# Analysis of microbial reduction of graphene oxide: A green synthesis approach

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## DECLARATION

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## ABSTRACT

Over the last decade, graphene and its related materials have gained intense research interest because of their remarkable physical, electrical, and thermal properties. However, producing graphene at large scales is often expensive. Conventional production methods use high heat, leading to a rise in carbon dioxide emissions and the use of hazardous materials. This study explored using E-Coli as a more economical, eco-friendly electron transfer medium for rGO production. The E-Coli was collected from the Beira river basin and grown using LB broth. GO was synthesized with Tour's method and reduced with E-Coli at 37 °C to boost bacterial activity. Samples were characterized at intervals of 24, 48, and 72 hours. MrGO was further analyzed with UV-visible absorption spectroscopy (UV-Vis), Powder X-ray diffraction (XRD), Raman spectroscopy, X-ray photo spectroscopy (XPS), and scanning electron microscopy (SEM). After the reduction, XPS data showed a considerable amount of oxygen species were removed, and the C/O ratio evidenced it with an increase from 1.84 to 3.24, which confirmed that $sp^2$ graphitic carbon content has increased over time. FTIR showed similar results, indicating that E-Coli intermediated reduction is successful and displayed a severe reduction in oxygen functional peak intensities. Raman spectroscopy showed that the ID/IG ratio increased from 1.01 to 1.17 after 72 hours. XRD data validated the shift from crystalline nature to amorphous after 24 hours and which increased towards the end of 72 hours.

Moreover, E-Coli reduced MrGO exhibited traces of nitrogen as well. N-Doped logo can be used in composite applications due to its enhanced mixing capabilities and improved stability in the dispersion stage. The microbial pathway is a partial reduction pathway, capable mainly of reducing hydroxyl, carbonyl, and epoxy groups than ketones and carboxyl, which can be a selective reduction method and biological functionalization method.



Keywords: Graphene oxide, Reduced graphene oxide, Microbial reduction, Green synthesis, Nitrogen doping

## DEDICATION

I dedicate this thesis to my wife, parents, and in-laws for their support and encouragement and unconditional love

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## LIST OF ABBREVIATION

| | |
|---|---|
| GO | - Graphene oxide |
| rGO | - Reduced graphene oxide |
| NMR | - Nuclear magnetic resonance spectroscopy |
| STM | - Scanning tunnelling microscopy |
| CO | - Carbon monoxide |
| $CO_2$ | - Carbon dioxide |
| GIC | - Graphite intercalation compound) |
| PGO | - Pristine graphite oxide |
| XRD | - X-ray diffraction |
| 2D | - Two-dimensional |
| CV | - Cyclic voltammetry |
| $KNO_3$ | - Potassium nitrate |
| C/O | - Carbon to Oxygen |
| EPD | - Electrophoretic deposition |
| CNT | - Carbon nanotubes |
| PVA | - Polyvinyl alcohol |
| CVD | - Chemical vapour deposition |
| AFM | - Atomic force microscopy |
| $HNO_3$ | - Nitric acid |
| $H_2SO_4$ | - Sulfuric acid |
| $KClO_3$ | - Potassium chlorate |
| $NO_2$ | - Nitrogen oxide |
| $N_2O_4$ | - Dinitrogen tetroxide |

| | |
|---|---|
| $KMnO_4$ | - Potassium permanganate |
| $K_2S_2O_8$ | - Potassium persulfate |
| $P_2O_5$ | - Phosphorous pentoxide |
| $H_2O_2$ | - Hydrogen peroxide |
| $H_3PO_4$ | - Phosphoric acid |
| $N_2$ | - Nitrogen |
| $NH_3$ | - Ammonia |
| MrGO | - Microbial reduced graphene oxide |
| XPS | - X-ray photoelectron spectroscopy |
| TEM | - Transmission electron microscope |
| ATP | - Adenosine triphosphate |
| EDX | - Energy dispersive x-ray analysis |
| FTIR | - Fourier transform infrared |
| TGA | - Thermogravimetric analysis |
| YR-GO | - Yeast-reduced graphene oxide |
| HR-TEM | - High-resolution transmission electron microscope |
| NADPH | - Nicotinamide adenine dinucleotide phosphate |
| $MnO_3^-$ | - Manganate (V) |
| $Mn_2O_7$ | - Manganese heptoxide |
| HCl | - Hydrochloric acid |
| DI water | - Deionized water |
| SEM | - Scanning electron microscope |
| PXRD | - Powder x-ray diffraction |
| NIR | - Near infrared reflectance |

MIR - Mid infrared reflectance

FIR - Far infrared reflectance

NaCl - Sodium chloride