

Supporting Information

Designing and photovoltaic studies of W@TiO₂/rGO Nanocomposites with Polymer Gel Electrolyte

Prakash S. Pawar^{a,b}, Pramod A. Koyale^a, Vijay S. Ghodake^{a,c}, Swapnajit V. Mulik^a, Navaj B. Mullani^{e,f}, Yash G. Kapdi^d, Saurabh S. Soni^d, Sagar D. Delekar^{a,*}

^aNanoscience Research Laboratory, Department of Chemistry, Shivaji University, Kolhapur 416 004, Maharashtra, India

^bDepartment of Chemistry, Shri Yashwantaro Patil Science College Solankur, Kolhapur, 416 212, Maharashtra, India

^cDepartment of Chemistry, Yashwantrao Chavan Mahavidyalaya, Halkarni, Kolhapur, 416552, Maharashtra, India

^dDepartment of Chemistry, Sardar Patel University, Vallabh Vidyanagar, 388120, Gujarat, India

^eResearch Institute for Green Energy Convergence Technology, Gyeongsang National University, Jinju 52828, Rep. of Korea

^fDepartment of Materials Science & Convergence Technology, Gyeongsang National University, Jinju 52828- Rep. of Korea

*Corresponding author:

Prof. (Dr.) Sagar D. Delekar

E-mail: sdd_chem@unishivaji.ac.in

(Tel.: +91-231-2609311, Fax: +91-231-2692333)

Synthesis of Graphene Oxide (GO)

The modified Hummers method was used for the synthesis of graphene oxide (GO)¹. Initially, 2 g of graphite powder was dissolved in a 9:1 equimolar proportion of H₂SO₄ and H₃PO₄ under stirring followed by an addition of some quantity of potassium permanganate. Then the mixture was continuously stirred for 8 hours until the color of suspension turned to slightly green. Further excess amount of KMnO₄ with 30% hydrogen peroxide (H₂O₂) was added gradually under stirring. The said mixture was acidified with dilute hydrochloric acid. Thereafter, the mixture was centrifuged up to 5000 rpm for 30 minutes. The supernatant was discharged followed by washing with an excess quantity of dilute HCl and double-distilled water (DDW). Finally, graphene oxide was desiccated overnight at around 100°C to obtain the GO powder.

Synthesis of Reduced Graphene Oxide (rGO)

100 mg of GO was placed in a round-bottom flask with an equivalent quantity of water to produce a yellow–brown dispersion. The solution was thoroughly sonicated with a bath sonicator until it was clean and no particle matter was visible. Then solution was heated in an oil bath at 120 °C with addition of 1 mL of hydrazine hydrate and NaBH₄ under continuous stirring. The solution was kept for 24 hours; in addition to that, the entire setup was maintained cold by a water-cooled condenser. The GO slowly turned into a black precipitate. After that, it was rinsed in water as well as ethanol and then dried to form a powder².

Synthesis of TiO₂ NPs

TiO₂ NPs were synthesized via sonochemical assisted sol-gel technique, which is reported previously by our research group³. Initially, 5 mL of titanium tetraisopropoxide [Ti (OCH (CH₃)₂)₄] (IV) was added in 5 mL of glacial acetic acid with constant stirring to form a clear solution. To avoid the agglomeration, 0.2 gm of sodium dodecyl sulfide (NaC₁₂H₂₅SO₄) was added to above clear solution followed by the addition of 100 mL distilled water (DW) with constant stirring for 3 hours at 60°C. Thereafter, the whole solution was hydrolysed with dropwise addition of 2 M NH₃ up to a pH of 10.00 for complete hydroxylation to form Ti (OH)₂. The above solution of Ti (OH)₂ was heated to 60°C with constant stirring for 3 hours. Afterward, the solution was cooled and centrifuged followed by washing with DW. Final white colored powder of TiO₂ NPs was obtained after calcination at 450°C for 2 hours.

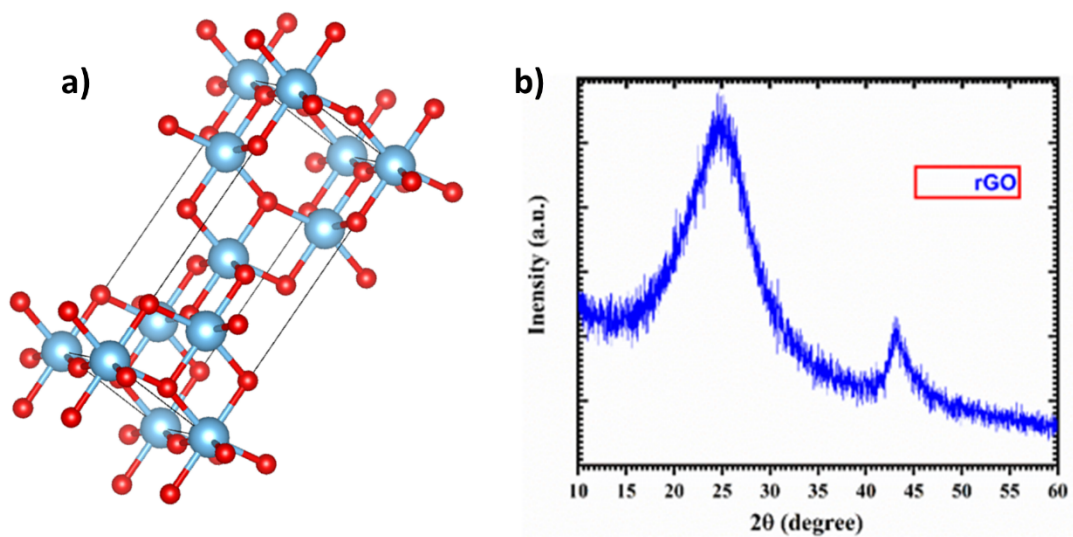


Figure S1. a) Crystal lattice structure of anatase TiO₂ and b) XRD pattern of rGO.

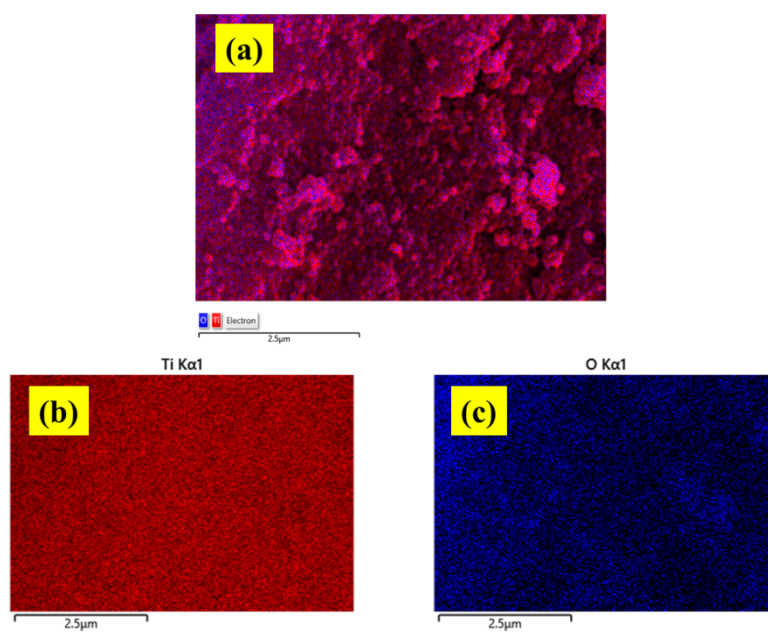


Figure S2. a) Elemental mapping images of TiO₂ NPs, (b) and (c) representing elemental composition of Ti and O with scale bar.

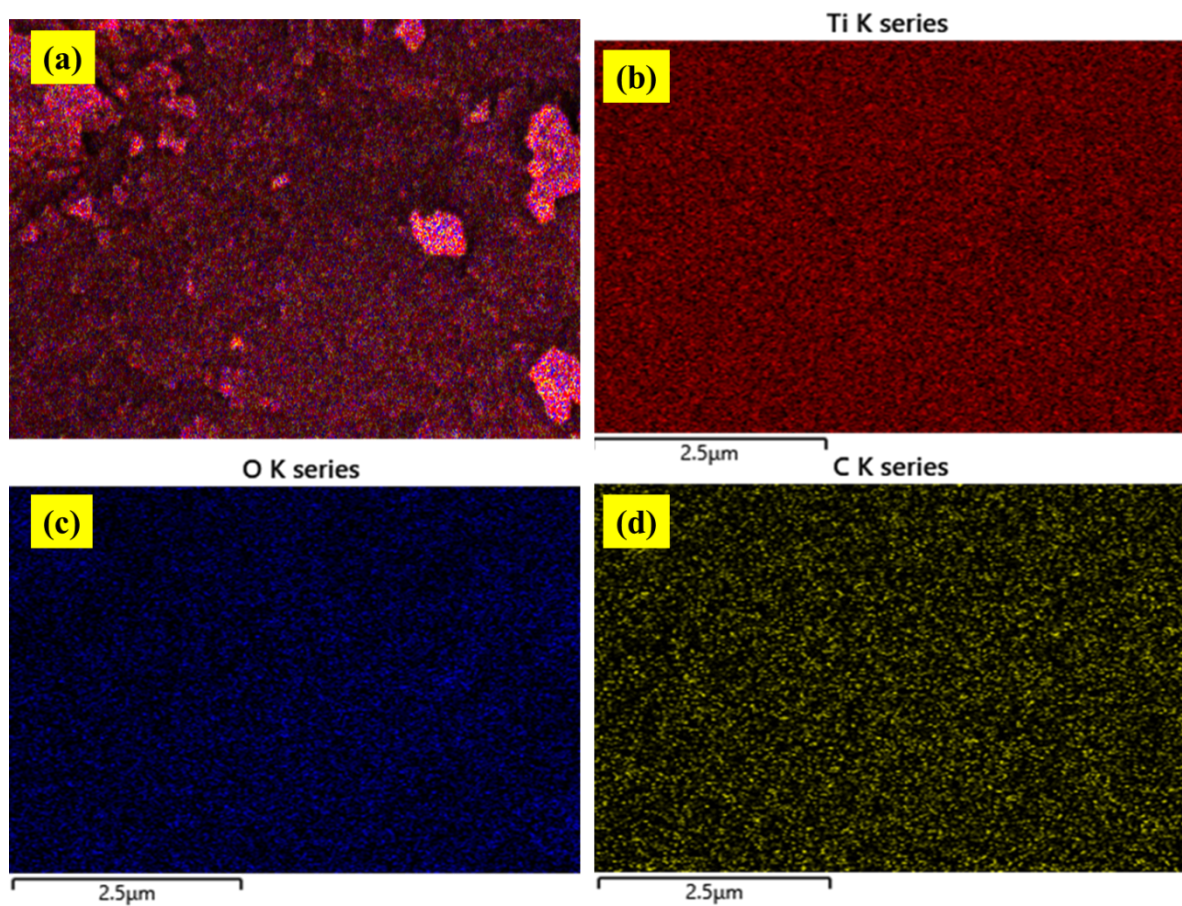


Figure S3. a) Elemental mapping images of TR NCs representing elemental Ti (b), O (c), and C (d).

Table S1. Elemental composition in WR-2 NCs analyzed by XPS data

Element	Atomic (%)
Ti	27.69
O	48.3
C	23.91
W	0.1

Table S2. Demonstrates the comparison of present work with previously reported some research undertakings

Sr. No.	Photoanode materials	Sensitizer	J_{sc} (mA/cm ²)	V_{oc} (mV)	FF (%)	η (%)	Ref.
1	TiO ₂	N719 dye	6.571	450	45.72	1.35	4
2	TiO ₂	N719 dye	07.221	450	46.91	1.52	5
3	TiO ₂	N719 Dye	07.37	0.330	43.77	1.04	3
4	TiO ₂	N3 dye	5.921	430	44.03	1.12	4
5	TiO ₂	N3 dye	1.53	687	0.67	2.36	6
6	Nb ₂ O ₅	N3 dye	0.74	650	0.31	0.50	7
7	ZnO	N3 dye	1.40	470	0.49	0.32	8
8	ZnO	Rose Bengal	4.04	500	0.51	1.03	9
9	TiO ₂	Spinach oleracea	1.11	583	0.46	0.29	10
10	TiO ₂	Rose Bengal	0.12	370	0.46	0.03	11
11	TiO ₂	RuPc Dye	0.46	0.300	57.49	0.07	3
12	TiO ₂ /MWCNTs	RuPc Dye	6.73	0.580	53.24	2.07	3
13	TiO₂	SK3 dye	2.45	0.76	76.79	1.43	Present work
14	TiO₂/rGO	SK3 dye	4.20	0.72	76.65	2.31	Present work
15	W@TiO₂/rGO	SK3 dye	13.1	0.80	65.60	6.87	Present work

References:

- 1 J. Chen, B. Yao, C. Li and G. Shi, *Carbon N. Y.*, 2013, **64**, 225–229.
- 2 K. Prabakaran, P. J. Jandas, S. Mohanty and S. K. Nayak, *Sol. Energy*, 2018, **170**, 442–453.
- 3 S. D. Delekar, A. G. Dhodamani, K. V More, T. D. Dongale, R. K. Kamat, S. F. A. Acquah, N. S. Dalal and D. K. Panda, *ACS omega*, 2018, **3**, 2743–2756.
- 4 A. G. Dhodamani, K. V More, V. B. Koli, A. R. Shelke, N. G. Deshpande, D. K. Panda and S. D. Delekar, *ChemistrySelect*, 2019, **4**, 1055–1068.
- 5 A. G. Dhodamani, K. V More, S. M. Patil, A. R. Shelke, S. K. Shinde, D.-Y. Kim and S. D. Delekar, *Sol. Energy*, 2020, **201**, 398–408.
- 6 S. S. Mali, C. A. Betty, P. N. Bhosale and P. S. Patil, *Electrochim. Acta*, 2012, **59**, 113–120.
- 7 N. I. Beedri, P. K. Baviskar, V. P. Bhalekar, C. V Jagtap, A. M. Asiri, S. R. Jadkar and H. M. Pathan, *Phys. status solidi*, 2018, **215**, 1800236.
- 8 G. Koo, W. Lee, B. Kil, H. Ahn, B. W. Cho and S.-H. Han, *J. Nanosci. Nanotechnol.*, 2011, **11**, 4476–4479.
- 9 S. S. Khadtare and H. M. Pathan, *J. Renew. Sustain. Energy*.
- 10 G. Richhariya, A. Kumar, P. Tekasakul and B. Gupta, *Renew. Sustain. Energy Rev.*, 2017, **69**, 705–718.
- 11 M. A. Waghmare, N. I. Beedri, P. K. Baviskar, H. M. Pathan and A. U. Ubale, *J. Mater. Sci. Mater. Electron.*, 2019, **30**, 6015–6022.