

1 **Facile preparation of cellulose microfibers exfoliated graphite composite; A robust sensor**
2 **for determination of dopamine in biological samples**

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13

14 **Abstract**

15 A simple and robust dopamine sensor was developed using cellulose microfibers (CMF)
16 exfoliated graphite composite modified screen-printed carbon electrode (SPCE) for the first time.
17 The graphite-CMF composite was prepared by sonication of pristine graphite in CMF solution and
18 was characterized by high-resolution scanning electron microscopy, Fourier transform, infrared,
19 and Raman spectroscopy. The cyclic voltammetry results reveal that graphite-CMF composite
20 modified SPCE has superior electrocatalytic activity against oxidation of dopamine (DA) than
21 SPCE modified with pristine graphite and CMF. The presence of large edge plane defects on
22 exfoliated graphite and abundant oxygen functional groups of CMF enhance electrocatalytic
23 activity and decrease potential towards the oxidation of DA. Differential pulse voltammetry was
24 used to quantify the DA using graphite-CMF composite modified SPCE and demonstrates a linear
25 response for DA detection in the range 0.06 to 134.5 μM . The sensor shows a detection limit as 10
26 nM with an appropriate sensitivity, and displays appropriate recovery of DA in human serum
27 samples with good repeatability. Sensor selectivity is demonstrated in the presence of 50 fold
28 concentrations of potentially active interfering compounds including ascorbic acid, uric acid, and
29 dihydroxybenzene isomers.

30 **Keywords:** Exfoliated graphite; Cellulose microfibers; Functional composite; Dopamine;
31 Electrochemical sensor

32 **Introduction**

33 Over the past two decades, the synthesis of novel composite materials has received
34 substantial attention in electroanalytical chemistry and have shown great potential capacity and
35 signal-enhancing characteristics in electroanalytical applications for sensing of small molecules
36 (Shrivastava et al. 2016). Dopamine (DA) is an inhibitory neurotransmitter and plays an important
37 role in human metabolism, and in the renal and central nervous systems (Pandikumar et al. 2014).
38 Dysfunction of DA transmission in the substantia nigra of the central nervous system (CNS) are
39 implicated in Parkinson's disease and schizophrenia (Mo and Ogorevc 2001; Galvan and
40 Wichmann 2001). Accordingly, the real-time monitoring of DA concentrations in human tissue
41 samples has received considerable interest. To date, a range of analytical methods has been
42 employed for clinical DA determination (Palanisamy et al 2013). However, electrochemical
43 techniques are ideally suited to the detection of DA due to their robustness with fast response, high
44 sensitivity, stability and selectivity (Liu et al. 2008; Paleček 2002).

45 Composite modified electrodes have been widely used as transducers for detection of DA,
46 and they demonstrate improved detection limit (LOD), sensitivity, and linear response over
47 unmodified electrodes (Jackowska and Krysinski 2013). Although DA is a highly electroactive
48 molecule, interactions with unmodified electrodes exhibit low sensitivity, poor selectivity, and
49 surface fouling, effectively limiting their practical application in electrochemical sensing
50 (Thirumalraj et al. 2016). Consequently, carbon nano/micro materials, metal nanoparticles,
51 transition metal oxides, and conducting polymer-based composite modified electrodes (including
52 carbon nanotubes, graphene and its derivatives) are widely applied for different potential
53 applications including the determination of DA (Vellaichamy et al. 2017a; Vellaichamy and
54 Prakash 2016; Vellaichamy et al. 2017b; Jacobs et al. 2010; Sajid et al. 2016; Yang et al. 2015).

55 Accordingly, the preparation of simple and robust composite materials for the detection of DA is
56 of interest to the applied analytical chemists. As a low-cost carbon material, graphite has been
57 widely used as a starting point for synthesis of graphene oxide and its derivatives (Özerol et al.
58 2015; Choi et al. 2010). However, the electrochemical application of pristine graphite is limited
59 by its low surface area and strongly linked carbon atoms (Ku et al. 2013). Thus, a range of materials
60 and preparative approaches have been developed enhance the synergistic properties of graphite.
61 For instance, we have more recently demonstrated the preparation of carbohydrate polymers
62 dispersed graphite as an alternative composite material to graphene based DA sensors (Ku et al.
63 2013; Palanisamy et al. 2016a; Palanisamy et al. 2016b; Gui et al. 2013; Ruiz-Palomero et al.
64 2017). On the other hand, cellulose based materials have emerged as a new biomaterial and
65 exhibited extraordinary electronic and structural properties with low toxicity (Gui et al. 2013).
66 Additionally, they have high surface area, high porosity, and tend to bond easily with the variety
67 of conductive materials (Gui et al. 2013; Ruiz-Palomero et al. 2017). Recently published literatures
68 indicate that nano and micro cellulosic materials act to exfoliate bulk graphite into layered graphite
69 flakes, particularly multi-layer graphene (Carrasco et al. 2014; Malho et al. 2012). In addition, as
70 a composite component, cellulose-exfoliated graphite confers significantly improved electronic
71 properties over pristine graphite (Malho et al. 2012). In the present work, we demonstrate a simple
72 preparation of cellulose microfibers exfoliated graphite (graphite-CMF) composite by sonication
73 method.

74 Our literature survey indicates that cellulose exfoliated graphite composite has not been
75 previously used in electrochemical sensor applications. Consequently, we have also utilized the
76 special properties of graphite-CMF composite for electrochemical determination of DA for the
77 first time. We have also discussed the relation of DA electro-oxidation by graphite-CMF

78 composite modified electrode with graphite and CMF modified electrodes. As a proof of concept,
79 we have also utilized the fabricated sensor towards the determination of DA in human serum
80 samples.

81 **Experimental**

82 *Materials and methods*

83 Raw graphite with an average diameter 10 μm was purchased from Sigma-Aldrich. Screen-
84 printed carbon electrodes were purchased from Zensor R&D Co. Ltd, Taiwan. Cellulose medium
85 fibers powder (10 microns) was obtained from Sigma and used as received. Dopamine
86 hydrochloride and dopamine injections were received from Sigma-Aldrich. Human serum samples
87 were obtained from Valley Biomedical, Taiwan product & services, and were approved by the
88 ethics committee of Chang-Gung memorial hospital through the contract no.IRB101-5042A3. All
89 the chemicals used in this work were of analytical grade and was purchased from Sigma-Aldrich.
90 The supporting electrolyte was pH 7.0 phosphate buffer and was prepared using 0.05 M Na_2HPO_4
91 and NaH_2PO_4 in doubly distilled water. The stock solutions were prepared using the doubly
92 distilled water.

93 The electrochemical studies such as cyclic voltammetry and differential pulse voltammetry
94 (DPV) were performed using computerized CHI410A electrochemical workstation from CH
95 instruments. High-resolution scanning microscopic images were obtained using Hitachi S-
96 4300SE/N High Resolution Schottky Analytical VP scanning electron microscope (SEM). The
97 elemental mapping of the materials was analyzed using Hitachi S-4300SE/N High Resolution
98 Schottky Analytical VP SEM attached BRUKER AXS elemental analyzer. Raman spectrum of
99 materials was acquired using Dong Woo 500i Raman spectrometer from Korea. Fourier transform
100 infrared (FTIR) spectroscopy analysis was performed using JASCO FTIR-6600 spectrometer.

101 Electrochemical studies were accomplished using a typical three-electrode system consisting of a
102 modified Screen-printed carbon electrode (SPCE) as the working electrode, and saturated Ag|AgCl
103 and Pt wire as the reference and auxiliary electrodes, respectively. The geometric surface area of
104 unmodified SPCE was 0.07 cm² and the electrochemically active surface area (ECAS) of the
105 modified SPCE (graphite-CMF) was 0.106 cm².

106 *Preparation of graphite-CMF composite and electrode modifications*

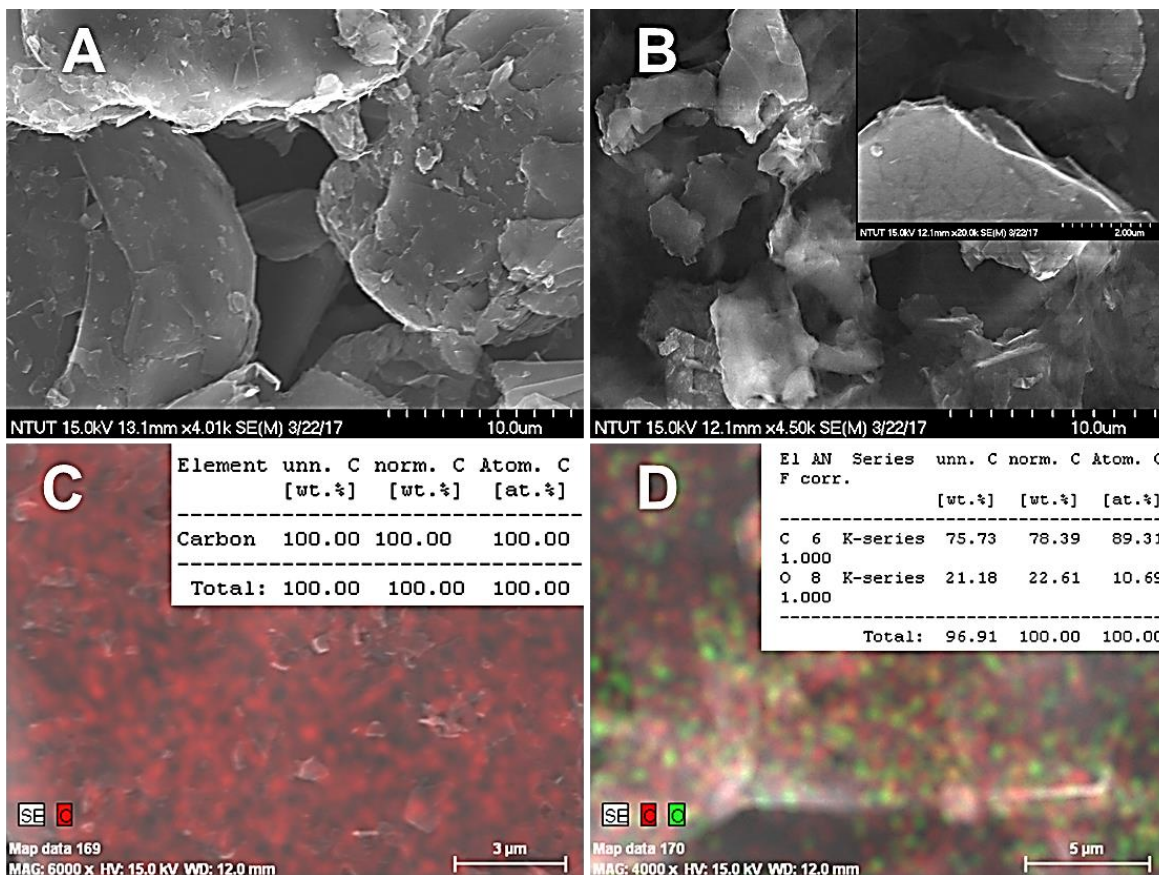
107 The graphite-CMF composite was prepared by dispersing of 10 mg graphite into 2 mL CMF
108 solution and ultrasonication for approximately 45 min. The CMF stock solution was prepared by
109 sonication of 50 mg of CMF in 5 mL doubly distilled water for 45 min. The raw graphite dispersion
110 was prepared by adding 5 mg of graphite to 1 mL of dimethylformamide and sonicated for 30 min.
111 For electrode modifications, 9 μL (optimum, see **Fig. 4 inset**) of the as-prepared graphite-CMF
112 composite dispersion was drop coated on unmodified SPCE. The resulting graphite-CMF
113 composite modified SPCE was dried in air oven. The graphite and CMF modified SPCEs were
114 prepared by drop coating of 5 μL of graphite and CMF on the unmodified SPCEs. The
115 electrochemical measurements were performed in a room temperature under the oxygen-free
116 atmosphere by purging pure N₂ in the electrolyte solution for 10 min. The modified SPCEs were
117 stored at room temperature under dry conditions when not in use.

118 **Results and discussion**

119 *Characterization of graphite-CMF composite*

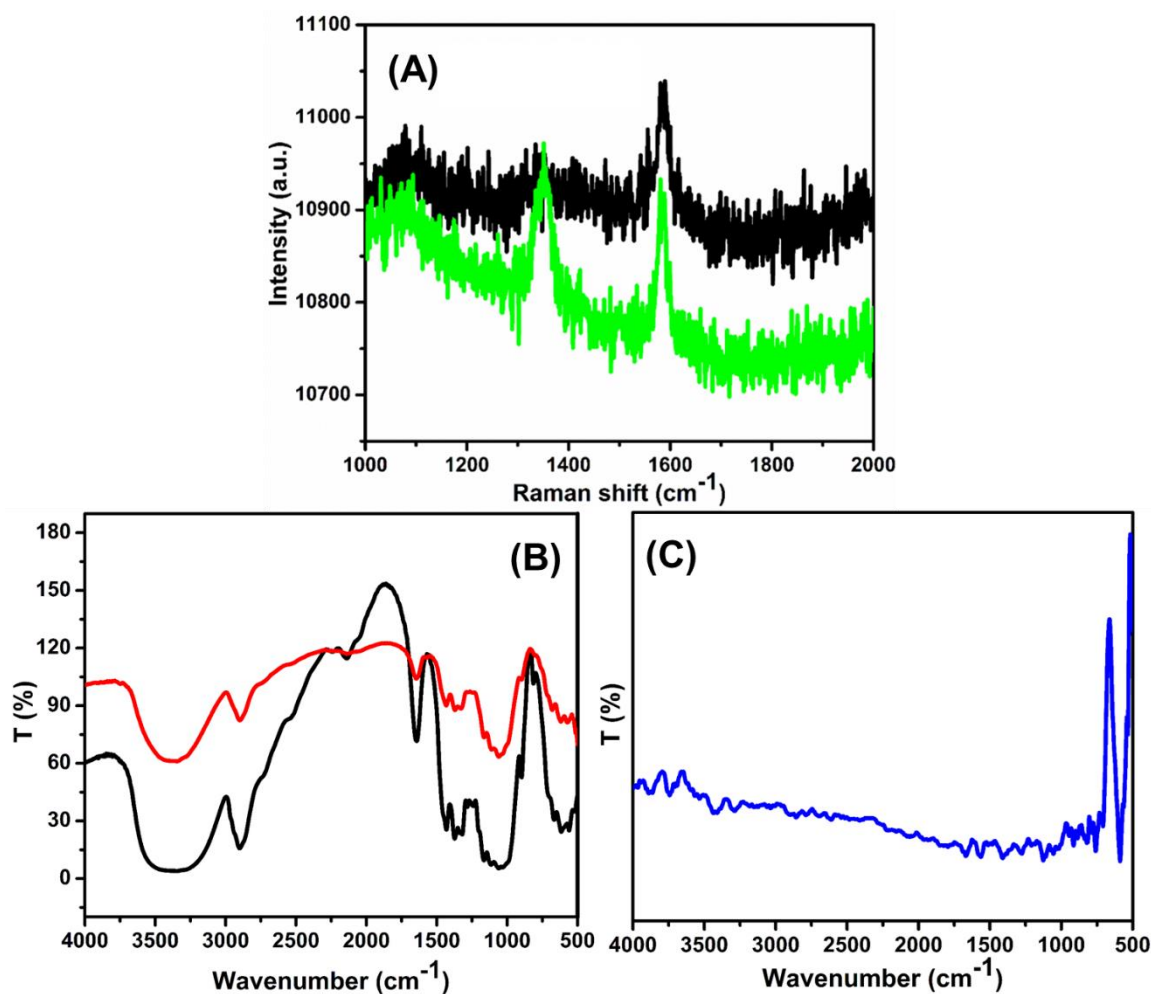
120 **Fig. 1** displays the high-resolution SEM images of graphite (A) and graphite-CMF
121 composite (B). The SEM image of graphite-CMF composite reveals that the surface of graphite
122 layers is highly exfoliated and uniformly wrapped by CMF. Conversely, the SEM image of
123 graphite shows its layered structure with highly ordered graphite microsheets. The high

124 magnification SEM image of graphite-CMF composite (**Fig. 1B inset**) also confirmed the
 125 exfoliation of graphite and presence of CMF on the surface of graphite; the strong non-covalent
 126 interaction between the graphitic carbons and the CMF resulting in exfoliation of graphite. In
 127 addition, the hydrophilicity nature of CMF allows the dispersion of graphite-CMF composite into
 128 the water (Carrasco et al. 2014; Malho et al. 2012). The elemental mapping of the SEM images of
 129 graphite and graphite-CMF composite is shown in **Fig. 1C** and **D**. The elemental mapping of
 130 graphite-CMF composite confirms the presence of carbon and oxygen due the presence of graphite
 131 and CMF. In contrast, oxygen is absent in the elemental mapping of pristine graphite, and confirms
 132 the pure carbon nature of pristine graphite. The above observations confirm formation of the
 133 graphite-CMF composite.



134

135 Raman spectroscopy is widely used as a standard tool to confirm the defects and disorders
136 of carbon materials. **Fig. 2A** shows the Raman spectra of graphite (black color) and graphite-CMF
137 composite (green color). The Raman spectrum of graphite shows a sharp G band at 1584 cm^{-1} ,
138 while D bands are absent in the Raman spectrum of graphite. This G band is associated with
139 vibrations of the sp^2 domains of graphite (Thirumalraj et al. 2015). Alternatively, the Raman
140 spectrum of graphite-CMF shows an intense D and G bands at 1336 and 1581 cm^{-1} . Typically, the
141 appearance of D band vibrations is due to the presence of defects at the edges in pristine graphite
142 and exfoliation bulk graphite into the multi-layered graphene (Malho et al. 2012). Accordingly,
143 the result confirms that graphite-CMF composite has more edge defects than pristine graphite.



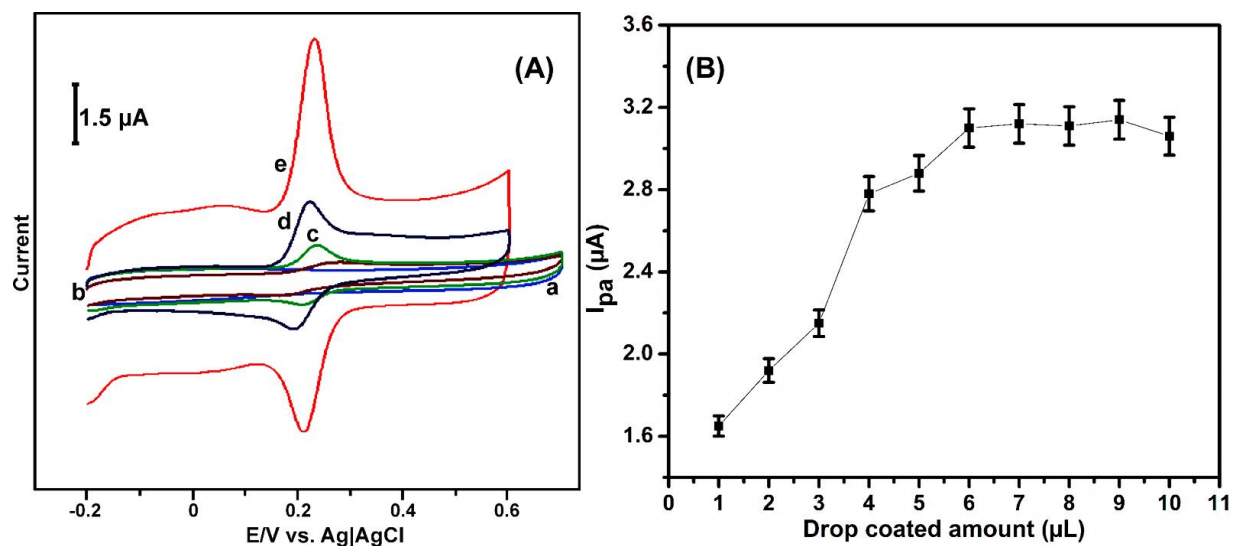
144

145 FTIR was used to characterize the presence of CMF and interactions between the CMF and
146 graphite in the composite. **Fig. 2B** shows the FTIR spectra of CMF (red color) and graphite-CMF
147 composite (black color,) and **Fig. 2C** shows the FTIR spectrum of graphite. A broad vibration
148 band was detected at 3300–3500 cm^{-1} in graphite-CMF composite. This is due to the stretching
149 vibrations of –OH group of CMF (Abdulkhani et al. 2013). The graphite-CMF composite also
150 shows 2 additional bands at 2892 and 2220 cm^{-1} , which are associated with the stretching
151 vibrations of –CH and –CH₂ from CMF (Abdulkhani et al. 2013). In addition, three characteristic
152 bands were appeared at 1640, 1372 and 1058 cm^{-1} , are attributed to the vibrations of –OH, C=O
153 and C–O from CMF (Abdulkhani et al. 2013). The similar characteristic stretching bands were
154 observed for the FTIR spectrum of pure CMF. Conversely, the FTIR spectrum of graphite as
155 shown in **Fig. 2C** do not show the obvious bands in the fingerprint region, and confirms the
156 presence of pure carbon nature of graphite. The above results are more consistent with our previous
157 reported literature for CMF and confirm the presence of CMF in graphene-CMF composite
158 (Palanisamy et al. 2017).

159 *Electrocatalytic ability of modified SPCEs towards DA*

160 To investigate the electrocatalytic ability, the different modified SPCEs were tested by
161 cyclic voltammetry (CV) in pH 7.0 containing 10 μM DA. **Fig. 3A** shows the CV response of bare
162 (a), GR (b), CMF (c), CMF drop coated graphite (d) and graphite-CMF composite (e) modified
163 SPCEs in 10 μM DA at pH 7.0 and at a scan rate of 50 mV/s. The unmodified SPCE did not show
164 any obvious electrochemical response for the presence of DA, and reflects the poor electrocatalytic
165 activity of unmodified SPCE towards DA. The graphite modified SPCE shows weak
166 electrochemical redox behaviour towards DA and the oxidation peak of DA is appeared at 0.396
167 V and is due to the oxidation of DA to corresponding quinone. The oxidation mechanism of DA

168 at carbon modified electrodes is well studied and documented (Ku et al. 2013; Palanisamy et al.
169 2016a; Palanisamy et al. 2016b; Gui et al. 2013; Ruiz-Palomero et al. 2017). The electrochemical
170 redox behaviour of DA was enhanced upon the SPCE modified with CMF and the oxidation
171 potential of DA (0.286 V) was detected at a lower potential than with the graphite modified SPCE.
172 The results indicate that CMF has high catalytic activity and lower oxidation potential towards the
173 detection of DA than graphite modified electrode. The graphite-CMF composite SPCE shows 10
174 folds enhanced oxidation peak current to DA than CMF modified SPCE and the oxidation potential
175 of DA was 64 mV (0.224 V) lower than those observed at CMF modified SPCE. These results
176 demonstrate the higher DA electrocatalytic activity of graphite-CMF composite SPCE in
177 comparison to other modified SPCEs. The large defects at the edges of graphite and high
178 adsorption ability of CMF in the composite are the main reasons for enhanced sensitivity and low
179 oxidation potential towards the detection of DA than graphite and CMF modified electrodes. To
180 verify the enhanced catalytic activity of DA by edge plane effects of graphite in graphite-CMF
181 composite, the CMF was detected using pristine graphite modified SPCE and its response to DA
182 was analyzed. As can be seen from **Fig. 3A** curve d, the CMF coated pristine graphite modified
183 SPCE show 3.5 folds reduction in oxidation peak current response to DA than graphite-CMF
184 composite electrode. This result further indicates that the enhanced sensitivity of DA is due to the
185 presence of large edge plane effects of graphite in graphite-CMF composite and is in good
186 agreement with the Raman spectrum (**Fig. 2A** green profile).



187

188 Optimization of the graphite-CMF composite towards the detection of DA is critical and

189 has a direct influence on the sensitivity of the modified electrode. Accordingly, the effects on DA

190 detection for differing volumes of graphite-CMF composite drop coated on modified SPCEs was

191 studied by CV. The optimization results are shown in **Fig. 3B** and the experimental conditions are

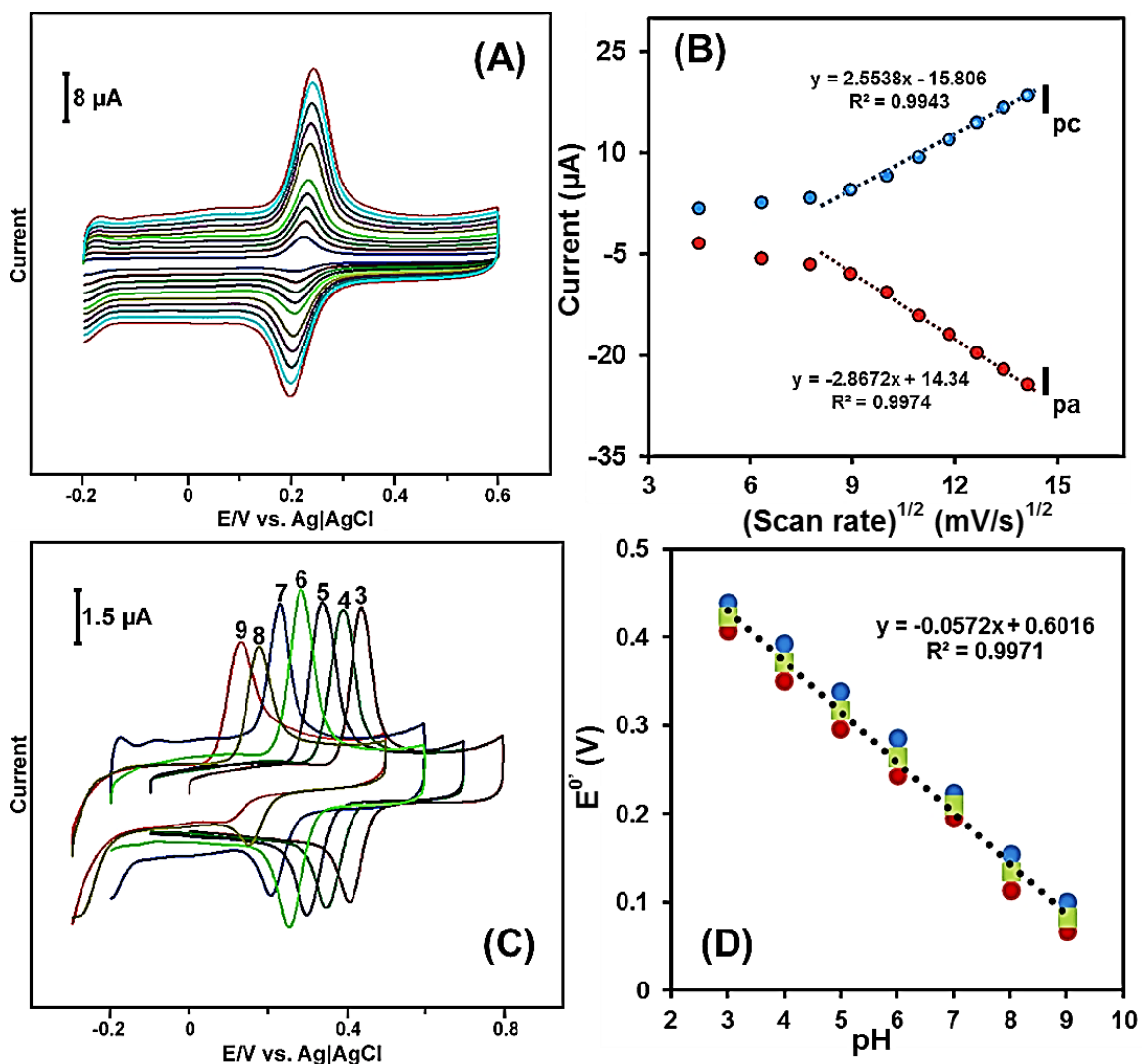
192 similar to **Fig. 3A**. The oxidation peak current response of DA can be clearly seen to increase

193 alongside the volume of drop coated graphite-CMF composite on the SPCE surface. In addition,

194 the response of DA was decreased above or below 9 μL drop coated graphite-CMF composite

195 modified SPCE. Therefore, 9 μL drop coated graphite-CMF composite modified SPCE was used

196 as an optimum of further electrochemical studies.



197
 198 To verify the electrochemical behavior of DA, the effect of scan rate on the redox behavior
 199 of DA was studied. **Fig. 4A** shows the CVs of graphite-CMF composite modified SPCE in pH 7.0
 200 containing 10 μM of DA at scan rates from 20 to 200 mVs⁻¹. The CV profile of graphite-CMF
 201 composite modified SPCE towards DA clearly demonstrate an increase in anodic and cathodic
 202 peak currents for DA with increasing scan rates. The corresponding anodic and cathodic
 203 currents vs. square root of scan rates were plotted and shown in **Fig. 4B**. The anodic and cathodic
 204 peak current of DA was linear over the scan rate from 90 to 200 mVs⁻¹, which suggests the
 205 electrochemical redox activity at the surface of graphite-CMF composite modified SPCE to be a

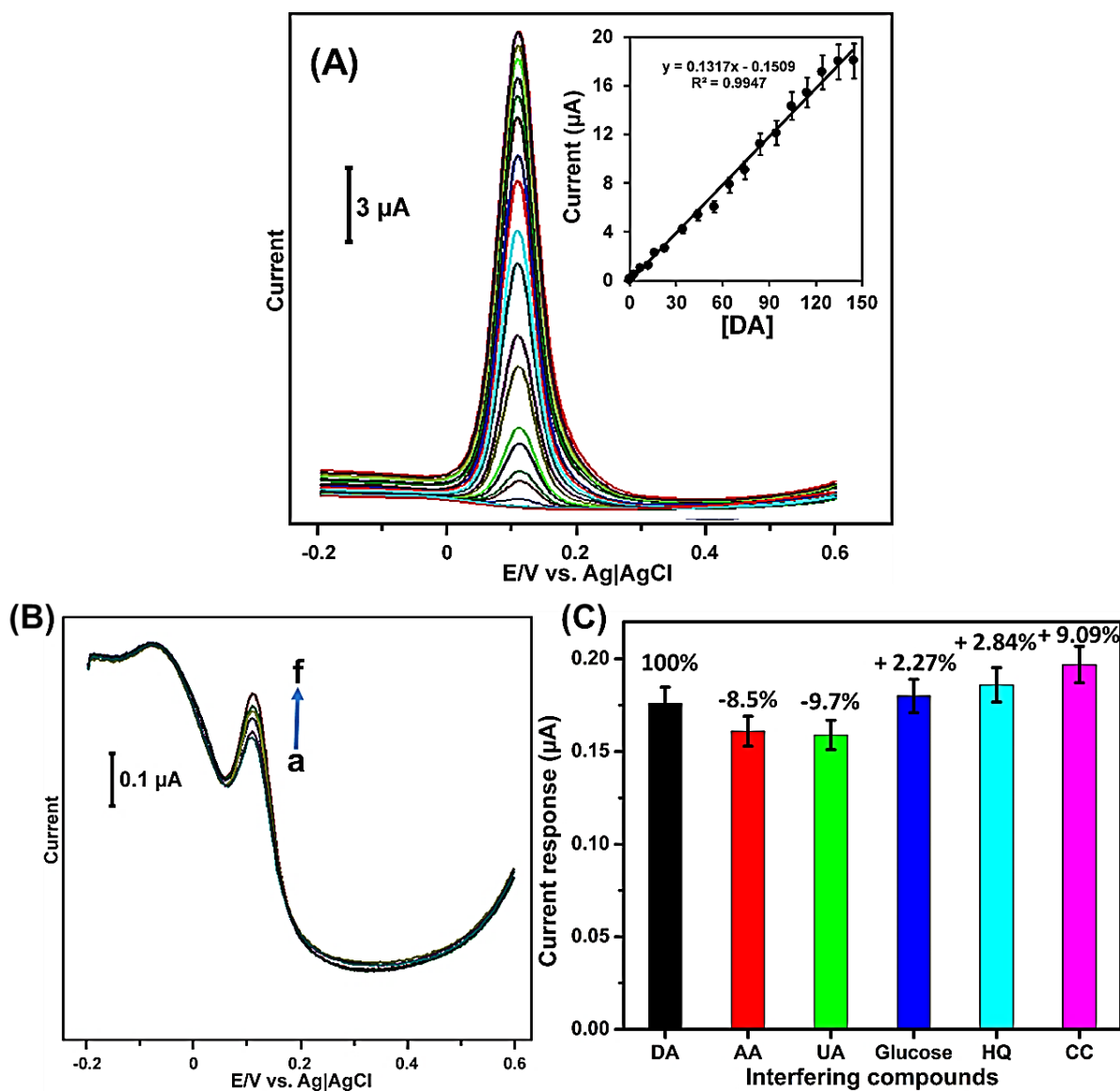
206 diffusion-controlled process at higher scan rates (Palanisamy et al. 2016a). However, as shown in
207 **Fig. 4B**, the anodic and cathodic peak currents of DA exhibit a linear relationship to the scan rate
208 and suggest the electrochemical redox behavior of DA at graphite-CMF composite modified SPCE
209 to be an adsorption-controlled process at slow scan rates (Palanisamy et al. 2016a).

210 The influence of pH on the electrochemical redox behaviour of DA was investigated by
211 CV. Over a pH range from pH 3 to PH 11, the electrochemistry of a graphite-CMF composite
212 modified SPCE in 10 μ M DA was investigated by CV at a scan rate of 50 mVs⁻¹. As shown in **Fig.**
213 **4C**, the graphite-CMF composite modified SPCE displays a well-defined redox couple for DA at
214 each pH value, and the enhanced redox couple of DA were obtained at pH 3.0 to 7.0. In addition,
215 the anodic (E_{pa}) and cathodic peak (E_{pc}) potential of DA shifted towards negative and positive
216 direction upon increasing and decreasing the pH. The result indicates that protons are involved in
217 the electrochemical redox reaction of DA at the graphite-CMF composite modified SPCE. As
218 shown in **Fig. 4D**, the formal potential (defined as $(E_{pa} + E_{pc})/2$) of DA displays a linear relationship
219 with pH over the range of pH 3 to pH 9, with a slope and correlation coefficient of 57.2 mV/pH
220 and 0.9971, respectively. The slope value 57.2 mV/pH is very close to the theoretical slope value
221 for an equal number of protons and electrons transferred electrochemical reaction (Palanisamy et
222 al. 2016a). Hence, the electrochemical redox reaction of DA at graphite-CMF composite modified
223 SPCE is involving of equal number of protons and electrons transferred electrochemical reaction.
224 According to early reports, the electrochemical redox reaction of DA is involving the transfer of
225 two protons and electrons, whereby DA is oxidised to quinone and subsequently reduced to DA
226 (Palanisamy et al. 2016a; Palanisamy et al. 2016b).

227 *Determination of DA*

228 DPV was used for the determination of DA, due to its higher sensitivity and better
229 resolution than other voltammetric methods (Palanisamy et al. 2016c). Under optimized
230 experimental conditions, the DPV response of graphite-CMF composite modified SPCE for the
231 absence and presence of different concentration of DA (0.06 to 144.5 μM) containing N_2 saturated
232 pH 7.0 was examined and the obtained DPV results are shown in **Fig. 5A**. The graphite-CMF
233 composite modified SPCEs do not show any obvious response in the absence of DA (bottom first
234 DPV curve), while a clear oxidation peak response was observed at 0.186 V for the presence of 60
235 nM DA. The oxidation peak current response of DA increased with the addition of DA at pH 7.0.
236 As shown in **Fig. 5A** inset, the oxidation peak current response of DA showed a linear relationship
237 to [DA] 0.06 to 134.5 μM . The regression equation for current response vs. [DA] was i (μA) =
238 $0.1317 + 0.1509 c$ (μM) with the correlation coefficient of 0.9947. The detection limit (LOD) for
239 DA was calculated as 10 nM using the IUPAC recommendations. The sensitivity (defined as slope
240 of calibration plot ($0.1317/\text{ECAS}$ (0.106 cm^2))) of the sensor was estimated to be $1.24 \mu\text{A}\mu\text{M}^{-1}$
241 cm^{-2} . To explain the advantages and novelty of the sensor, the analytical parameters of the sensor
242 was compared with existing DA sensors and comparative results are shown in Table 1. As can be
243 seen that the fabricated DA sensor exhibited a lower LOD, higher sensitivity, and a wider linear
244 range in the detection of DA than previously reported DA sensors using different composite
245 modified electrodes (Palanisamy et al 2013; Palanisamy et al. 2016a; Palanisamy et al. 2016b;
246 Shanbhag et al. 2017; Xu et al. 2017; Caetano et al. 2017; Rahman et al. 2017; Haldorai et al. 2017;
247 Yang et al. 2017; Fang et al. 2017; Daemia et al. 2017; Wang et al. 2017; Zhang et al. 2017;
248 Vellaichamy et al. 2017b). Accordingly, graphite-CMF composite modified SPCE represent an
249 alternative sensitive catalyst for low-level detection of DA. Additionally, the developed DA sensor

250 can be prepared in short time, is less expensive and is highly stable when compared to previously
 251 reported DA sensors as shown in Table 1.



252

253 *Selectivity of the sensor*

254 To evaluate the selectivity of the sensor, the DA response of graphite-CMF composite
 255 modified SPCE was tested in the presence of potential interfering compounds. **Fig. 5B** shows the
 256 DPV response of graphite-CMF composite modified SPCE for the presence of 1 μM DA (c) and
 257 50 μM additions of UA (a), AA (b), glucose (d), HQ (e) and CC (f) into PBS. The corresponding

258 current response change for DA for the presence of a 50 fold addition of interfering species are
259 shown in **Fig. 5C**. It can be seen that the 50 fold addition of interfering species resulted in a limited
260 effect (<10%) on the oxidation peak current response of DA at graphite-CMF composite modified
261 SPCE due to the selective adsorption ability of DA by CMF. The developed sensor is therefore
262 suited to the selective detection of DA in clinical samples.

263 *Determination of DA in human serum samples*

264 To evaluate the practicality of the sensor, the graphite-CMF composite modified SPCE was
265 used for the determination of DA in clinical human serum samples. The human samples were
266 tested by the sensor and showed no detection of DA. The standard DA solution containing human
267 serum samples was injected into the electrolyte solution and the recovery was calculated using
268 standard addition method. The obtained recoveries of DA from human serum samples are shown
269 in **Table 2**. In addition, the graphite-CMF composite modified SPCE shows an appropriate
270 recovery (98.0 to 99.0%) with good repeatability (relative standard deviation = 3.4%) towards the
271 determination of DA. The result indicates that graphite-CMF composite modified SPCE graphite-
272 CMF composite modified SPCE can be used for the accurate detection of DA in biological samples.

273 **Conclusions**

274 In summary, we have demonstrated for the first time, a sensitive and robust DA
275 electrochemical sensor based on graphite-CMF composite modified electrode. Physicochemical
276 characterizations confirmed the exfoliation of bulk graphite into the multi-layered graphene and
277 formation of graphite-CMF composite. Furthermore, the graphite-CMF composite modified
278 electrode displayed higher electrocatalytic activity and lower oxidation potential towards the
279 oxidation of DA than other modified electrodes. The fabricated sensor superior analytical features
280 (high sensitivity, lower LOD and wide linear response range) towards the detection of DA than

281 previously reported DA sensors. The high selectivity and practicality of the sensor further
282 authenticates its potential application in the determination of DA in clinical samples. Additionally,
283 the sensor preparation is simple and less expensive when compared to currently available DA
284 sensors.

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290

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392

393 **Table 1** Comparison of electroanalytical characteristics of graphite-CMF composite modified
 394 SPCE with previously reported modified electrodes for determination of DA.

Modified electrode	LOD (μM)	Linear range (μM)	Sensitivity ($\mu\text{A}\mu\text{M}^{-1}\text{cm}^{-2}$)	Reference
¹ RGO-PdNPs/GCE	0.233	1–150.0	2.62	Palanisamy et al. 2013
² GR-CD/SPCE	0.011	0.1-58.5	1.27	Palanisamy et al. 2016a
³ GR-CS/SPCE	0.0045	0.03-20.06	6.60	Palanisamy et al. 2016b
⁴ Sn@rGO-MnO ₂ NWs/GCE	0.13	0.1-350.0	4.334	Shanbhag et al. 2017
⁵ TGA-MoS ₂ /GCE	0.027	0.05-20.0	Not reported	Xu et al. 2017
⁶ MWCNT/GNPs/GCE	0.071	0.48-5.7	2.06	Caetano et al. 2017
⁷ GNP/FTO	0.22	30.0-100.0	0.15	Rahman et al. 2017
⁸ RGO-TiN/GCE	0.012	0.1-80.0	35.8	Haldorai et al. 2017
⁹ Fe ₂ O ₃ /N-rGO/GCE	0.49	0.5-340.0	0.42	Yang et al. 2017
¹⁰ CD/GO/CF	0.02	0.1-100.0	0.0065	Fang et al. 2017
¹¹ GNCs/CMG/GCE	0.028	0.1-80.0	Not reported	Daemia et al. 2017
¹² Pd/RGO/GCE	0.18	0.45-421.0	Not reported	Wang et al. 2017
¹³ mMWCNTs/SPCE	0.43	5.0-180.0	Not reported	Zhang et al. 2017
¹⁴ PPy-Ag-PVP/GCE	0.0126	0.01-0.09	0.0726	Vellaichamy et al. 2017b
Graphite-CMF/SPCE	0.01	0.06-134.5	1.24	This work

395
 396 ¹RGO-PdNPs/GCE – Reduced graphene oxide-palladium nanoparticles composite modified
 397 glassy carbon electrode
 398 ²GR-CD/SPCE – Graphite-cyclodextrin composite modified screen-printed carbon electrode
 399 ³GR-CS/SPCE – Graphite-chitosan composite modified screen-printed carbon electrode

400 ⁴Sn@rGO-MnO₂ NWs/GCE – Hydrothermally synthesized reduced graphene oxide and Sn doped
401 manganese dioxide nanowires modified glassy carbon electrode

402 ⁵TGA-MoS₂/GCE – Thiol-functionalized single-layered MoS₂ nanosheet modified glassy carbon
403 electrode

404 ⁶MWCNTs/GNPs/GCE – Multiwalled carbon nanotubes and gold nanoparticles modified glassy
405 carbon electrode

406 ⁷GNP/FTO – Gold nanoparticles modified fluorine doped oxide electrode

407 ⁸RGO-TiN/GCE – Reduced graphene oxide and titanium nitride modified glassy carbon electrode

408 ⁹Fe₂O₃/N-rGO/GCE – Iron oxide and nitrogen doped reduced graphene oxide modified glassy
409 carbon electrode

410 ¹⁰CD/GO/CF – Carbon dots and graphene oxide modified carbon fiber

411 ¹¹GNCs/CMG/GCE – Gold nanocages decorated chemically modified graphene oxide modified
412 glassy carbon electrode

413 ¹²Pd/RGO/GCE – Palladium nanoparticles and reduced graphene oxide modified glassy carbon
414 electrode

415 ¹³mMWCNTs/SPCE – Magnetic multiwalled carbon nanotubes modified glassy carbon electrode

416 ¹⁴PPy-Ag-PVP/GCE – Polypyrrole-silver-polyvinylpyrrolidone modified glassy carbon electrode

417

418

419 **Table 2** Determination of DA in human serum samples using graphite-CMF composite (n = 3).

Sample	Detected (μM)	Added (μM)	Found (μM)	Recovery (%)	RSD* (%)
Human serum	0.0	2.0	1.98	99.0	3.1
		2.0	1.96	98.0	3.7

420 *Relative standard deviation for three measurements

421

422 **Figure captions**

423 **Fig. 1** High-resolution SEM images of graphite (A) and graphite-CMF composite (B). Inset of B
424 is the magnified SEM image of graphite -CMF composite. The elemental mapping of graphite (C)
425 and graphite-CMF composite (D).

426 **Fig. 2** A) Raman spectra of graphite (black color) and graphite-CMF composite (green color). B)
427 FTIR spectra of CMF (red color) and graphite-CMF composite (black color). C) FTIR spectrum
428 of graphite.

429 **Fig. 3** A) Cyclic voltammetry response of bare (a), GR (b), CMF (c), CMF drop coated graphite
430 (d) and graphite-CMF composite (e) modified SPCEs in 10 μM DA containing pH 7.0 at a scan
431 rate of 50 mV/s. B) Effect of drop coating amount of graphite-CMF composite on SPCE vs. DA
432 oxidation current response. The experimental conditions are similar to Fig. 3A.

433 **Fig. 4** A) Cyclic voltammograms obtained for graphite-CMF composite modified SPCE in pH 7.0
434 containing 10 μM of DA at different scan rates. Inner to outer shows the scan rates from 20 to 200
435 mVs^{-1}). B) Calibration plot of square root of scan rate vs. I_{pa} and I_{pc} of DA. C) Cyclic
436 voltammograms obtained for graphite-CMF composite coated SPCE for 10 μM of DA containing
437 different pH, pHs were tested in the ranging from 3 to 9 at a scan rate of 50 mVs^{-1} . D) Calibration
438 plot for pH vs. E^0 .

439 **Fig. 5** A) DPV response of graphite-CMF composite modified SPCE in the absence and presence
440 of different concentration additions of DA (0.06 to 144.5 μM) into the N_2 saturated pH 7.0 Inset
441 shows the linear calibration plot for DPV current response vs. [DA]. B) C) DPV response of
442 graphite-CMF composite modified SPCE for the presence of 1 μM DA (c) and 50 μM additions
443 of UA (a), AA (b), glucose (d), HQ (e) and CC (f) into PBS. C) The corresponding results for the
444 effect of 50 folds addition of interfering species vs. DA current response change.