ENHANCED SEPARATION OF HETEROGENEOUS CARBON MICROSPHERES FOR SUPERCAPACITOR ELECTRODES

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Thesis submitted in partial fulfillment of the requirements for the degree

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DECLARATION

I declare that this is my own work, and this thesis/dissertation does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other University or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text. I retain the right to use this content in whole or part in future works (such as articles or books).

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DEDICATION

To my family for always believing in me and cheering me on.

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ABSTRACT

This study focuses on the development and optimization of a microfluidic system for effective separation of carbon microspheres with heterogeneous surface properties. Traditional microparticle separation methods such as, micro-sieving, centrifugal separation, and gravity flotation rely only on size and weight differences. To address this limitation, coated microchannels were employed for the separation process, allowing for separation of microspheres based on surface heterogeneity. The separation efficiency was evaluated by analyzing particle flow rates with ImageJ software, indicating the potential of this approach for precise particle sorting.

Additionally, diffusion experiments were conducted within a microfluidic chip to investigate the impact of externally applied electric fields on the diffusion coefficient of nanoparticles with surface functional groups. The results demonstrated that electric fields could effectively manipulate nanoparticle diffusion, facilitating nanoscale particle separation.

Further, a computational model was developed using ANSYS Fluent to simulate the diffusion behavior of nanoparticles under varying electric field strengths. The model was validated against experimental data collected under identical conditions confirming the reliability of the simulation. This study highlights the potential of microfluidic systems as versatile platforms for advanced particle separation and nanoscale particle manipulation, offering significant implications for materials science, biotechnology, and nanotechnology.

Keywords: Carbon microspheres, Surface chemistry, Microfluidics, Paper based microfluidics

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LIST OF ABBREVIATIONS

Abbreviation	Description
(FTIR)	Fourier Transform Infrared Spectroscopy
(SEM)	Scanning Electron Microscopy
(UDF)	User Defined Function
(XRD)	X-Ray Diffraction
(PMMA)	Poly Methyl Methacrylate
(ATR)	Attenuated Total Reflectance
(EDLC)	Electrical Double Layer Capacitors
(UPS)	Uninterruptible Power Supplies
(AEDLC)	Asymmetric Electrochemical Double Layer Capacitor
(CNT)	Carbon Nanotubes
(DEP)	Dielectrophoresis
(DNA)	Deoxyribonucleic Acid
(RNA)	Ribonucleic Acid
(SEC)	Size Exclusion Chromatography
(μPAD)	Paper Microfluidic Devices
(FA)	Formic Acid
(TFA)	Trifluoroacetic Acid
(NH_4OH)	Ammonium Hydroxide
(ACN)	Acetonitrile
(MNP)	Magnetic Nanoparticles
(DPA)	Dipicolylamine
(RBC)	Red Blood Cells
(CAM)	Cell Adhesion Molecule
(AA)	Ascorbic Acid
(DA)	Dopamine Hydrochloride
(PBS)	Phosphate-Buffered Saline
(MEMS)	Microelectromechanical Systems

(CTC)	Circulating Tumor Cells
(PCR)	Polymerase Chain Reaction
(PDMS)	Polydimethylsiloxane
(CFD)	Computational Fluid Dynamics
(TEOS)	Tetraethyl Orthosilicate
(CNC)	Computer Numerical Control
(PTFE)	Polytetrafluoroethylene
(LED)	Light Emitting Diode
(FWHM)	Full-Width Half Maximum
(LAP)	Linear Assignment Problem
(HPLC)	High-Performance Liquid Chromatography
(DC)	Direct Current
(LC)	Liquid Chromatography
(HTC)	Hydrothermal Carbonization
(CVD)	Chemical Vapor Deposition
(XPS)	X-ray Photoelectron Spectroscopy
(USP)	Ultrasonic Spray Pyrolysis
(CMOS)	Complementary Metal Oxide Semiconductor