SUPPORTING INFORMATION

Cost-Effective Quantification of Uric Acid Using Niobium Oxide and Graphene Oxide-Modified Pencil-Drawn Electrodes on PVC Substrates

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Modification process

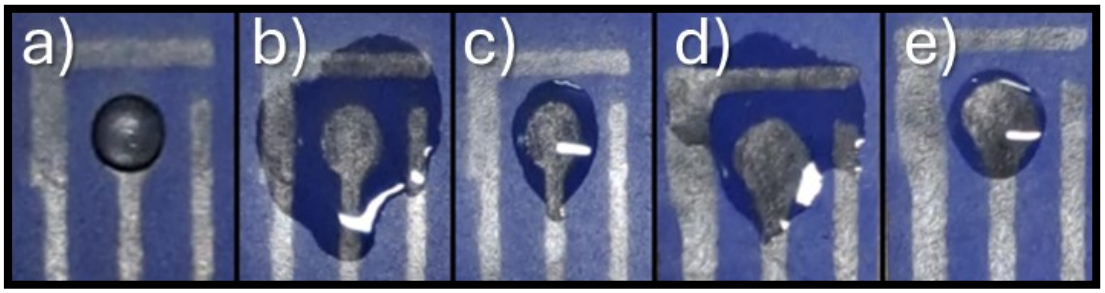

Figure S1 - Amplified photographs of the electrode with a single droplet of 5 µL of (a) water, (b) ethanol, (c) propanone, (d) iso-propanol, and (e) acetonitrile.

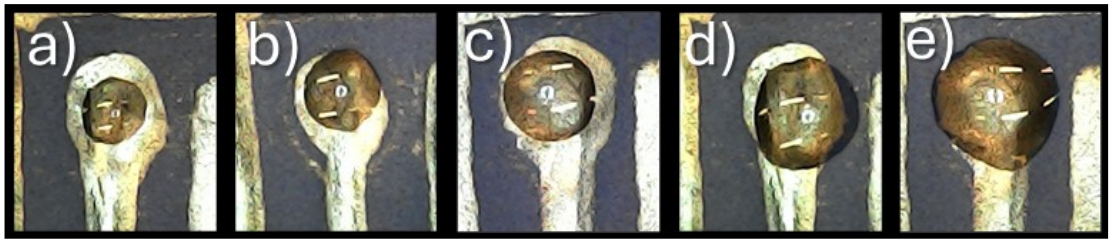

Figure S2 - Photographs of the electrode with 1.0 µL (a), 1.5 µL, (c) 2.0 µL, (d) 2.5 µL and (e) 3.0 µL of acetonitrile above the working electrode.

Graphene optimization

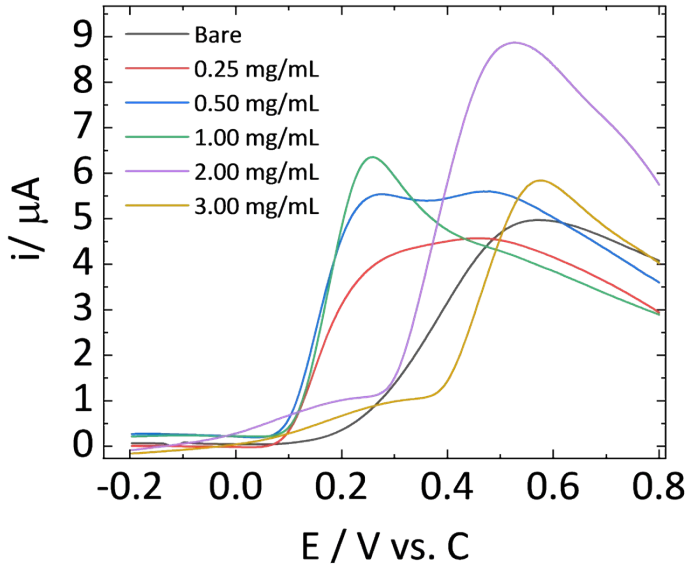

Figure S3 – Blank subtracted voltammetric responses in 1.0 mmol L^{-1} uric acid solution in PBS for the bare electrode and modified electrodes prepared with different graphene oxide contents.

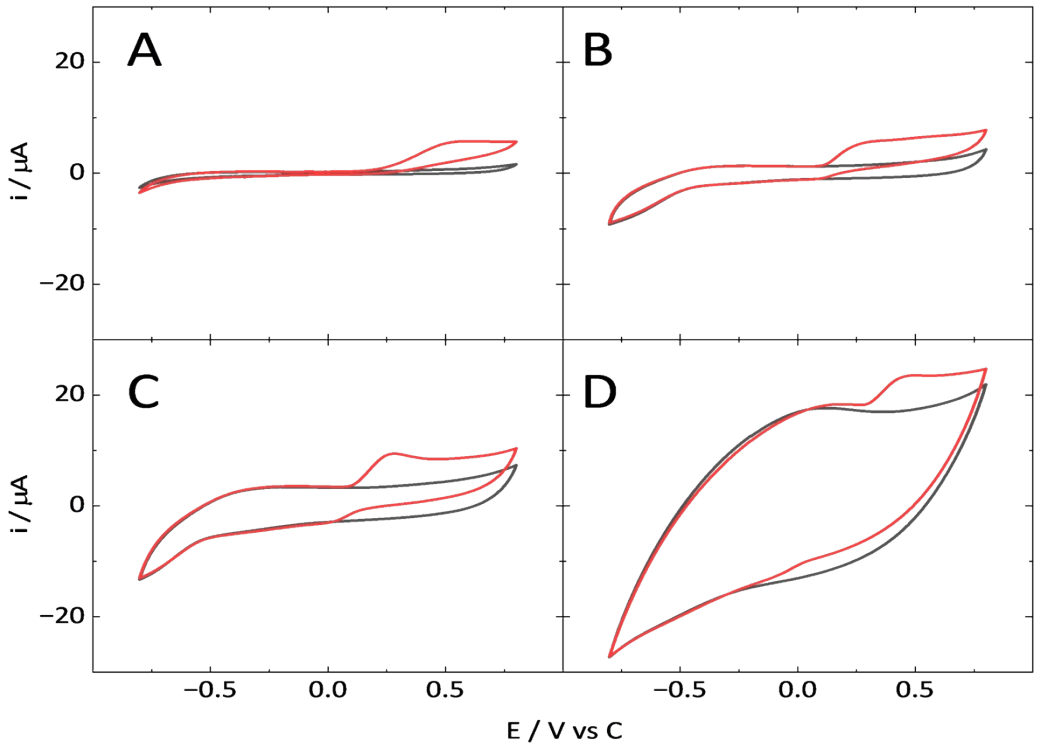

Figure S4 – Voltammetric responses in 1.0 mmol L^{-1} uric acid solution in PBS for the electrodes prepared with different graphene oxide contents. A) Bare and modified electrodes with 3 µL of dispersed graphene oxide at concentrations of B) 0.25 g L^{-1}, C) 1.00 g L^{-1}, and D) 3.00 g L^{-1}. Red: In presence of uric acid. Black: In PBS only. Scan rate: 0.1 Vs^{-1}.

Niobium oxide optimization

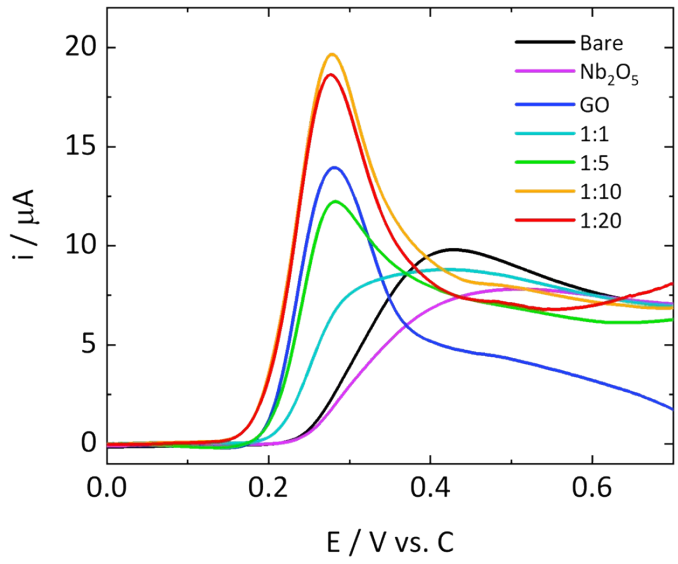

Figure S5 – Voltammetric responses in 2.0 mmol L^{-1} uric acid solution in PBS for the bare and modified electrodes prepared with different proportions of graphene oxide and niobium oxide for. Background current subtracted.

Modification sequence

The modification sequence was evaluated using both oxides at the optimized quantities (Graphene Oxide: Nb_2O_5 proportion of 1:10) described in the main text. Figure S5 presents the blank subtracted voltammetric response obtained for the electrode as produced (bare) and modified with both oxides for the mixed and sequential deposition. The comparison between the mixed and sequential depositions is crucial. As can be seen in the voltammograms in Figure S7, adding graphene and niobium oxide improves uric acid detection. This is evident in the increased oxidation current and the shift of the peak potential to a more positive value. The mixed deposition of both oxides resulted in the most significant change in both potential and current, with a clear current peak observed at less positive potentials. In contrast, both sequential depositions exhibited a lower current than for the mixed deposition. Notably, graphene deposited on niobium oxide did not show a well-defined current peak. On the other hand, depositing niobium oxide on graphene did produce a small peak current. However, this peak occurred at potentials approximately 150 mV more positive and with a 17% lower current than the mixed deposition.

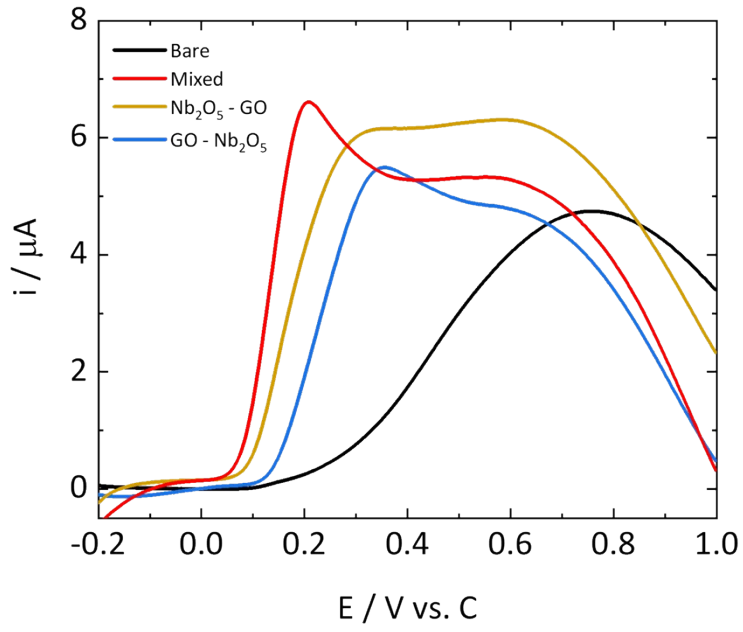

Figure S6 – Voltammetric response in 1 mmol L^{-1} uric acid in PBS for the electrodes without modification and modified with graphene and niobium oxides. Black: bare electrode. Red: mixed deposition of both oxides. Yellow: Graphene oxide over niobium oxide. Blue: Niobium oxide over graphene oxide. Scan rate: 50 mV s^{-1}. The response of the electrodes in PBS was subtracted for better visualization of the Faradaic process.

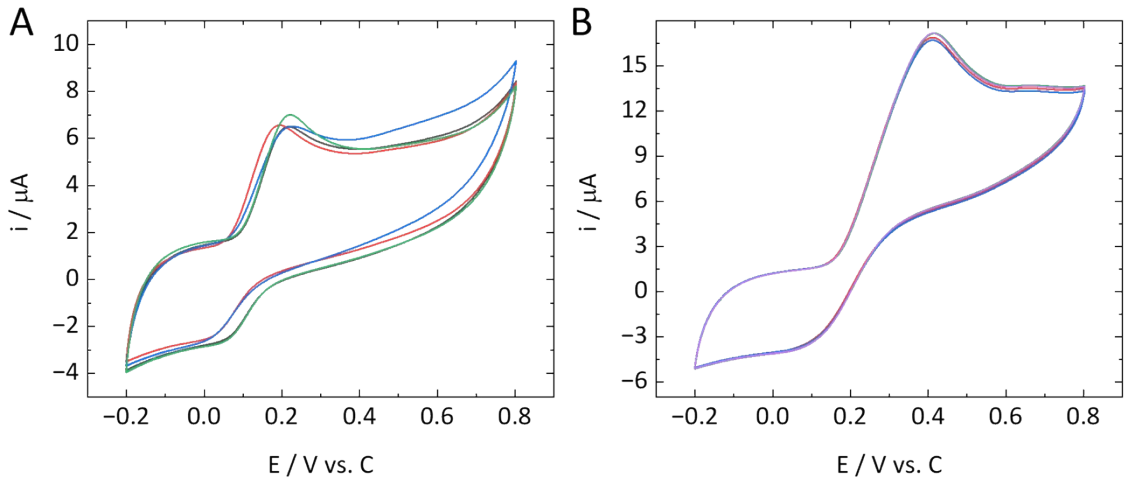

Figure S7 – Voltammograms of A) 4 different electrodes in 1.0 mmol L^{-1} uric acid in PBS and B) consecutive measurements with a single electrode in 2.0 mmol L^{-1} uric acid in PBS. Scan rate: 50 mV s^{-1}.

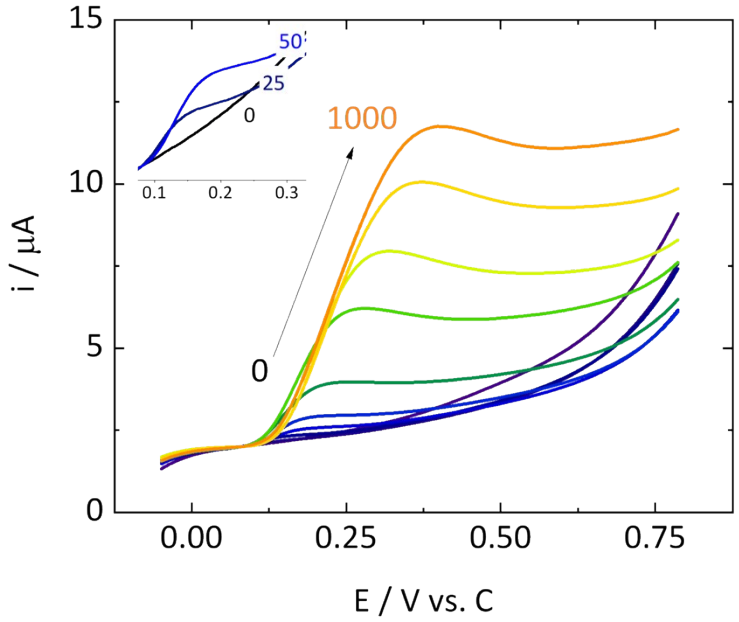

Figure S8 – Voltammograms of the optimized electrode at different uric acid concentrations in PBS. Scan rate: 100 mV s^{-1}.

Price estimates

Table S1 - Sensor price breakdown by components

Component	Price per quantity	Quantity per sensor	Price per sensor (USD cents)
Kraft paper	4 USD per 3 m^2	0.0005 m^2*	0.070
PVC adhesive	6 USD per 1 m^2	0.0005 m^2 *	0.300
8B pencil	6 USD per 12 units	>200 per pencil **	0.250
Niobium oxide	100 USD per 25 g	30 µg	0.012
Graphene oxide	160 USD per 1 g	3 µg	0.048
		Total per sensor:	0.680

*Area values overestimated to account for cuttings. ** underestimated value of sensors possible to be produced with a single pencil.

Although the cost for sensors produced is not usually presented in other works, an easy estimate can be obtained considering the commercial prices of the sensors´ components and their quantity. Some materials can easily be recycled from one use of the sensor to another, as is the case with the electrode's substrates, such as glassy carbon electrodes and gold electrodes. Other components, conversely, can be considered non-recyclable, such as oxides, enzymes, carbonaceous materials such as carbon nanotubes, graphene oxide, polymers, and so on. The recyclable materials are listed as substrate costs to operate the sensor, and the non-recyclable materials are listed as modifier costs. The price was estimated using the reported amount of material on the reference and the lowest price found on the online suppliers. It is important to note that not all components are used for price estimates. Thus, the values are only an approximation.

Table S2 – Price estimate for sensors reported in the literature.

Material	Substrate (cost in USD)	Modifiers (costs in USD)	REF
Glass/Ti/Pt/NiO/Uricase	Glass (0.03 USD)	Uricase (0.50)	[1]
Au/MWCNT/AuNP/Uricase	Gold wire (0.14 USD)	Uricase (1.00)	[2]
GCE/Cu_2O/Fc/ Uricase	GCE (500 USD)	Uricase (1.50)	[3]
GCE/MWCNT/PSVM/Au	GCE (500 USD)	MWCNT (0.10)	[4]
GPE/ac-dERGO	GPE (1.00 USD)	GO (0.01)	[5]
GCE/RGO/Au	GCE (500 USD)	GO (0.01)	[6]
GCE/UNC/Fe_xO_y	GCE (500 USD)	Oxides (0.01)	[7]
GCE/ZnO NRs-CuO NSs	GCE (500 USD)	Oxides (<0.01)	[8]
GCE/MWCNT/Al_2O_3/MIP	GCE (500 USD)	MWCNT (0.10)	[9]
GPE/PDA/AuNP	GPE (1.00 USD)	AuNP (0.50)	[10]
PDE/Nb_2O_5-GO	PVC/Kraft (<0.01 USD)	Oxides (<0.01)	This

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