

Electronic Supplementary Material

Sol-gel derived ceramic nanocomposite CNFs anchored with nanostructured CeO₂ modified graphite electrode for monitoring the interaction of a selective tyrosine kinase inhibitor capmatinib with dsDNA

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Experimental

Reagents and Instruments

Capmatinib (CAP, 99 % purity) was obtained as a generous gift from Novartis company (Basel, Switzerland). Carbon nanofibers [(iron free) composed of conical platelets, D × L = 100 nm × 20–200 nm] (CNFs), calf thymus double stranded deoxyribonucleic acid (dsDNA), hydrochloric acid (HCl), and methanol (CH₃OH) were purchased from Sigma-Aldrich chemicals (St. Louis, Mo, USA). Methyltrimethoxysilane (MTMOS) and Cerium(III) nitrate hydrate [Ce(NO₃)₃·6H₂O] were obtained from Alfa Aesar. Standard stock solution of CMB was prepared with a concentration of 1 × 10⁻³ M in methanol, and stored in a cool and dark place. This solution was diluted to various concentrations by mixing with the buffer solutions. Stock standard solution of dsDNA was prepared by dissolving 0.1 g of dsDNA in 100 ml autoclaved double-distilled deionized water and stored at 4 °C. The concentration of the stock solution of ds-DNA was determined by UV absorbance at 260 nm using the molar extinction coefficient (ε) of 6600 M⁻¹ cm⁻¹. The electrolytes Britton–Robinson buffer (BRB), and phosphate buffer (PB) were studied. All solutions were prepared using water purified in a Millipore Milli-Q system (conductivity < 0.1 μS cm⁻¹).

The synthesized CeNPs@CNF hybrid nanocomposite was characterized by powder X-ray diffraction (XRD), scanning electron microscopy (SEM), high-resolution transmission electron microscopy (HRTEM, JEOL-2100F) and energy dispersive X-ray spectroscopy (EDX). The morphology of PGE and CeNPs@CNF-CF/PGE was characterized by SEM. Measurements of CV and AdS-SWV were performed using a polarographic analyzer EG&G PAR 384 B. A three electrode system was used consisting of a reference electrode (Ag/AgCl, KCl_{sat}), the auxiliary electrode (Pt wire) and CeNPs@CNF-CF modified pencil graphite electrode (CeNPs@CNF-CF/PGE) as a working electrode. The new design of a mechanical pencil (Fig. S1), which was used as the holder for the pencil graphite rod (PGR). Electrical contact to the PGR was obtained by wrapping a copper wire to the metallic front part of the holder. The PGE was retained vertically with 10 mm immersed in the solution.

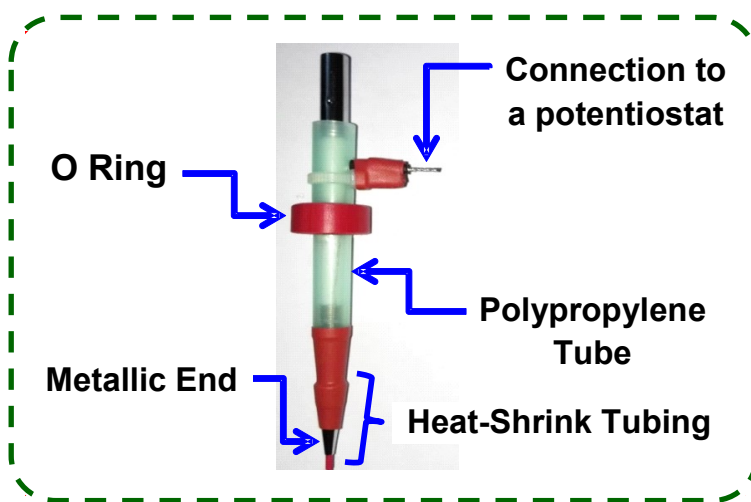


Fig. S1: New design of pencil graphite rod holder

Analytical procedure

Initially, the produced CeNPs@CNF ceramic film (CeNPs@CNF-CF) modified PGE underwent rinsing with deionized water and was subsequently dried before utilization. The typical recommended steps proceeded as follows: A precise volume (5 mL) of pH 7.4 phosphate buffer (PB) solution was carefully transferred into the electrochemical cell as the supporting electrolyte, followed by purging the test solution with N_2 gas for 15 minutes before conducting the electrochemical experiments. The blank electrolyte solution was subjected to square-wave voltammetry (SWV) at optimal settings, and the resulting

voltammogram was recorded. Subsequently, a micropipette was employed to transfer an exact volume of the CAP drug into the PB solution.

Modification of PGE with CeNPs@CNF-CF

The three-step fabrication procedure for the CeNPs@CNF (1:1) ceramic film-modified PGE was as follows: In step (1), PGRs are generally a mixture of graphite, clay, and a binder (wax, resins, or high polymers) [1]. Therefore, to remove the coating polymer on the PGRs (Pentel Hi-Polymer, 2B, 0.5 mm, Pentel, Japan) and obtain a porous surface, the whole PGR was flame-heated for 30 seconds. Next, the PGRs were air-cooled until they reached room temperature. After that, flame-heated PGRs were cleaned in an ultrasonic bath for 5 min in acetone and dried in a hot air oven for 2 h at 90 °C. Finally, insert the flame-heated PGRs into heat-shrinkable tubing (4 mm long, 0.6 mm diameter) and apply heat. The heat shrinks the tube, creating a tight-fitting cover that maintains a constant surface of PGRs wrapped with CeNPs@CNF ceramic film. Step (2) used the sol-gel technique to fabricate the CeNPs@CNF ceramic film [2]. The sol was obtained by sonicating CH₃OH (3.75 mL), methyltrimethoxysilane (2.5 mL) and HCl (0.25 mL of 11 mol L⁻¹) for 2 min. Next, the stock sol solution was diluted with methanol and sonicated with CeNPs@CNF (0.23, 0.6, 1.2, 1.75, and 2.34 g) for 2 min. Immediately, in step (3), all flame-heated and covered PGRs were dipped in the CeNPs@CNF ceramic sol-gel for a few seconds. After drying for 5 h at room temperature, CeNPs@CNF ceramic film-modified PGEs (CeNPs@CNF-CF/PGEs) were obtained. For comparison purposes, CeNPs-CF/PGE and CNF-CF/PGE were prepared similarly. The new design of a mechanical pencil, which was used as the holder for the pencil graphite rod (Fig. S1).

2. Results and discussion

Representative XRD patterns of CeNPs synthesized is shown in Fig. S2A. As expected, CeNPs displays sharp diffraction peaks at (111), (200), (220), (311), (222), and (400) for face center cubic CeO₂. These resulted XRD patterns are well matched with standard CeO₂ crystal lattice (JCPDS card No. 04-013-4459). Fig. S2B shows the TEM image of CeNPs material, indicating that it consists of a large quantity of particles. The histogram of Fig. S2C reveals the particle size distribution with an average diameter of 12 nm.

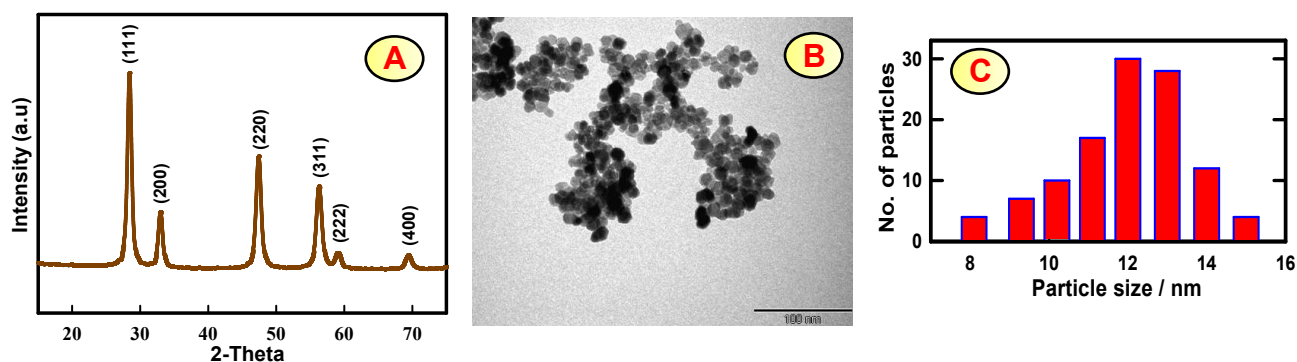


Fig. S2 XRD (A) and TEM (B) images of CeNPs. Particle size distribution plot for CeNPs (C).

The XRD patterns of the CNF and CeNPs@CNF were recorded as shown in Fig. S3. The CNF display diffraction peaks at 2θ of 26.1°, 43.12°, and 54.02°, which relate to the hkl planes of (002), (101), and (004) of the graphitic carbon structure, respectively (Fig. S3, curve a). As presented in Fig. S3 (curves b), the XRD of the synthesized CeNPs@CNF nanocomposite showed well-defined diffraction peaks at (111), (200), (220), and (311), which confirmed the formation of CeNPs (JCPDS card No. 04-013-4459). Notably, the CNF XRD peaks vanished in the CeNPs@CNF nanocomposite. This may be attributed to the high degree of CeNPs coating on CNF.

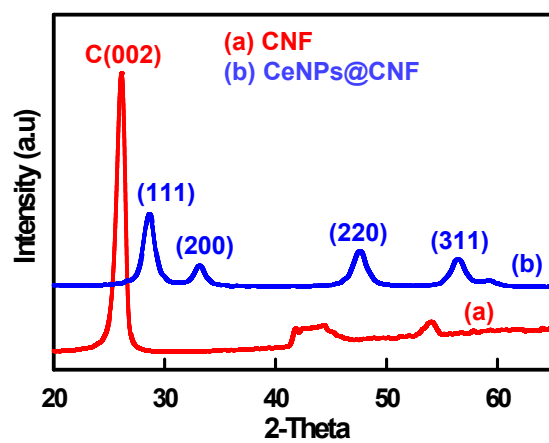


Fig. S3 XRD patterns of (a) CNF and (b) CeNPs@CNF nanocomposite.

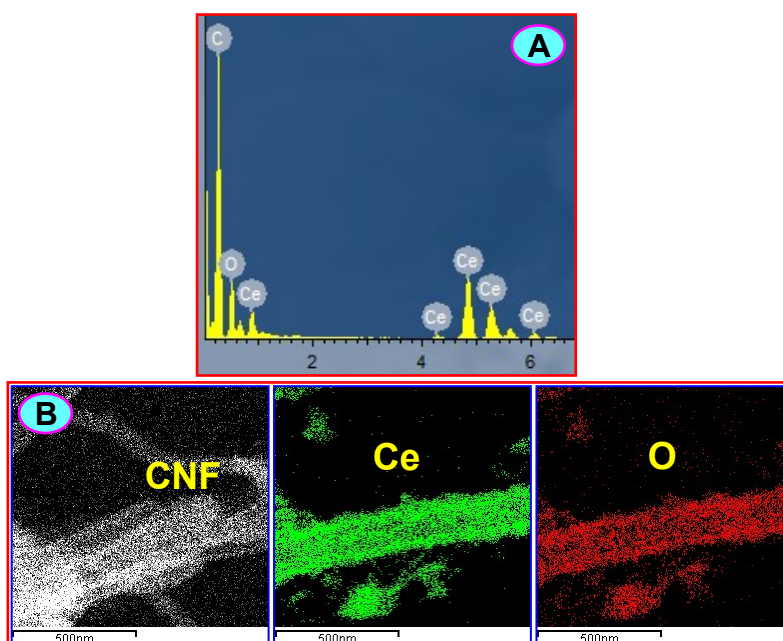


Fig. S4 EDX spectrum (A) and EDX mapping of CeNPs@CNF nanocomposite (B).

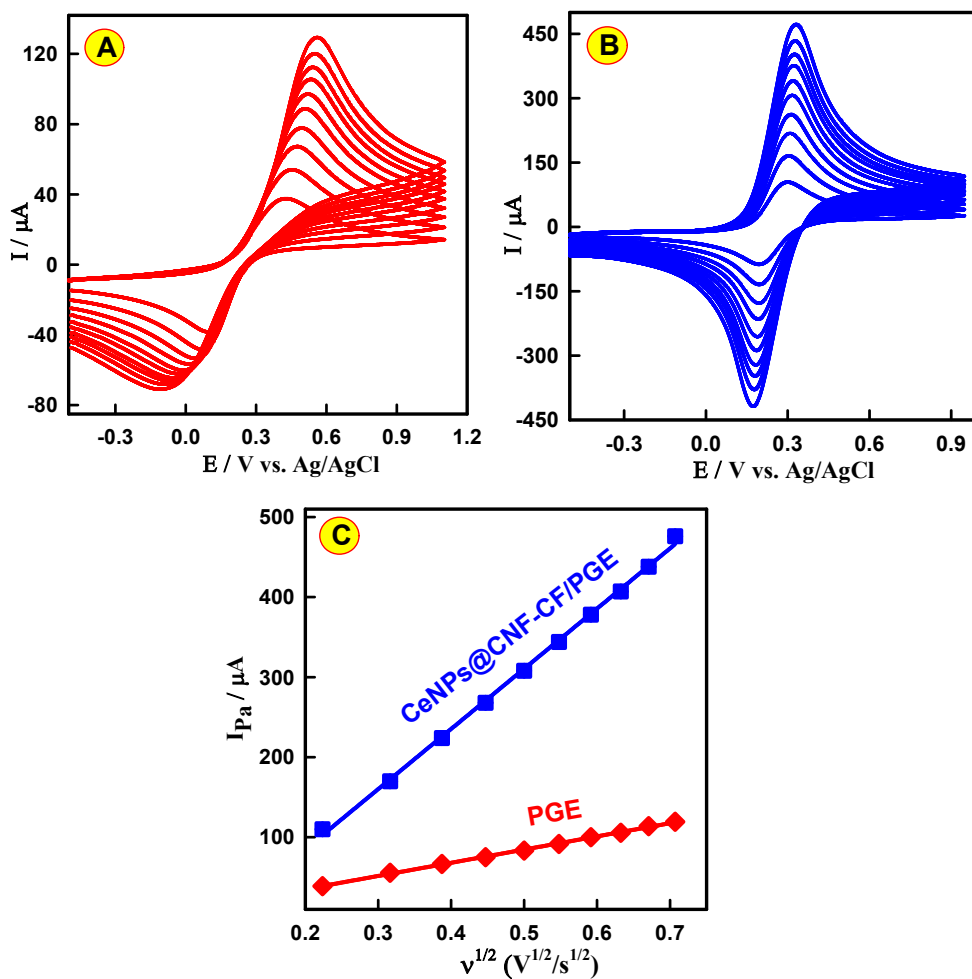


Fig. S5 CV curves of PGE (A) and CeNPs@CNF-CF/PGE (B in 5 mM [Fe(CN)₆]^{-3/-4} solution containing 0.1M KCl at different scan rates. (C) Plots of the anodic peak current (I_{p_a}) versus the square root of the scan rate ($v^{1/2}$).

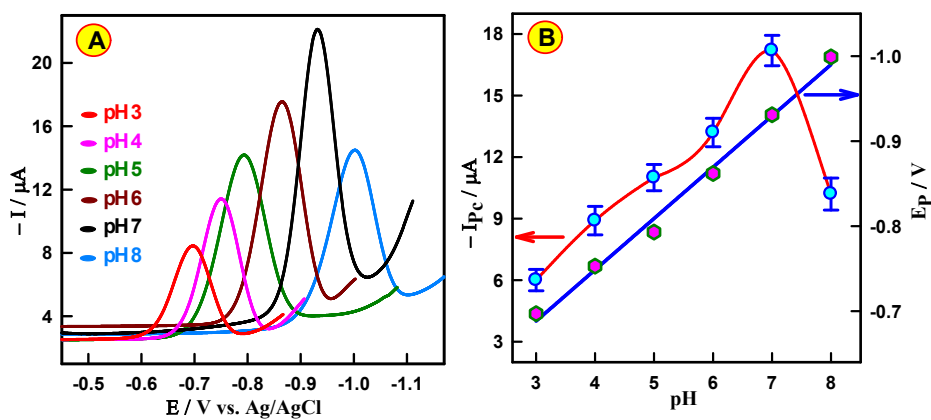


Fig. S6 (A) SW voltammograms of CAP at different pH values (PB solution). (B) Effect of pH on I_p & E_p .

The effect of adsorption potential was recorded in a range from +0.1 to -0.6 V in a PB solution of pH 7.4. From +0.1 to -0.4 V, the cathodic peak current increased with potential and after -0.4 V, the current decreases (Fig. S7A). Therefore, CAP was monitored at -0.4 V. Adsorption time has a major influence on the electro-catalytic sensing of CAP. The affinity of CAP to CeNPs@CNF-CF/PGE surface was examined by recording the peak current at different time intervals (Fig. S7B). The cathodic peak current was found to increase with increasing the time and reached its maximum value at 100 sec. Conversely, when the time exceeded 100 s, the peak current started to decrease. Hence, an adsorption time of 100 s was chosen for electro-catalytic detection of CAP at the sensing electrode.

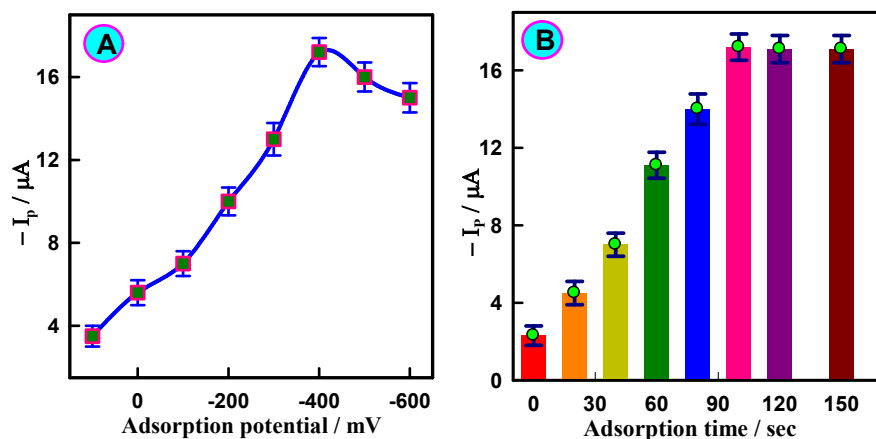


Fig. S7 Influence of (A) adsorption potential; (B) adsorption time on the cathodic peak currents of 85 nM CAP.

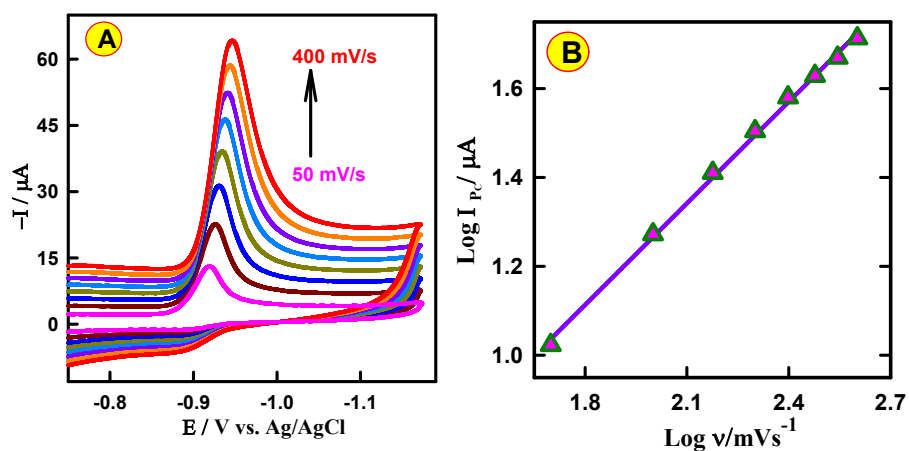


Fig. S8 (A) CVs of 150 nM CAP on surface of CeNPs@CNF-CF/PGE at various scan rates (50–400 mVs⁻¹) in PB solution of pH 7.0 (B) Plot of Log I_p vs. Log v.

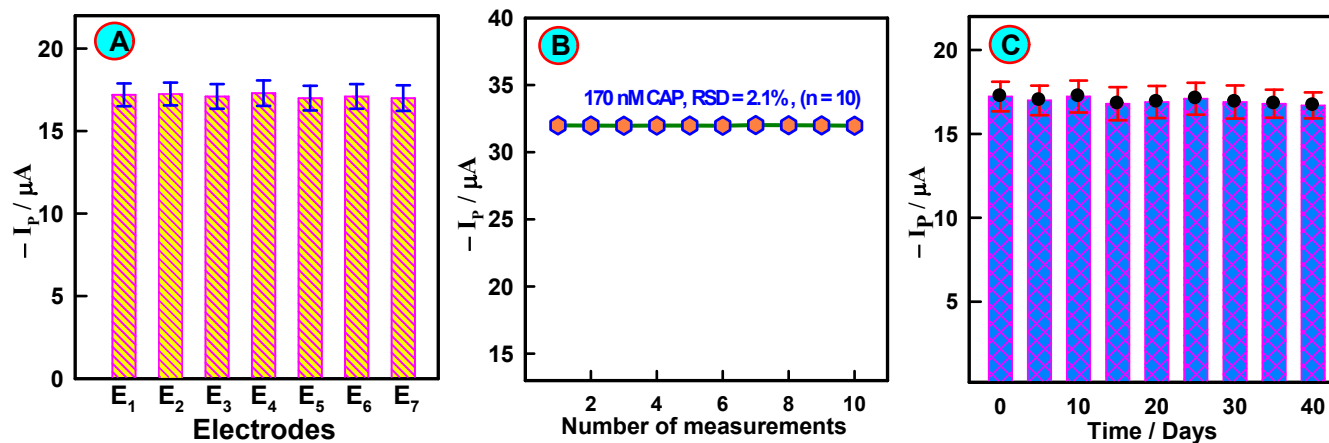


Fig. S9 (A) Reproducibility studies of seven different CeNPs@CNF-CF/PGE sensors for 85 nM CAP. (B) The repeatability of CAP determination with the CeNPs@CNF-CF/PGE sensor was evaluated from the peak current responses of ten measurements of CAP at concentration of 170 nM. (C) Long-term stability of CeNPs@CNF-CF/PGE sensor over 40 days.

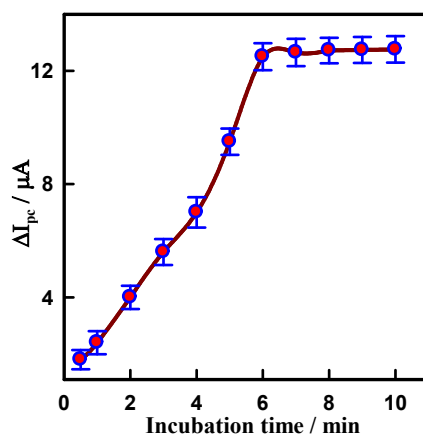


Fig. S10 Plot of ΔI_{pc} versus incubation time for the CAP-dsDNA interaction.

References

1. E. Alipour, M. R. Majidi, A. Saadatirad, S. M. Golabi, and A. M. Alizadeh, Simultaneous determination of dopamine and uric acid in biological samples on the pretreated pencil graphite electrode, *Electrochimica Acta* 91 (2013) 36–42.
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