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MXene Titanium Carbide-interdigitated Holey-Graphene Oxide Nanocomposite for Simultaneous Detection of Antibiotic and Anticancer Drugs with Ultra-high Sensitivity

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Abstract

In electrochemical sensors, signal overlap makes detecting and distinguishing molecules with the same electroactive functional group difficult. Novel electrode materials with high sensitivity must be developed to identify and separate the signal from such target analytes. Herein, a sustainable approach to designing a functional nanocomposite of holey-graphene oxide with partially-oxidized MXene titanium carbide (p-TC/hGO) is described for simultaneous electrochemical detection of antibacterial medicine nitrofurantoin (NFT) and anticancer drug nilutamide (NLT). The XRD, FE-SEM, XPS, and HR-TEM investigation examined the as-prepared p-TC/hGO nanocomposite. The hGO nanosheets build a 3D network and facilitate rapid electron transport by connecting the p-TC flakes. The p-TC/hGO nanocomposite's enlarged surface area and highly exposed reactive sites come from the numerous holes in hGO's basal plan nanosheets and the stacked layer of p-TC with oxygencontaining surface functional groups. The p-TC/hGO modified electrode demonstrated a dramatically improved electrocatalytic performance in the simultaneous detection of NFT and NLT with a low reduction potential, high peak current responsiveness (-53.31 μA for NFT, and − 43.85 μA for NLT), and ultra-high high sensitivity (52.8 μA μM^{-1} cm^{-2} for NFT, and 19.5 μA μM^{-1} cm^{-2} for NLT) in comparison to literature reports. Under optimal conditions, the devised sensor performed well analytically, as evidenced by a low detection limit of 1.2 nM for NFT and 1.9 nM for NLT and substantial recovery results (~98%, (n = 3)) in artificial urine samples. In addition, the sustainability of the sensor was proved by its outstanding performance in repeatability, reproducibility, and longterm storage (>30 days). In light of this, the present work demonstrates the design of functional electrocatalysts and opens new doors for developing sustainable electrode material for simultaneous electrochemical detection.

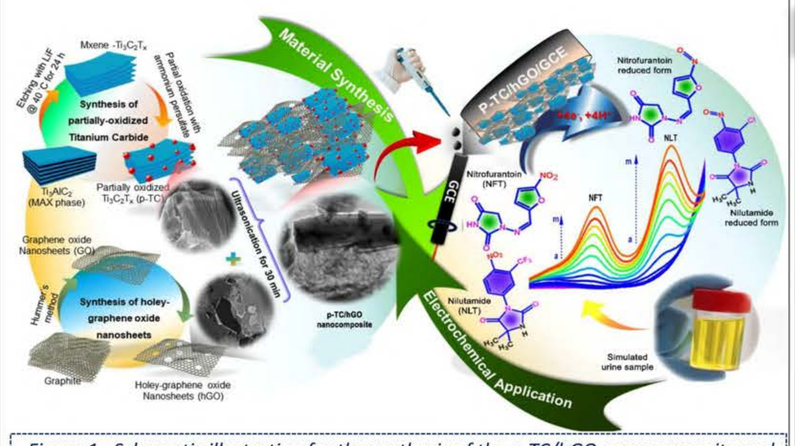

Figure 1. Schematic illustration for the synthesis of the p-TC/hGO nanocomposite and its electrochemical application in simultaneous drugs detection.

XPS Analysis

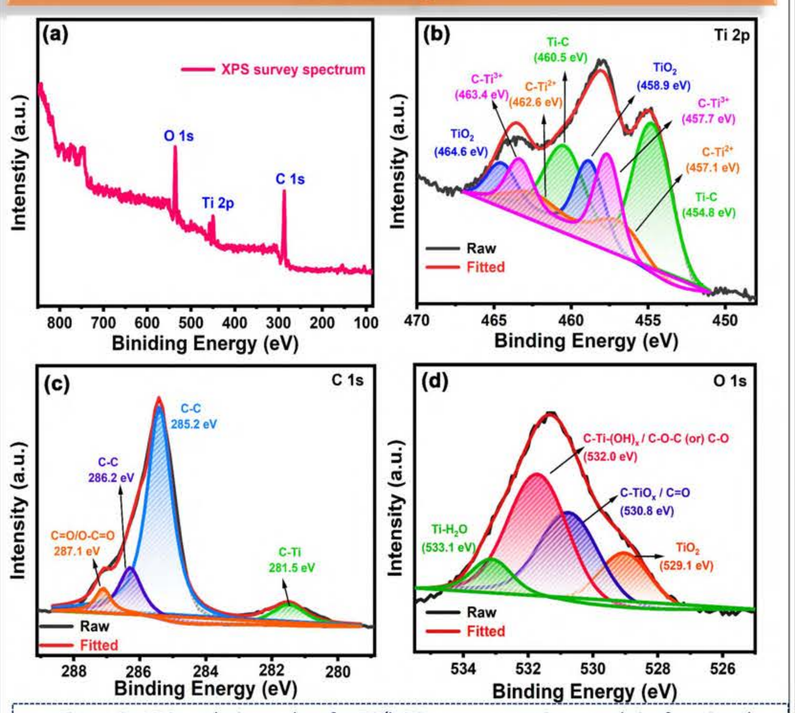

Figure 2. XPS analysis results of p-TC/hGO nanocomposite reveals its functional groups.

- *XRD confirms the successful formation of partially oxidized MXene titanium carbide nanosheets (p-TC NSs).*
- *XPS analysis confirms the various functional groups in P-TC/hGO NSs nanocomposite.*
- *Morphological analysis confirms the stacked layers of MXene nanosheets, ultra-thin nanosheets of holey- graphene oxide, and the successful integration of nanocomposite.*
- *The p-TC/hGO nanocomposite modified GCE effectively distinguish the reduction response of the drugs nilutamide and nitrofurantoin, as shown in Figure3 – 5.*

Morphological Analysis

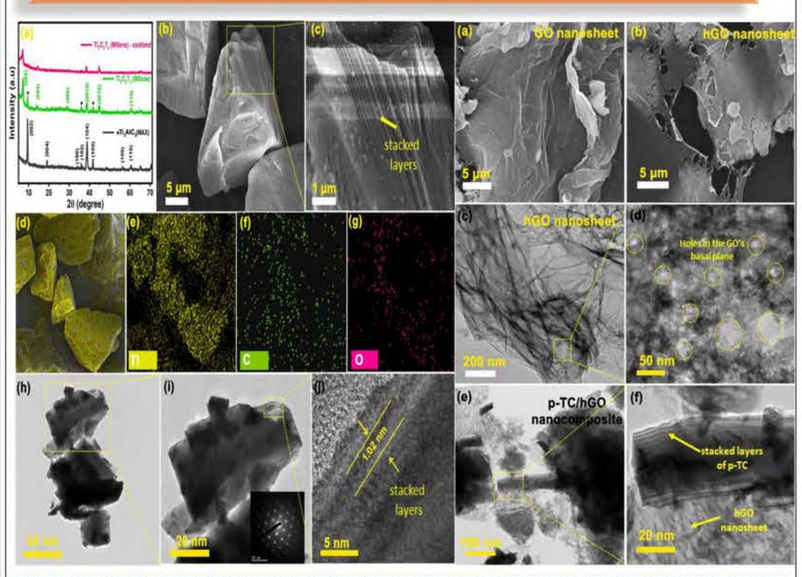

Figure 3. XRD, FE-SEM, and HR-TEM analysis results of p-TC/hGO nanocomposite and its constituents.

Electrochemical studies

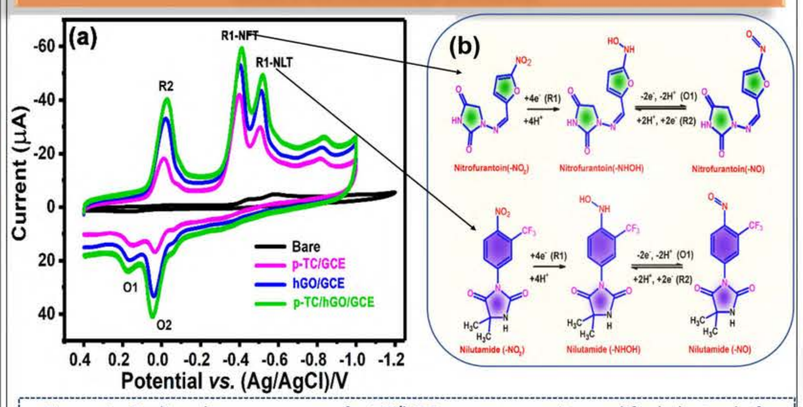

Figure 4. Cyclic voltammograms of p-TC/hGO nanocomposite modified electrode for the simultaneous detection of NFT and NLT.

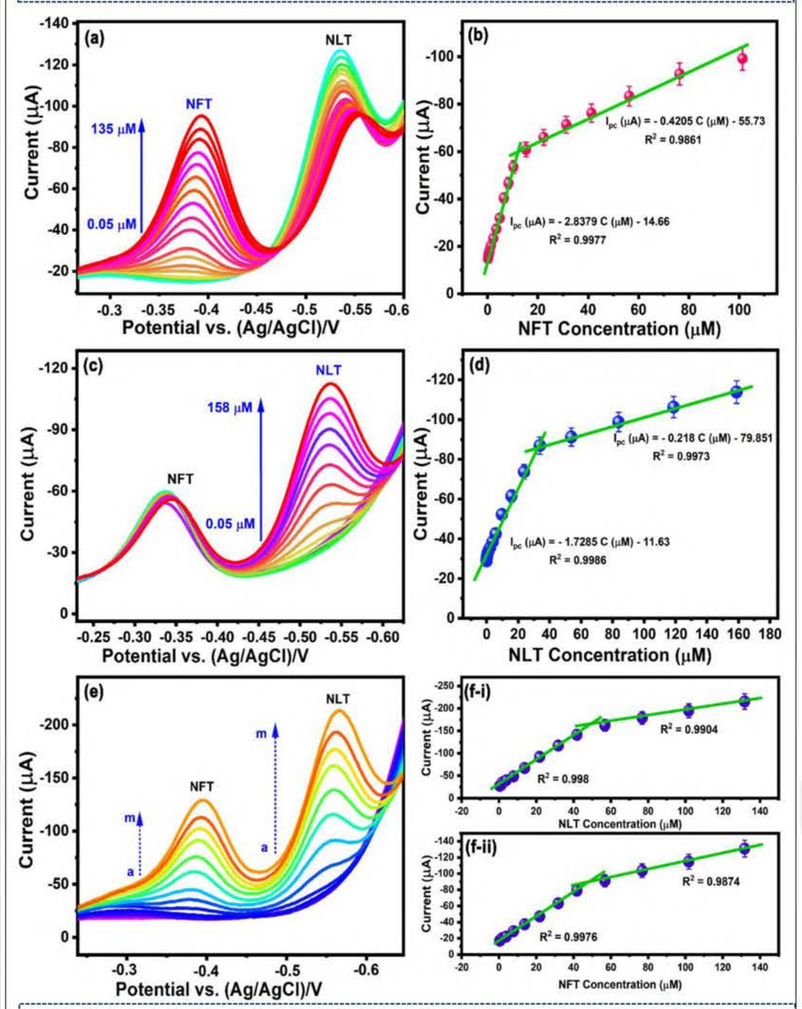

Figure 5. Differential pulse voltammograms of p-TC/hGO nanocomposite modified electrode for the simultaneous detection of NFT and NLT.

Interference and Real Sample Analysis

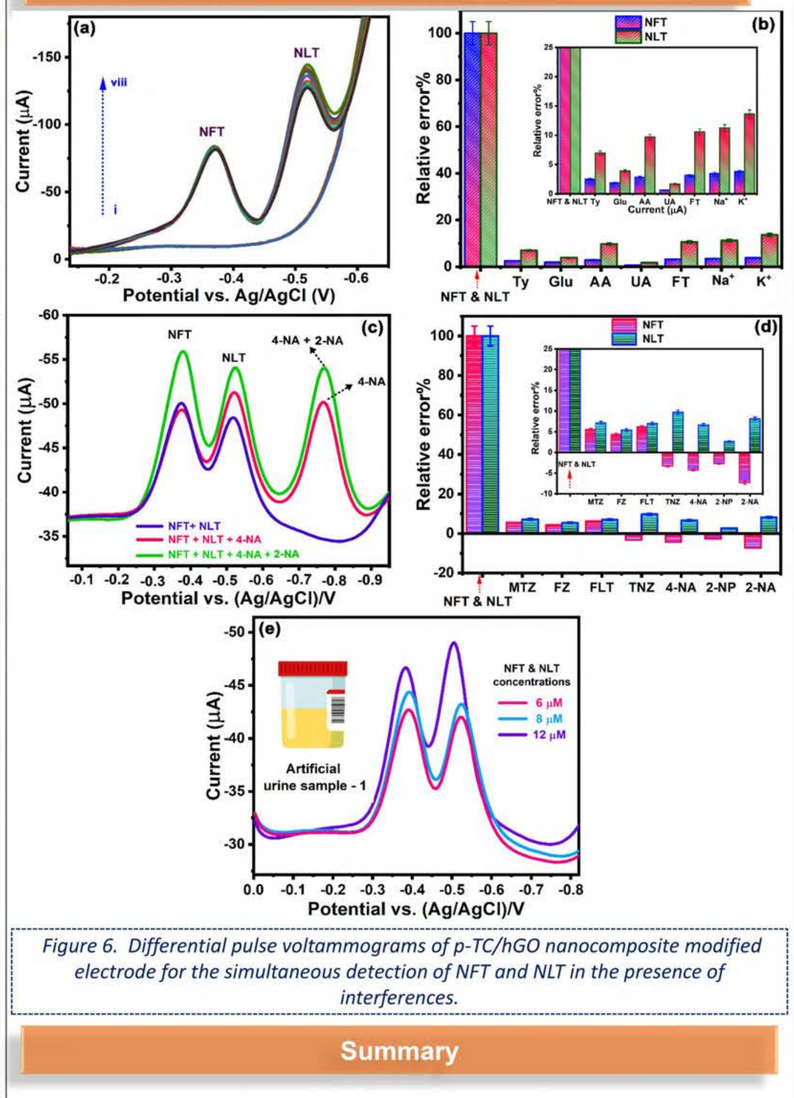

Figure 6. Differential pulse voltammograms of p-TC/hGO nanocomposite modified electrode for the simultaneous detection of NFT and NLT in the presence of interferences.

Summary

- We have successfully developed novel electrode modifiers based on p-TC/hGO hybrid nanocomposite.
- Two significant stages are focused in the material preparation: the p-TC/hGO nanocomposite was produced effectively, resulting in well-stacked p-TC nanoparticles that are covered by hGO nanosheets.
- p-TC/hGO nanocomposite has superior electron transport capacities when comparing its R_{ct} to other as-prepared catalysts. Moreover, CV tests demonstrated that the p-TC/hGO nanocomposite was more electrochemically efficient when used for the simultaneous electro-reduction of NFT and NLT.
- The hybrid nanocomposite exhibits enhanced electrochemical properties such as high surface area, low charge transfer resistance, and excellent electrocatalytic performance towards anticancer molecules as follows;

  low detection limit: 1.2 nM for NFT and 1.9 nM for NLT

  high sensitivity: *52.8 μA μM^{-1} cm^{-2} for NFT, and 19.5 μA μM^{-1} cm^{-2} for NLT*
- Thus, the present research has authenticated that p-TC/hGO hybrid nanocomposite can be an excellent electrode modifier for the detection of antibiotic drug molecules both individually and simultaneously. The presented sensor demonstrated simultaneous electrochemical NFT and NLT detection in simulated urine samples, and thus it may pave the path for application in real-time clinical analysis.

Publication

R. Keerthika Devi, M. Ganesan, T.-W. Chen, S-M Chen, A. M. Abbasi, M.A. Ali, M.S. Elshikh, J. Yu, H.-Y. Chuang, B. Xu, S.K. Ravi, "*MXene-interdigitated Holey-Graphene Oxide Electrocatalytic Nanocomposite for Simultaneous Ultra-Sensitive Detection of Antibiotic and Anticancer Drug*" **Chemical Engineering Journal**, 474 (2023) 145693 (**Impact factor: 16.744**)