L. Agui, J. Manso, P. Yanez-Sedeno, and J. M. Pingarron, Amperometric biosensor for hypoxanthine based on immobilized xanthine oxidase on nanocrystal gold-carbon paste electrodes. *Sensors and Actuators B-Chemical* 113 (2006):272–280.
218. Z. Y. Lin, J. J. Sun, J. H. Chen, L. Guo, Y. T. Chen, and G. N. Chen, Electrochemiluminescent biosensor for hypoxanthine based on the electrically heated carbon paste electrode modified with xanthine oxidase. *Analytical Chemistry* 80 (2008):2826–2831.
219. A. Rittmannsberger, W. Likussar, and A. Michelitsch, Development of an enzyme-modified carbon paste electrode for determining inhibitors of lipoxygenase. *Biosensors & Bioelectronics* 21 (2005):655–660.
220. F. C. Gong, X. B. Zhang, C. C. Guo, G. L. Shen, and R. Q. Yu, Amperometric metronidazole sensor based on the supermolecular recognition by metalloporphyrin incorporated in carbon paste electrode. *Sensors* 3 (2003):91–100.
221. Y. H. Yang, M. H. Yang, H. Wang, L. Tang, G. L. Shen, and R. Q. Yu, Inhibition biosensor for determination of nicotine. *Analytica Chimica Acta*, 509 (2004):151–157.
222. L. Liu, J. F. Song, P. F. Yu, and B. Cui, Sensing system integrating lanthanum hydroxide nanowires with Copper(II) ion for uracil and its application. *Analytical Letters* 40 (2007):2562–2573.
223. P. Tomcik, C. E. Banks, T. J. Davies, and R. G. Compton, A self-catalytic carbon paste electrode for the detection of vitamin B-12. *Analytical Chemistry* 76 (2004):161–165.