

Progress in Graphene/Metal Oxide Composite Photocatalysts for Degradation of Organic Pollutants

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Table S1. The performance of graphene/TiO₂ composite in degradation of organic dyes.

| Composite/method | Dye/concentration | Light | Degradation performance | Refer. |
|--|---|------------------------------|--|--------|
| GO/F-TiO ₂ composite | MB(10mg/L) | 250W-Hg lamp | 96% in 96min | 1 |
| GO-wrapped TiO ₂ nanoparticles | MB(2.7 × 10 ⁻² mM) | 450W-Xenon lamp | Rate constant: 3.41 × 10 ⁻² min ⁻¹ | 2 |
| G-TiO ₂ composite | MB(1.56 × 10 ⁻³ M) | 500W-Hg lamp | Rate constant: 0.211 min ⁻¹ | 3 |
| TiO ₂ -GO Hydrogel(TGH). | MB(10ppm) | 300W-Hg lamp | | 4 |
| TiO ₂ /GO porous composite | MB(10mg/L) | 50W-Xenon lamps | 96% in 150 min | 5 |
| rGO/TiO ₂ nanocomposite | MB(10mg/L) | UV-vis | 94.2% in 30 min | 6 |
| N,S co-doped rGO/TiO ₂ | MB(3.12 × 10 ⁻⁵ M) CR(3.12 × 10 ⁻⁵ M) RO16(3.12 × 10 ⁻⁵ M) | 500 W-Tungsten lamp | 93% for CR in 50 min, 95% for MB in 120 min; 96% for RO16 in 120 min | 7 |
| Ag/TiO ₂ /rGO composite | MB(10mg/L) | 200W fluorescence xenon lamp | 53% in 4h | 8 |
| Oxygen deficient TiO ₂ -graphene quantum dot hybrid | MB(8mg/L) | Xe-lamp visible light | 97% in 120 min | 9 |
| TiO ₂ /GO nanocomposite by liquid phase deposition | MB (0.1g/L) Ciprofloxacin (0.1 g/L) | UV-visible | 98.67% MB in 45 min; 96.73% ciprofloxacin in 60 min | 10 |
| GR-TiO ₂ composites | MO(10mg/L) | 400 W Halogen-tungsten lamp | Rate constant: 5.66 × 10 ³ min ⁻¹ | 11 |
| TiO ₂ -graphene by electrospinning | MO | UV-light | 46% in 3h | 12 |
| Graphene/TiO ₂ hybrid | Rh B | Mercury lamp | Rate constant (k=0.128 min ⁻¹) | 13 |
| Graphene/mesoporous hollow TiO ₂ nanospheres | Rh B(20ppm) | 11W-Mercury lamp | 91% in 90 min | 14 |

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|--|---------------|---------------------------------|---|----|
| Graphene/Pd/TiO ₂ Nanocomposites | RhB(10ppm) | 400W Mercury lamp | 90% in 40 min | 15 |
| TiO ₂ @rGO composite | Rh 6G(20mg/L) | 300W mercury lamp | k = 0.0717 min ⁻¹ (120 min) | 16 |
| Fe-TiO ₂ /rGO | RhB(20mg/L) | 150 W Xe lamp | 91% in 120 min | 17 |
| RGO-3DGN-TiO ₂ | Phenol | UV-light irradiation | 33×10 ⁻² min ⁻¹ | 18 |
| TiO ₂ /Graphene composite | NO(1ppm) | 8W UV light | NO decrease (~52%); NO _x removal (~43%) | 19 |
| P25-graphene (P25-GR) | NAs (0.1g/L) | 12 W ultraviolet lamp | P25-GR-1%: 80 min | 20 |
| TiO ₂ /GO composite | Yellow 145 | Ultraviolet-visible light lamps | TiO ₂ /GO was almost twice as high as that of TiO ₂ | 21 |

Table S2. The performance of graphene/ZnO composite in degradation of organic dyes.

| Composite/method | Dye/concentration | Light | Degradation performance | Refer. |
|--|-----------------------------|--|---|--------|
| GO/ZnO hybrid thin films | MB/3M | 250 W mercury lamp | 4 cm ² of ZnO nanorod-1 wt% GO thin films: 99% MB in 450 min | 22 |
| 3D graphene/ZnO nanorods by CVD and hydrothermal | MO/0.1mM | UV light-300W | 120mg/20ml G/ZnO composite, 92% after 3h | 23 |
| ZnO quantum dot/GO by chemical method | MO/1.5×10 ⁻⁴ M | UV light-100W | Entirely degrading MO in 30 min | 24 |
| ZnO-GO composite by chemical corrosion | MO/5.0×10 ⁻⁵ M | UV-VIS, 300W xenon lamp, 20.15mW/cm ² | 87% in 180 min, 8 mg photocatalyst | 25 |
| Cu-coated ZnO/rGO microwave-assisted hydrothermal | MB/10 ppm | 40W UV light | 98% in 120 min | 26 |
| ZnO-GO by microwave ultrasound | MB/0.045mg/ml | UV Hg lamp λ _{max} =365nm | 70% in 70 min | 27 |
| ZnO/GO by electrochemical deposition | MB/1 μM | 4W UV lamp | 60% in 120 min | 28 |
| ZnO on NGO by in-situ growth | MB/10 mg/L | Xenon lamp-300W | 99% in 120 min | 29 |
| ZnO/GO by solvothermal | MB/1 mmol | UV light-40W | 98.5% in 15 min | 30 |
| ZnO nanoparticles/rGO by one-step photochemical method | MB/0.01 g/L | UV lamp, UV-VIS-300 W | 10 mg, 99% and 90% in 120 min by UV and visible light | 31 |
| ZnO/NG material by in-situ thermal precipitation | MB/100 mg/L | 300W-UV lamp (300W xenon lamp) | 100 mg, 96% in 30 min by UV light; 93.2% in 120 min by visible light | 32 |
| N-doped ZnO/GO by microwave reactor | MB/30 ppm | 200 W-UV lamp; 50W halogen lamp | 98% in 35 min by UV, 93% by visible light | 33 |
| rGO/ZnO hollow sphere by ultrasonic treatment | MB/1×10 ⁻⁵ mol/L | 500 W mercury lamp | 20 mg, 100% in 1.5h | 34 |

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|---|---------------------------------------|--|---|----|
| ZnO/GO by ultrasonic assisted precipitation method | MB/25 ppm | a400 W halogen lamp | 0.1g, 86.9% in 105 min | 35 |
| ZnO/GO by chemical precipitation | MB/ 1×10^{-5} mol/L | 300 W-Xe lamp | 50 mg, 100% in 100 min | 36 |
| ZnO-GO by solvent milling and annealing | MB/20 ppm | 400-W halide lamp | 15 mg, 100% in 70 min | 37 |
| ZnO microsphere/rGO by solution method | MB/10mg/L | 300W xenon lamp (200-400 nm) | 0.2 g; maximum degradation rate of $\sim 0.21 \text{ min}^{-1}$ | 38 |
| Graphene quantum dots/ZnO nanorods | MB/ 1×10^{-5} mol/L | Natural sunlight | 20 mg; 95% in 70 min | 39 |
| ZnO nanoparticles/rGO surface by photochemical reaction | MB/0.01g/L | 300 W xenon lamp | 10 mg; 60% in 2h | 40 |
| ZnO nanoparticles/rGO | MB/ 1×10^{-5} mol/L | 8W-UV lamp | $k = 0.098 \text{ min}^{-1}$ | 41 |
| Flower-like ZnO/GO by chemical precipitation | MB/ 5.0×10^{-5} mol/L | 300W-Xe light | 80 mg; 98.1% in 60 min | 42 |
| Ag NPs/ZnO NRs/3DG by hydrothermal deposition | MB/10 ppm | 15W-UV irradiation; 8 W-LED lamp | 43% by visible illumination; 40% under UV light | 43 |
| TiO ₂ nanorod array/graphene/ZnO by chemical deposition method | MB/5 mg/L | 300W xenonarc lamp | 82% | 44 |
| ZnS-ZnO/Graphene by solid-phase method | RhB/ 1×10^{-5} mol/L | 400W halide lamp | 10 mg; 99% in 90 min | 45 |
| ZnO NR/rGO by low temperature chemical method | RhB/ 2.0×10^{-5} mol/L | 300W xenon Lamp | 5 mg; 97% in 140 min | 46 |
| G-ZnO NCs by chemical precipitation | RhB/ 1×10^{-5} M | UV-VIS $\lambda_{\text{max}} = 660\text{nm}$ | 100% in 90 min | 47 |
| Flower-like ZnO/rGO | RhB/ 1×10^{-5} mol/L | 500W Xe lamp | 50 mg; 100% in 40 min | 48 |
| rGO-ZnO | | UV-light | 98.9 % in 60 min | 49 |
| Core-shell structure ZnO/graphene by solvothermal | RhB/10 mg/L | 300W xenon lamp | 50 mg; 98.5% in 35 min | 50 |
| ZnO/3D rGO foam by one-step hydrothermal method | RhB/5 ppm | High-pressure Xe lamp | 95% in 150 min | 51 |
| Oval-shaped graphene/ZnO quantum dots by hydrothermal method | 2-nitroaniline 7.5×10^{-4} M | UV light | 100% in 35 min | 52 |
| ZnO nanorods/rGO by solvothermal method | Orange II 10 mg/L | Solar light irradiation | 99% in 150 min | 53 |

Table S3. The performance of graphene/SnO₂ composite in degradation of organic dyes.

| Composite/method | Dye/concentration | Light | Degradation performance | Refer. |
|---|---------------------------|-------------------------|---|---------------|
| SnO ₂ nanorods-GR | RhB(5×10 ⁻⁵ M) | 12 W UV lamp | 94% in 60 min | 54 |
| SnO ₂ /GO | RhB(10mM) | white light(100 W) | 86% in 360 min | 55 |
| SnS ₂ -SnO ₂ /rGO | RhB(100mg/L) | 500 W Xenon lamp | 95.9% RhB in 30 min | 56 |
| Fe-doped SnO ₂ /rGO | RhB(5.1-6.0m) | 0.2 W visible light | 93% RhB in 2h | 57 |
| rGO/SnO ₂ nanocomposite | RhB(10ppm) | UV light | 100% RhB in 25 min | 58 |
| | | solar light | 98%RhB in 50 min | |
| SnO ₂ /GO nanocomposite | MO(20mg/L)、RhB(20mg/L) | 300W mercury lamp | 95% MO in 40 min 97% RhB in 60 min | 59 |
| SnO ₂ /rGO-HM | MB(10mg/L) | UV light | Rh B in 40 min | 60 |
| | RhB(10mg/L) | | MB in 20 min | |
| SnO ₂ /GO microspheres | MO(8mg/L) | 300 W mercury lamp | IO-SnO ₂ /G-0.06 the best photocatalytic effect | 61 |
| SnO ₂ @GO nanocomposites | MO(20mg/L) | UV-light | 100% in 120 min | 62 |
| SnO ₂ aerogel/rGO Nanocomposites | MO(1×10 ⁻⁵ M) | UV lamp(40W) | 84% in 60 min | 63 |
| SnO ₂ dense layers on rGO | PNP(0.02g/L) | UV tube-like lamp (8 W) | 95.6% in 6 h | 64 |
| Au-SnO ₂ -rGO ternary nanoheterojunction | Clothianidin(1.0mg/L) | 30W UV-LED light | 97% in 120 min | 65 |
| SnO ₂ /GQDs composites | NO(600ppb) | Xe lamp | 57% in 30min | 66 |

Table S4. The performance of graphene/WO₃ composite in degradation of organic dyes.

| Composite/method | Dye/concentration | Light | Degradation performance | Refer. |
|--|--------------------------|--------------------|---|---------------|
| Few-layer GO/WO ₃ thin films by nano-particle deposition system | MB(5ppm) | 100W halogen lamp | 37% in 2 h | 67 |
| WO ₃ -GO nanocomposite | MB(20ppm) IC(20ppm) | Sunlight | 97.03% MB in 150 min 95.43% IC in 120 min | 68 |
| WO ₃ /RGO composites by solvothermal method. | MB(15mg/L) | 350 W Xenon lamp | 94.1% in 150 min | 69 |
| Mesoporous WO ₃ -GO | MB(0.01mol/L) | 250 W visible lamp | 90% in 70 min; Pt/WO ₃ -GO nanocomposites: 94% in 70 min | 70 |
| WO ₃ nanorods-GO | MB(10mg/L) | 400W visible light | 80% in 5 h | 71 |
| WO ₃ nanorods @GO nanocomposites | MO(0.025g/L) | Xenon lamp (150W) | 92.7% in 120 min | 72 |

Table S5. The performance of graphene/Fe₂O₃ composite in degradation of organic dyes.

| Composite/method | Dye/concentration | Light | Degradation performance | Refer. |
|--|----------------------------|-------------------|----------------------------------|---------------|
| α -Fe ₂ O ₃ /GO | RhB(10 mg/L) | 350 W Xe light | 98% in 20 min | 73 |
| α -Fe ₂ O ₃ nanorod/RGO | 10 ppm phenol | visible-light | 67 % phenol in 2 h | 74 |
| γ -Fe ₂ O ₃ /GO | MO | solar irradiation | 98% MO in 60 min | 75 |
| Fe ₂ O ₃ /RGO nanocomposite | 4-Nitrophenol dye(10 mg/L) | Visible light | 100% 4-Nitrophenol dye in 50 min | 76 |
| Fe ₂ O ₃ /N-GO(MNG) | MB(40 mg/L) | 500W Xe lamp | MNG(0.5):100% MB in 240 min | 77 |

Table S6. The performance of graphene/other metal oxides in degradation of organic dyes.

| Composite/method | Dye/concentration | Light | Degradation performance | Refer. |
|---|-----------------------------------|--------------------|--|---------------|
| Gu ₂ O-RGO by in-situ reduction | RhB 10mg/L | 500W Xe lamp | 98.9% in 150 min | 78 |
| Cu ₂ O/rGO-x by wetchemical method | SMX 5mg/L MB 5mg/L | 300W Xe lamp | SMX: 50% in 120 min MB: 100% in 40 min | 79 |
| Cu ₂ O/RGO by chemical precipitation | Methylthionine chloride 10mg/L | 11W LED lamp | 55% in 200 min | 80 |
| graphene oxide-CeO ₂ nanocubes By a one-step hydrothermal route | MB 1 × 10 ⁻⁵ M | 500W mercury lamp | UV-light 90 min 87% | 81 |
| Graphene -V ₂ O ₅ by solution mixing method | MB | Mercury lamp | UV light k = 0.94 ± 0.047 visible light k = 1.54 Sunlight k = 2.2 ± 0.11 | 82 |
| rGO-V ₂ O ₅ | MB 50 mL | Mercury lamp | 85% in 225 min | 83 |
| p-type NiO/n-type GO | MB 50mg/L | 500 W mercury lamp | 97% in 150 min | 84 |
| GO wrapped α-MoO ₃ | MB 30M | Sun light | 78.89% in 75 min | 85 |
| Graphene nanocluster /Nb ₂ O ₅ nanofibers | MO 20mg/L | 400 W halide lamp | 1gk ⁻¹ =0.5470 h ⁻¹ | 86 |
| 3D porous graphene-Co ₃ O ₄ by freeze-drying | MO 20mg/L | 500W xenon lamp | 88.9% in 50 min | 87 |

Table S7. The performance of graphene-based ternary composite in degradation of organic dyes.

| Composite/method | Dye/concentration | Light | Degradation performance | Refer. |
|--|---|-------------------------------|--|--------|
| Ternary TiO ₂ /WO ₃ /graphene | RhB/ 50 mg g ⁻¹ | UV | 95% in 25 min | 88 |
| Graphene-Ag/ZnO ternary composite by solvothermal method | MB/ 20mg/L RhB/ 20mg/L MO/ 20mg/L | 400W Metal halogen lamp | MB r = 1.16×10 ² RhB r = 0.78 MO r = 0.56 | 89 |
| TiO ₂ NSAs / graphene / Cu ₂ O on carbon fiber | 20 ml RhB solution (10 mg/L). | 500 W Xe lamp | 80% in 180 min | 90 |
| BiVO ₄ /RGO/Ag ₃ PO ₄ by sequential deposition | 10 mg/L RhB 5 mg/L 4-NP | 500 W xenon lamp | 98.2% RhB in 45 min; 82.1% 4-NP in 45 min | 91 |
| BiVO ₄ /Mn-Znferrite(Mn _{1-x} Zn _x Fe ₂ O ₄)/rGO by calcination and reduction method | RhB 5.0 mg/L | 500 W Xe lamp | 96.0% in 1.5 h | 92 |
| 50%BiOCl/BiOI/RGO by solvothermal route | RhB 10 mg/L | 350 W Xe lamp | 51.1% in 5 min | 93 |
| Z-scheme g-C ₃ N ₄ /RGO/BiVO ₄ by hydrothermal method | RhB 20 mg L ⁻¹ | 300 W Xeon arc lamp | 100% in 20 min Rate constant = 1.537 | 94 |
| TiO ₂ /CNTS/RGO by one-pot pyrolysis method | RhB 10 mg L ⁻¹ | 300W Xenon lamp | k = 0.00689min ⁻¹ | 95 |
| RGO-Ag/TiO ₂ | Bisphenol A | 500W tungsten halogen lamp | 40.0% in 6 h | 96 |
| ZnO/COFe ₂ O ₄ /graphene | MB 5 mg/L | 12 W UV lamp | 98.9% in 2 h | 97 |
| RGO/BiVO ₄ /TiO ₂ hydrothermal method | MB 10 ppm | 500 W halogen lamp | Rate constant 4.59×10 ⁻¹ min ⁻¹ | 98 |

| | | | | |
|--|---|-----------------------------|--|-----|
| ZnO@ZnS/GR | MB | 400W | 99% MB and 97.5% MO | 45 |
| by solid thermal synthesis | MO | Metal halide lamp | in 150 min | |
| ZnO@ZnS hollow dumbbells-graphene | MO 10 ppm | High pressure mercury lamp | $K = 0.019 \text{ min}^{-1}$ | 99 |
| by hydrothermal reaction | | | | |
| Ni/graphene/Au/ZnO | MO 20mg/L | 300w mercury lamp | 90% in 3 h | 100 |
| by hydrothermal method | | | | |
| Fe-Cu-ZnO/GO composites | Dark green | 23W visible lamp | 99.28 % in 90 min | 101 |
| by sol-gel method | 50 mg/L | | | |
| Eu ³⁺ -ZnO/Bi ₂ O ₃ on the surface of GO sheets | 2,4-dimethyl phenol (DMP) | 400W halogen lamp | 98 % DMP in 100 min | 102 |
| Cu ₂ O/SnO ₂ /graphene(CSG) | 50 mg L ⁻¹ pendimethaln solution | 500W xenon lamp | 99% in 3 h | 103 |
| by simple sol-gel growth method | | | | |
| Cu ₂ O/RGO/In ₂ O ₃ | MB 10 mg L ⁻¹ | 300 W Xe-lamp | 95.1% in 2 h | 104 |
| Fe ₃ O ₄ @V ₂ O ₅ /rGO | Bismarck Brown Acid Orange 0.2mM | 400W visible lamp, 125 W UV | sunlight BB, AO 32% and 26% in 70-80 min | 105 |
| Indigo-rgo/WO ₃ /graphene | MB 10ppm | Sunlight | pH 11.0 with 30mg of catalyst. 80.41% | 106 |
| by hydrothermal method | | | | |
| Z-scheme BiVO ₄ /RGO/Ag ₃ PO ₄ /Ag | TC 0.5 g/L | 300W Xe lamp | pH 6.75: 94.96% in 60 min | 107 |

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