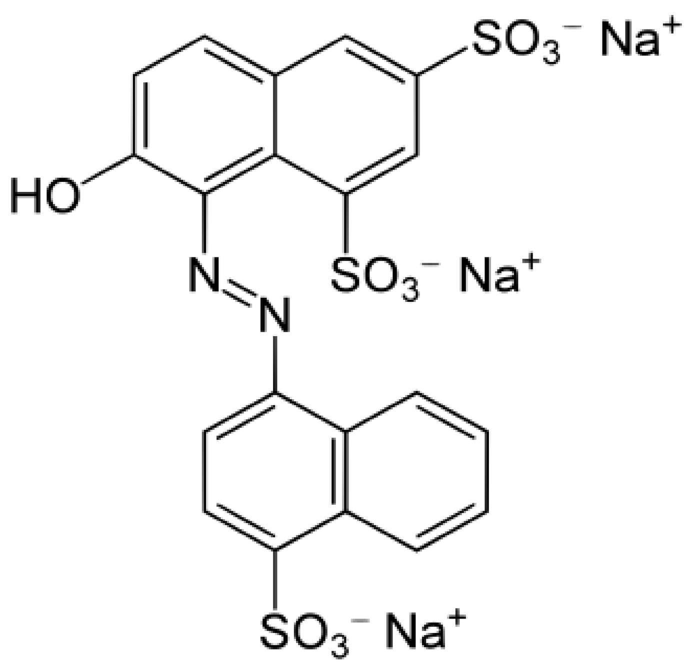
ASEC 2025 Conference
The 6th International Electronic Conference on Applied Sciences
09–11 December 2025 | Online
MDPI

Voltammetric sensor based on carbon nanotubes and cerium dioxide nanoparticles for Ponceau 4R

Guzel Ziyatdinova, Marina Vasilevskaya
Analytical Chemistry Department, Kazan Federal University, Russia

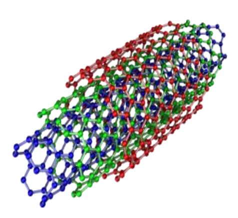
INTRODUCTION & AIM

Synthetic azo dyes including red Ponceau 4R (E124) are widely applied in the food industry to provide a bright, attractive, and stable color of the foodstuff.



Nevertheless, negative health effects can appear at high dye consumption. Therefore, the Ponceau 4R content in foods is strictly controlled. Voltammetric sensors are a promising tool for solving this problem. The glassy carbon electrode (GCE) with layer-by-layer coverage of multi-walled carbon nanotubes (MWCNTs) and cerium dioxide nanoparticle dispersion in cetylpyridinium bromide (CPB) has been designed as a novel sensitive voltammetric sensor for Ponceau 4R.

Modification of the electrode



MWCNTs

Aldrich (Germany)

Sonication in 1% SDS for 45 min

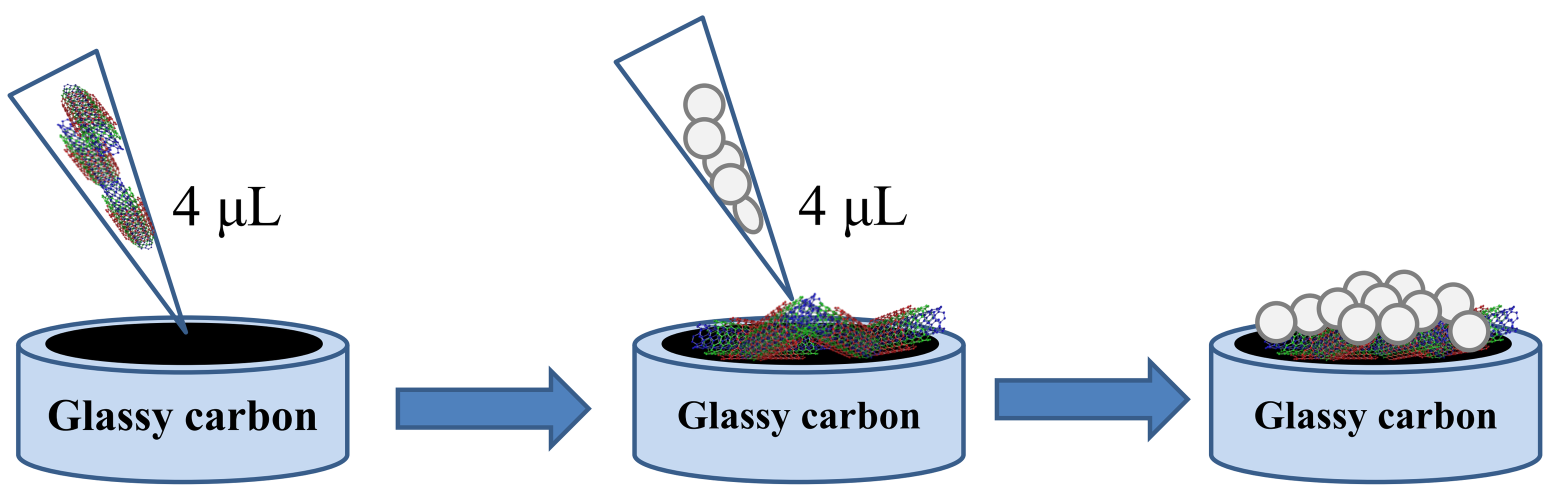
0.5 mg mL^{-1} suspension

10% (w/w) water dispersion of CeO_2 nanoparticles

Sigma-Aldrich (USA)

Sonication in 0.50 mM CPB for 10 min

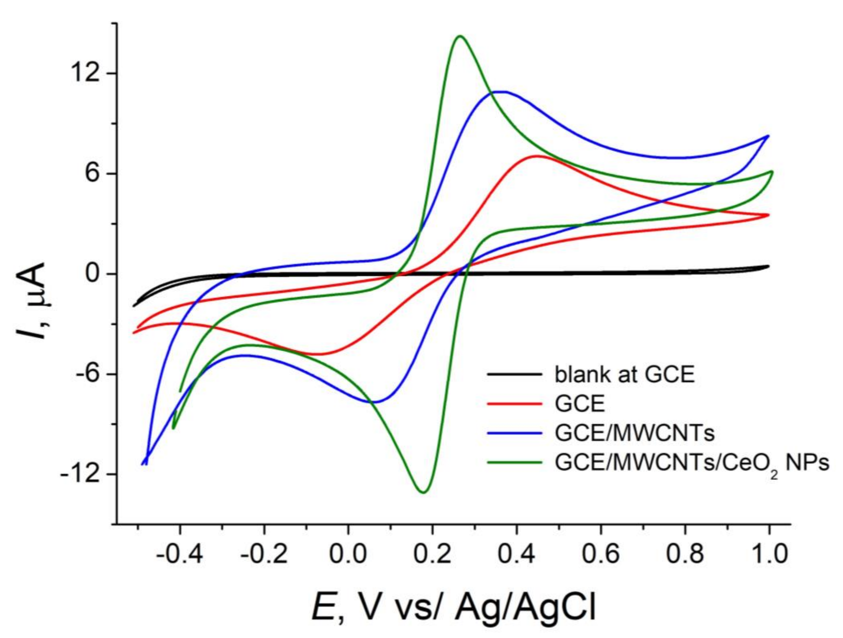
1.0 mg mL^{-1} dispersion



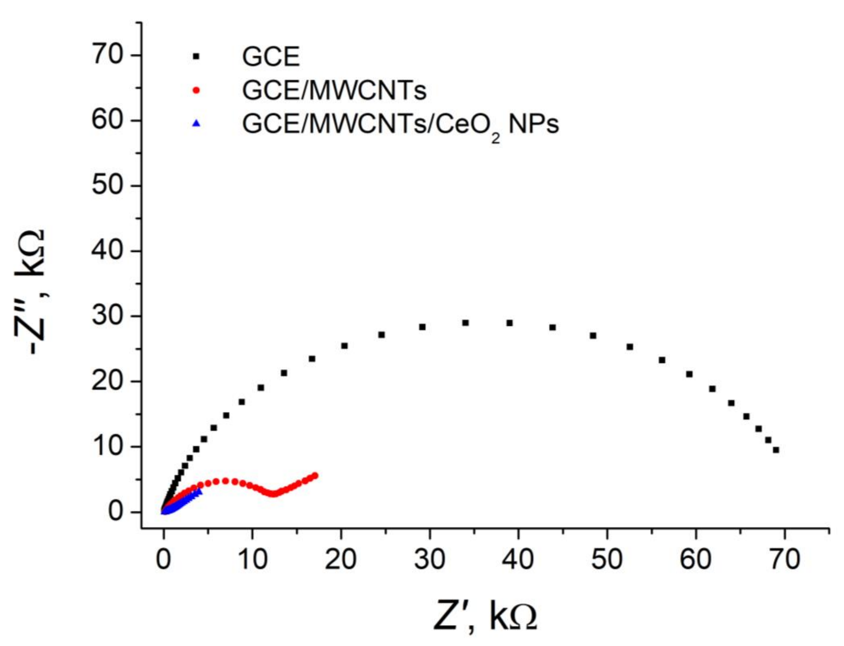
Electrode characterization

Electrochemical characteristics of the electrodes

1.0 mM $[Fe(CN)_6]^{4-}$ in 0.1 M KCl



1.0 mM $[Fe(CN)_6]^{3-/4-}$ in 0.1 M KCl



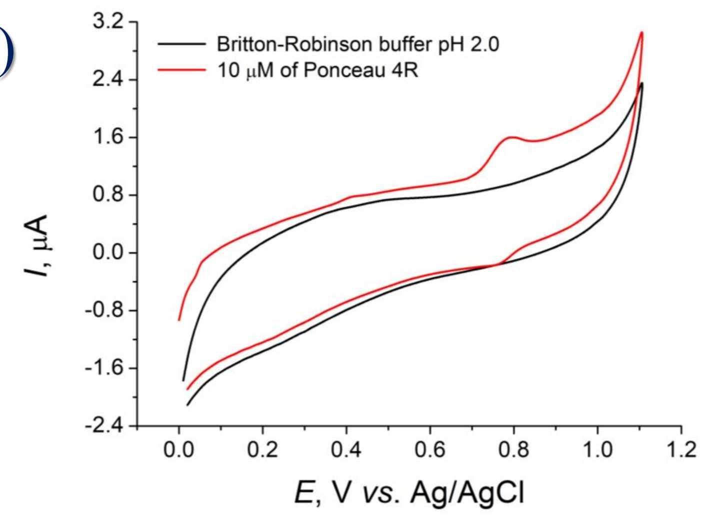
Electrode	A, mm^2	R_{et}, kΩ	k_{et}, cm s^{-1}
Bare GCE	8.9 ± 0.3	72.5 ± 0.9	5.19 × 10^{-5}
GCE/MWCNTs	75 ± 3	12.1 ± 0.9	3.11 × 10^{-4}
GCE/MWCNTs/CeO_2 NPs	32.4 ± 0.5	0.71 ± 0.4	1.15 × 10^{-3}

RESULTS & DISCUSSION

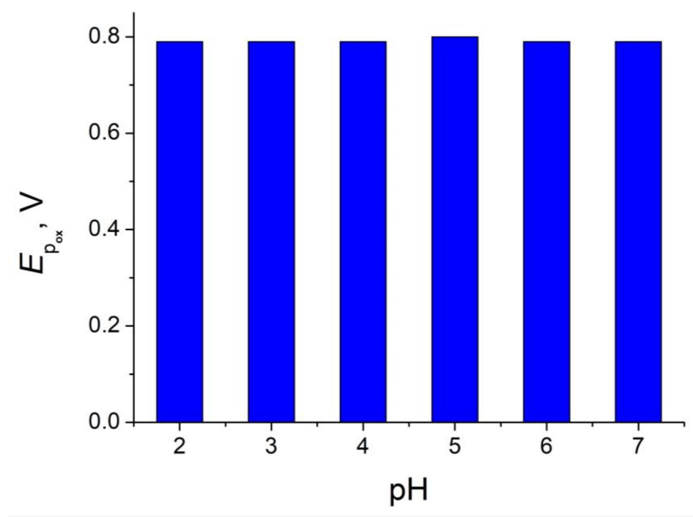
Cyclic voltammetry of Ponceau 4R

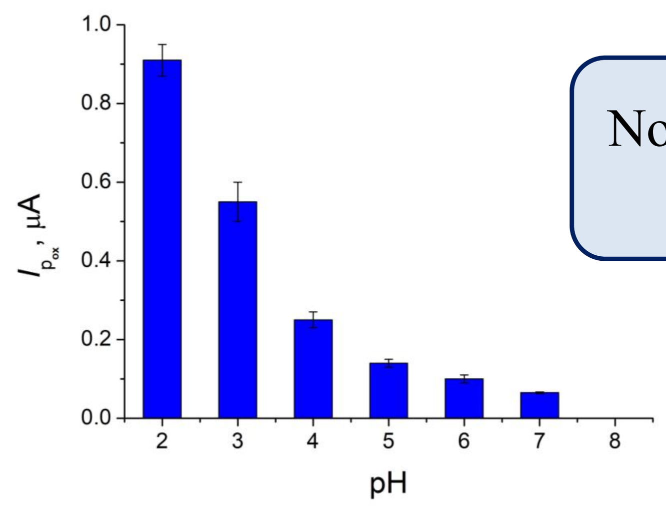
Dye voltammetric characteristics (n = 5; P = 0.95)

Electrode	E_{ox}, V	I_{ox}, μA	E_{red}, V	I_{red}, μA
Bare GCE	0.87	0.18 ± 0.02	—	—
GCE/MWCNTs	0.79	0.22 ± 0.02	0.77	−0.12 ± 0.01
GCE/CeO_2 NPs	0.84	0.20 ± 0.03	—	—
GCE/MWCNTs/CeO_2 NPs	0.79	0.30 ± 0.02	0.77	−0.14 ± 0.01

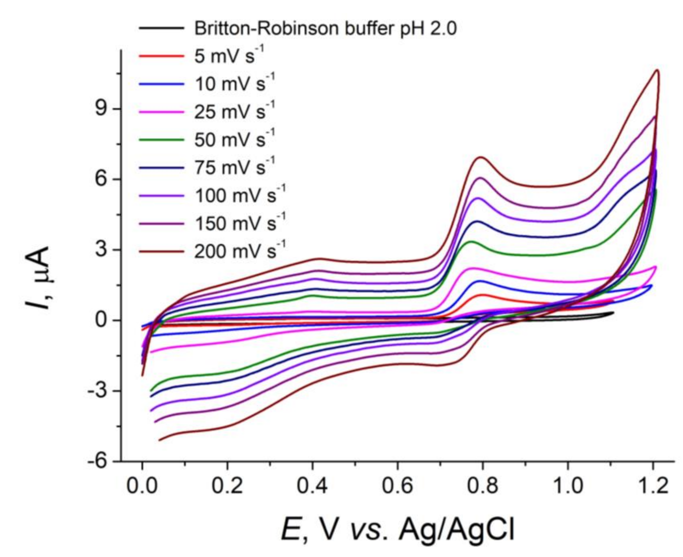


Effect of pH and potential scan rate on the response of 50 μM dye





No proton transfer
pH = 2.0



I_a [μA] = (0.41 ± 0.09) + (0.21 ± 0.01)$υ^{½}$ [mV s^{-1}] R^2 = 0.9834

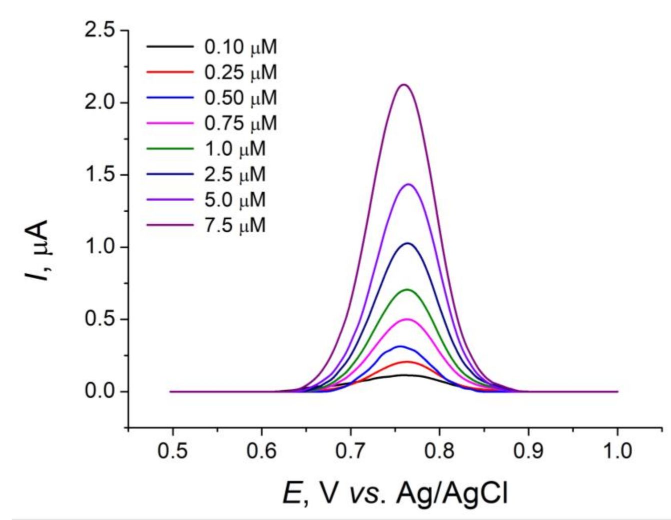
lnI_a[μ A] = (1.78 ± 0.07) + (0.37 ± 0.02)ln$υ$[V s^{-1}] R^2 = 0.9783

Diffusion-controlled quasi-reversible electrooxidation

$α_a$ = 0.72 n = 1

D = (8.2 ± 0.1)×10^{-6} cm^2 s^{-1}

Quantification of Ponceau 4R



Blank – Britton-Robinson buffer pH 2.0. $ΔE_{pulse}$ = 75 mV, t_{pulse} = 25 ms, $υ$ = 10 mV s^{-1}

Linear dynamic ranges
0.10–1.0 and 1.0–7.5 μM

Limit of detection is 0.023 μM

Ponceau 4R determination in model solutions (n = 5; P = 0.95)

Added, μg	Found, μg	RSD, %	R, %
0.24	0.242 ± 0.007	1.2	101 ± 3
1.8	1.78 ± 0.03	1.3	99 ± 2
2.4	2.39 ± 0.04	1.2	100 ± 2
12	12.0 ± 0.1	0.75	100.0 ± 0.8
18	17.9 ± 0.3	1.1	99 ± 2

CONCLUSIONS and FUTURE WORK

The sensor developed is simple in fabrication, highly reproducible and provides analytical characteristics of Ponceau 4R comparable to those ones reported for other voltammetric sensor based on the electrodes with more complex combinations of modifiers. High sensitivity of the dye response is caused by synergistic effect of caron nanotubes and metal oxide nanoparticles. Future work should be focused on the testing of the developed sensor in real sample analysis.