Fabrication of flexible, conductive polypyrrole-graphene quantum dot (PPy-GQD) nanocomposite via electrodeposition on carbon fiber mesh

Devon Leighton, Ankarao Kalluri, Isaac Macwan, Prabir Patra
Department of Biomedical Engineering
University of Bridgeport, Bridgeport, CT

Abstract

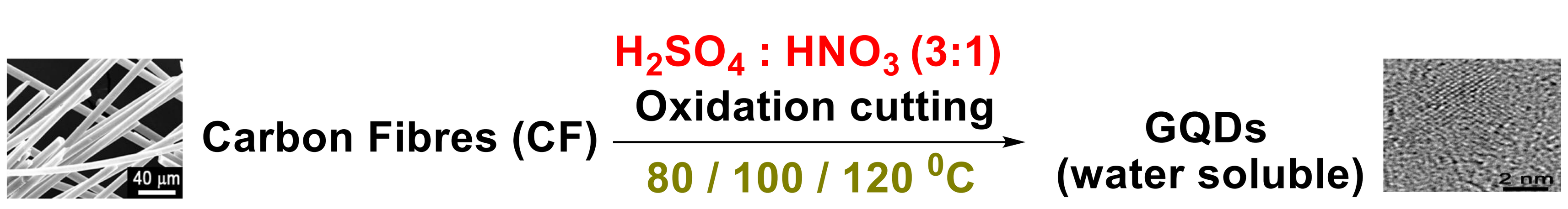
Carbon fibers have recently gained popularity for their variety of applications as a working electrode material. Due to their conductive nature, high specific surface area, and chemical inertness, they prove to be an ideal material for electrodeposition of a variety of materials for future in vivo or in situ biomedical applications. Here, we use cyclic voltammetry to simultaneously polymerize polypyrrole (PPy) and integrate graphene quantum dots (GQDs), while depositing onto a carbon fiber mesh (CF). Polypyrrole has been used in a variety of applications due to it's conductive nature and GQDs have been used for their electronic properties as well. This nanocomposite will be further characterized using SEM, TEM, Raman, cyclic voltammetry, and electrochemical impedance spectroscopy to determine structural and functional capabilities.

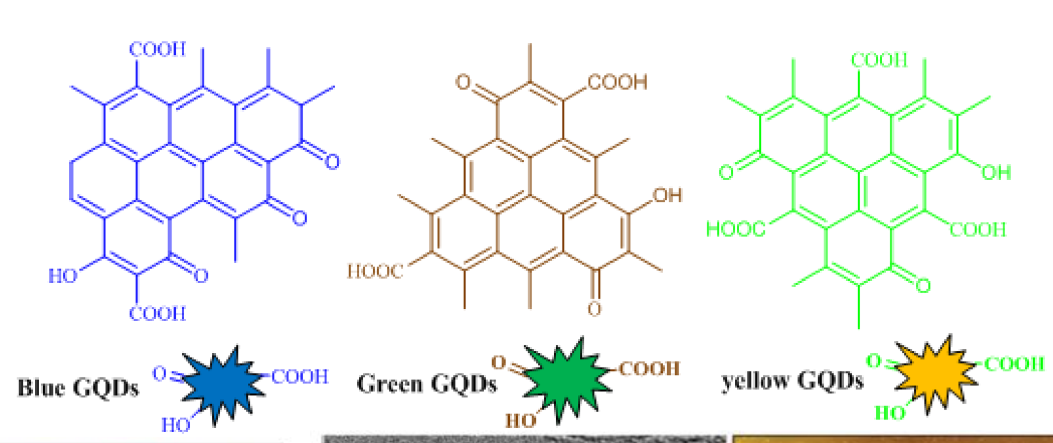
1. Introduction

- GQDs fabricated by chemical exfoliation of carbon fibers show incredible electronic and optical properties. GQDs are in the range of 1-4nm and have significant potential for neural probe applications.[1]
- Polypyrrole is a conductive polymer that can be synthesized via electropolymerization; a 3-electrode configuration (monomer: pyrrole, solvent: water, and electrolyte: $NaSO_4$) to produce thin films.[4]
- Doping material and amount can vary the conductivity of the polypyrrole due to it's enhanced charge mobility along and between polymer chains.[4]
- Carbon fiber mesh is used as a working electrode due to it's chemical inertness, outstanding mechanical and electrical properties, and high specific surface area for deposition. Further, due to their small diameter and biocompatibility, they have the potential to be used for in vivo and in situ applications.[3]
- Carbon fiber mesh was used in this application due to it's flexibility.
- The proposed use of this nanocomposite material is for neural probe applications. Research has shown that increased neurite outgrowth and neuron differentiation has occurred with applied electrical stimulation.[5]

2. Fabrication of GQDs

GQDs are fabricated by acid treatment and chemical exfoliation of carbon fibers[1].





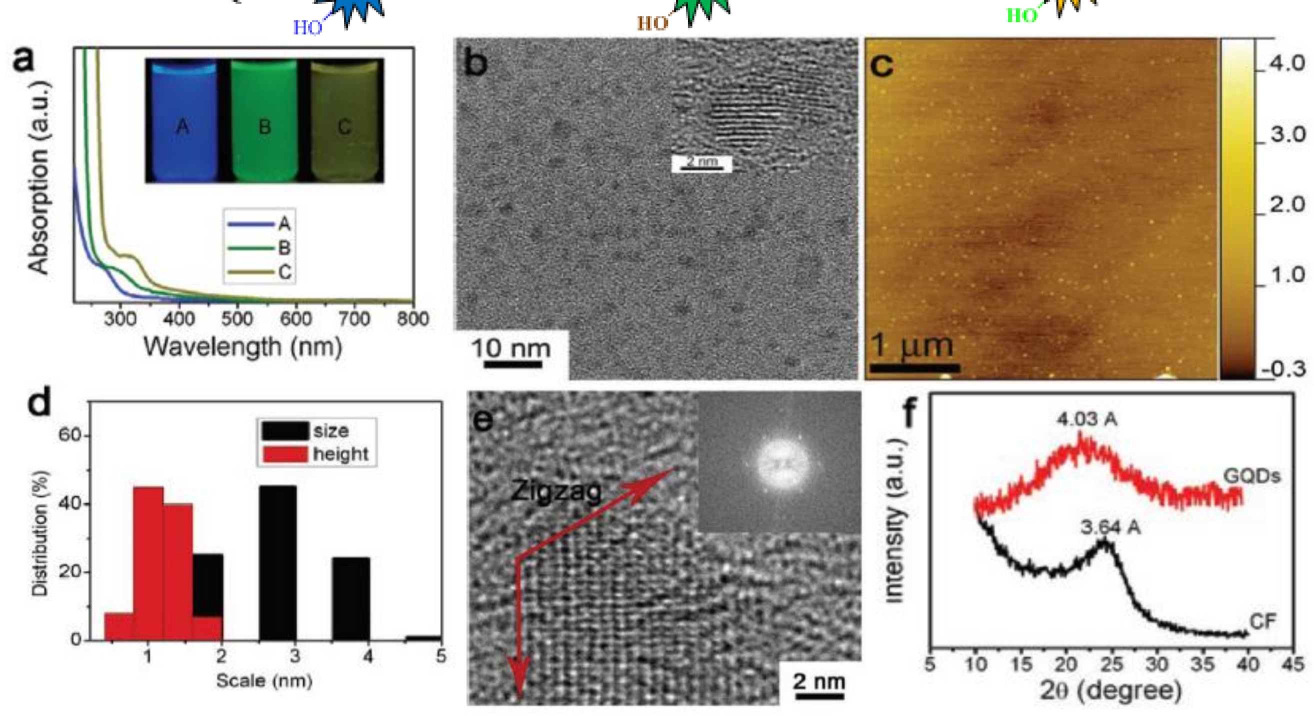
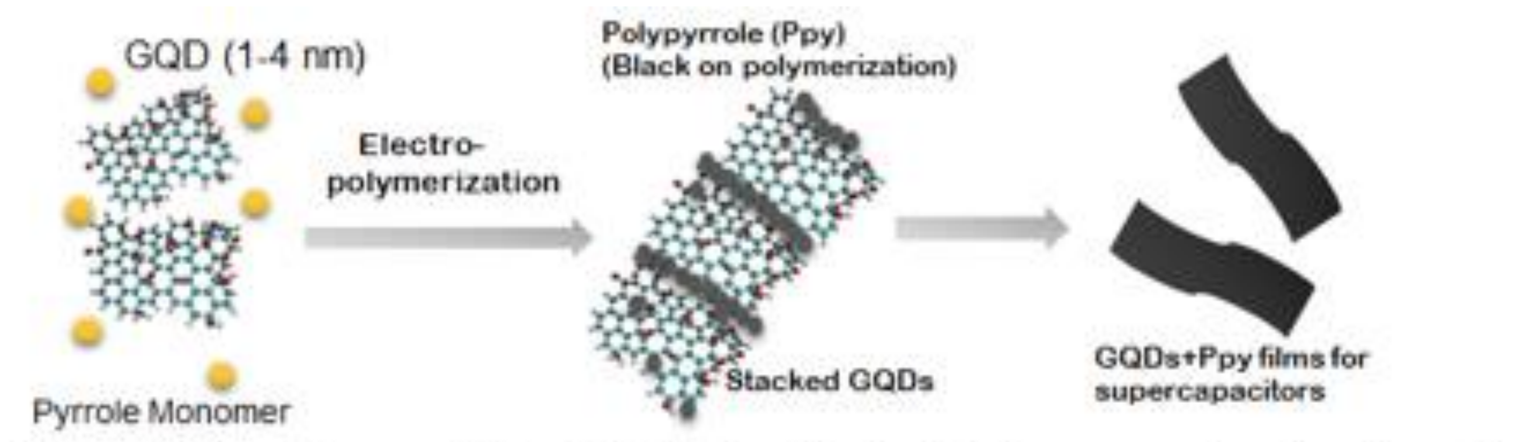


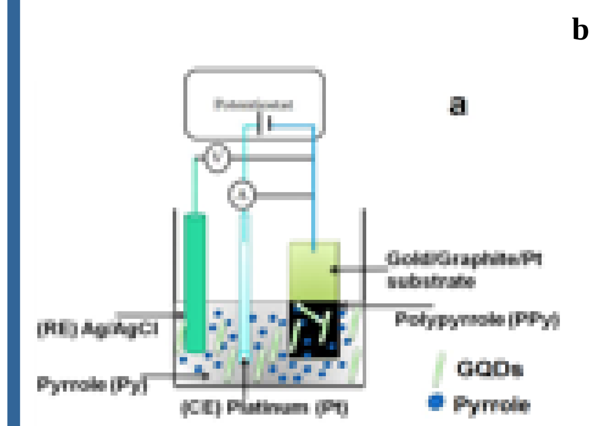
Fig 1: (a) UV−vis spectra of GQDs A, B, and C, corresponds to synthesized reaction temperature at 120, 100 and 80 °C respectively. (b) TEM images of GQDs (synthesized reaction temperature at 120 °C), inset of (b) is the HRTEM of GQDs. (c) AFM image of GQDs. (d) Size and height distribution of GQDs. (e) HRTEM image of the edge of GQD, inset is the 2D FFT of the edge.

3. Fabrication of Flexible Electrodes

Here, we report the in-situ fabrication of a flexible carbon fiber mesh electrode via electrochemical polymerization and deposition (CV) of pyrrole, integrated with GQDs.



Scheme 2: Schematic representation of GQDs-PPy electrodes fabrication process by cyclic voltammetry.



b

Sample	Voltage (mV)	Scan Rate	Cycles
CF-PPy	800-900	10mV/s	250 500
		20mV/s	250 500
CF-PPy-GQD	800-900	10mV/s	250 500
		20mV/s	250 500

Fig 2. (a) Schematic of CV fabrication process of GQD-PPy nanocomposite. (b) CV parameters for nanocomposite samples.

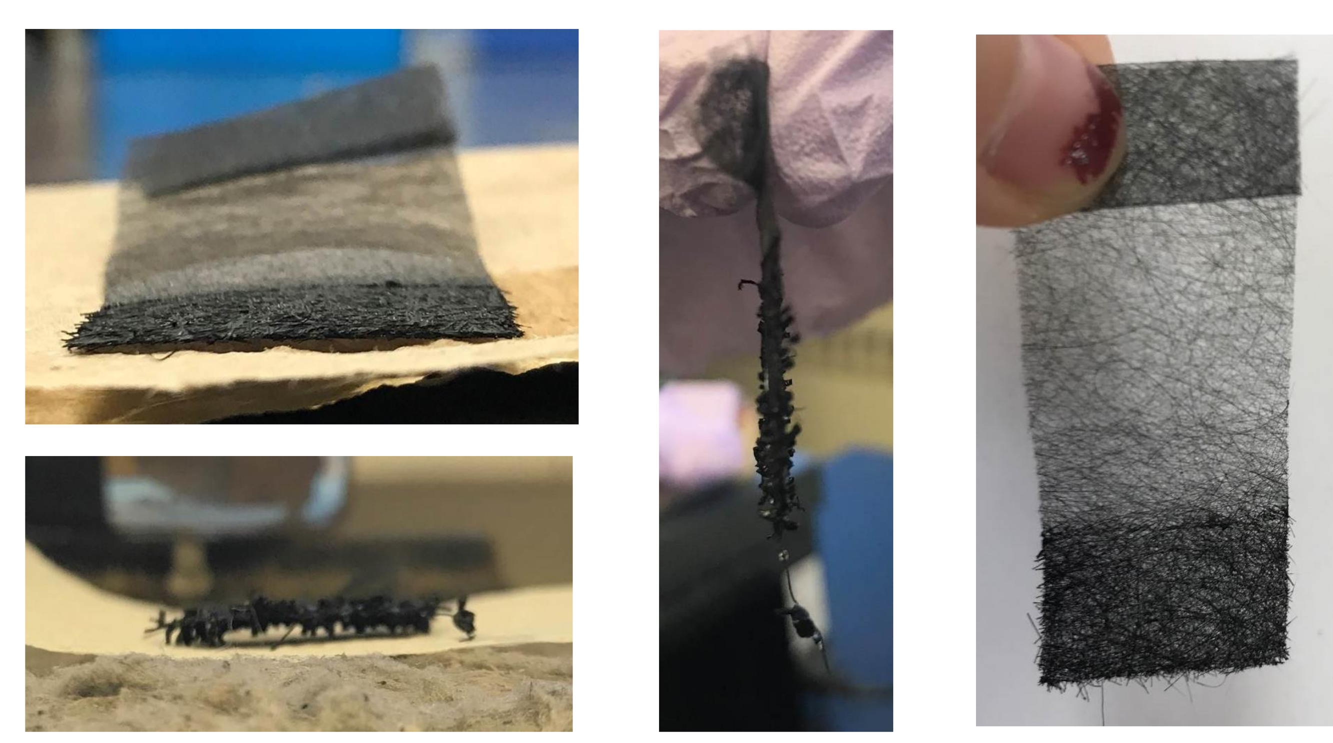


Fig 3. Optical image of CF-PPy-GQD nanocomposite at varied orientations.

4. Conclusions and Future Work

- Flexible nanocomposites were fabricated via electrodeposition, simultaneously incorporating a conductive polymer polypyrrole, nanomaterial graphene quantum dots, and a fibrous carbon fiber mesh.
- Due to high specific surface area, conductive nature, and unique nanomaterial properties, these materials have potential for a variety of biomedical and electronic applications.
- We will further focus on using these materials in neural probes applications.

References

1. Peng, J. *et.al.* Graphene quantum dots derived from carbon fibers. *Nano Letters* 12, 844-849 (2012).
2. Aphale, A. *et.al*, 2015. Hybrid Electrodes by In-Situ Integration of Graphene and Carbon-Nanotubes in Polypyrrole for Supercapacitors. *Sci. Rep.* 5, 14445 (2015).
3. Mohammadzadeh Kakhki, R. A review to recent developments in modification of carbon fiber electrodes. Arabian Journal of Chemistry (2014).
4. Huang, Z., Yin, G., Liao, X., & Gu, J. (2014). Conducting polypyrrole in tissue engineering applications. *Frontiers of Materials Science,8*(1), 39-45.
5. Schmidt, C. E., Shastri, V. R., Vacanti, J. P., & Langer, R. (1997). Stimulation of neurite outgrowth using an electrically conducting polymer. *Proceedings of the National Academy of Sciences,94*(17), 8948-8953.