



**The Hong Kong University of Science and Technology  
Department of Chemical and Biomolecular Engineering**

**Research Project  
Work Plan  
#17048**

**Project Title  
Design of Adsorption Devices for Blood Purification**

**Supervisor  
Prof. LUO Zhengtang, Tom**

## **Section1: General Information:**

**Name of researcher:**

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**Supervisor:**

Prof. LUO Zhengtang, Tom

**Project title:**

Design of Adsorption Device for Blood Purification

**Research area:**

CBME

**Proposed locations:**

Room 7109 Laboratory  
ENV Service Corridor

**Start date:**

26/6/2017

## **Section2: Project Description:**

### **A: Introductions:**

Blood purification is an essential tool for treating blood-related diseases, such as kidney disease, liver failure and intoxication which requires immediate treatment. The blood will be drawn and pumped through the arterial catheter in blood perfusion operations, flow into cartridge which contains the sorbent material such as carbon or resin. The toxic substance or harmful metabolic product will be absorbed on the sorbent surfaces and then trapped. After that, the purified blood will flow out and be returned to the patient. Incidence of kidney disease is increasing and more than 8000 patients are suffering every year in Hong Kong, while in China more than 150,000 patients died from poisoning every year. Therefore, there is an urgent need for low-cost high performance blood purification technology.

However, the polymeric resin is the common used material, the important component in blood perfusion cartridge, suffers from low and slow absorption. Besides that, the other material such as activated carbon, show well absorption but owing to their low biocompatibility, the direct use of them in blood perfusion has limited success, which led to decreased platelet and white blood cell levels, sometimes even lead to blood coagulation.

In this work, we will exploit the unique absorption ability of graphene, together with our expertise in the functionalization method, to encapsulate graphene with hydrophilic polymers in order to improve biocompatibility and solve the aforementioned side-effects. We will then identify the most cost-competitive method for the downstream blood purification.

Reference the webpage of WHO and the National Diabetes Statistics Report, 2014 show that in 2014, the worldwide prevalence of diabetes was estimated to be 9% among adults aged over 18. As with USA in 2012, 9.3% of the population had diabetes. Diabetes has been related to chronic disease of blood vessels and kidney failure, are serious problems in urban area. The common treatment of diabetes is dialysis. It is classified in 2 types, hemodialysis for serious kidney failure and peritoneal dialysis for minor kidney failure. Both are mature technique that has been used since 1943. Although the technology is advanced, the time efficiency, cost effectiveness and patient compliance of dialysis are still low.

Scientist and engineering start to propose new methods for the blood purification. Blood perfusion might be the next generation of diabetes treatment method that provided shorter time and better patient compliance. Recent study on activated carbon shown a faster diabetes treatment that 1/3 time required of the dialysis methods. However the biocompatibility of activated carbon based perfusion is relatively low and limited in effectiveness.

Graphene oxide (GO), reduced graphene oxide (rGO), and their derivatives are emerging materials exhibiting attractive electronic, catalytic, mechanical, optical, and magnetic properties, which endow GO and rGO with great potential in various applications ranging from energy storage to biomedical materials.[1] Recently, much research has been carried out to explore the biomedical benefits of GO and rGO and reveal remarkable performances of GO and rGO in drug delivery, cellular imaging, bone tissues, stem cell differentiation, biosensors, and so on[2].

However, GO or rGO also showed some fatal defects, such as the cytotoxicity, [2] hemolysis, [3] thrombogenic potential, [4] and pulmonary toxicity, which limited their applications as biomaterials.

By grafting hydrophilic polymers, chitosan, and proteins onto the surface or the edge of GO through the covalent chemistry has been taken for the preparation of water stable and biocompatible GO and rGO to overcome shortcomings of aggregation and formation of micro gel. Our aim is to produce water stable, green, and biocompatible GO and rGO nanosheets with tunable biopolymer loading ratio and maintained 2D morphology. Dopamine (DA) [5], a mussel-adhesive-protein- inspired molecule, has drawn strong interest because it could form irreversible covalent bonds to solid surfaces in alkaline aqueous solution. Meanwhile, Dopamine could also function as the reducing agent to convert GOES to rGO. Heparin[6], a highly sulphated linear polysaccharide, was chosen as the model biopolymer due to its versatile ability, such as remarkable biocompatibility,<sup>38,39</sup> excellent anticoagulant ability, mediating complement activation, vascular regeneration, and antiviral activity.

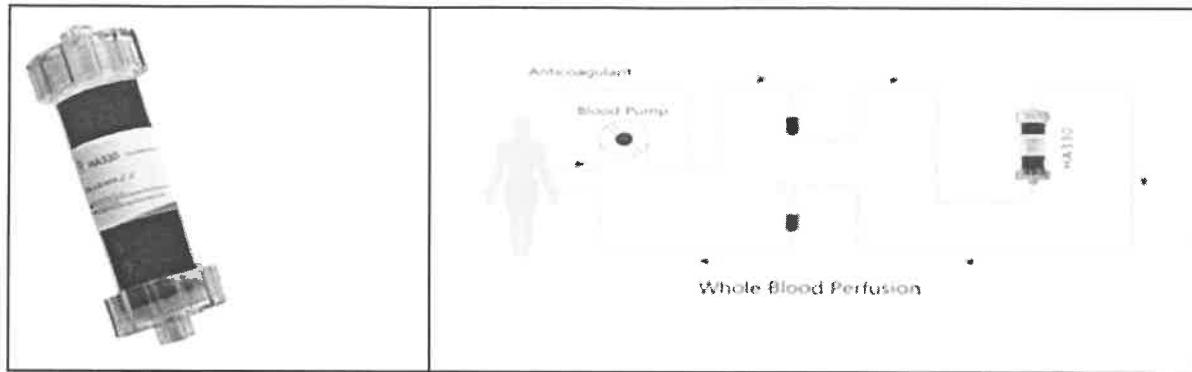
Hence, the following research is developed around the above ideas and the result is achieved by using instruments lists in the equipment list.

- [1] C. Cheng, S. Li, S. Nie, W. Zhao, H. Yang, S. Sun, C. Zhao, General and biomimetic approach to biopolymer-functionalized graphene oxide nanosheet through adhesive dopamine, *Biomacromolecules* 13(12) (2012) 4236-46.
- [2] D. Lahiri, R. Dua, C. Zhang, I. de Socarraz-Novoa, A. Bhat, S. Ramaswamy, A. Agarwal, Graphene Nanoplatelet-Induced Strengthening of UltraHigh Molecular Weight Polyethylene and Biocompatibility In vitro, *Acs Applied Materials & Interfaces* 4(4) (2012) 2234-2241.
- [3] K.-H. Liao, Y.-S. Lin, C.W. Macosko, C.L. Haynes, Cytotoxicity of Graphene Oxide and Graphene in Human Erythrocytes and Skin Fibroblasts, *Acs Applied Materials & Interfaces* 3(7) (2011) 2607-2615.
- [4] S.K. Singh, M.K. Singh, M.K. Nayak, S. Kumari, S. Shrivastava, J.J.A. Gracio, D. Dash, Thrombus Inducing Property of Atomically Thin Graphene Oxide Sheets, *Acs Nano* 5(6) (2011) 4987-4996.
- [5] J.-H. Jiang, L.-P. Zhu, X.-L. Li, Y.-Y. Xu, B.-K. Zhu, Surface modification of PE porous membranes based on the strong adhesion of polydopamine and covalent immobilization of heparin, *Journal of Membrane Science* 364(1-2) (2010) 194-202.
- [6] D.Y. Lee, Z. Khatun, J.-H. Lee, Y.-k. Lee, I. In, Blood Compatible Graphene/Heparin Conjugate through Noncovalent Chemistry, *Biomacromolecules* 12(2) (2011) 336-341.

## B: Objectives:

This project aims to prepare functionalized polystyrene particles and graphene structures for blood perfusion applications.

To fabricate a blood purification prototype, that looks like the following:



For this prototype it contains a novel adsorption material, based on a hydrophilic polymer encapsulated graphene, to allow biocompatible and high-efficiency blood purification.

### **Section 3**

3.1 Equipment for functionalizing polystyrene with cellulose acetate via dispersive precipitation

Fume hood	RM 7109
Oven	Corridor outside RM 7109
500mL flask	RM 7109
500mL, 1L, 2L beaker	RM 7109
filter paper	RM 7109
filter funnel	RM 7109
Magnetic stirrer	RM 7109
Balance	RM 7109
Conductivity meter	RM 7109
Beckman Coulter AU analyzer	RM 7109
Atomic force microscopy (AFM)	RM 7106
FTIR	RM 7106

3.2 Equipment for emulsion polymerization and functionalization of styrene

Fume hood	RM 7109
Oven	Corridor outside RM 7109
500mL flask	RM 7109
500mL, 1L, 2L beaker	RM 7109
Centrifuge	Corridor outside RM 6115
filter paper	RM 7109
filter funnel	RM 7109
Magnetic stirrer	RM 7109
Balance	RM 7109
Heater	RM 7109
Conductivity meter	RM 7109
Atomic force microscopy (AFM)	RM 7106

FTIR	RM 7106
Beckman Coulter AU analyzer	RM 7109

### 3.3 Equipment for coating polystyrene with polyethyleneimine (PEI)

Fume hood	RM 7109
Oven	Corridor outside RM 7109
500mL, 1L, 2L beaker	RM 7109
Filter paper	RM 7109
Filter funnel	RM 7109
Magnetic stirrer	RM 7109
Centrifuge	Corridor outside RM 6115
Test tube	RM 7109
Balance	RM 7109
Round-bottom flask	RM 7109
Condenser	RM 7109
Retort stand	RM 7109
Beckman Coulter AU analyzer	RM 7109
Conductivity meter	RM 7109
Atomic force microscopy (AFM)	RM 7106
FTIR	RM 7106

### 3.4 Equipment for synthesis of graphene based membrane for perfusion

Fume hood	RM 7109
Oven	Corridor outside RM 7109
500mL flask	RM 7109
500mL, 1L, 2L beaker	RM 7109
Centrifuge	Corridor outside RM 6115
filter paper	RM 7109

filter funnel	RM 7109
Magnetic stirrer	RM 7109
Mortar	RM 7109
Pestle	RM 7109
evaporating dish	RM 7109
Heater	RM 7109
Atomic force microscopy (AFM)	RM 7106
FTIR	RM 7106

### 3.5 Equipment for coating of graphene based membrane for perfusion

Fume hood	RM 7109
Oven	Corridor outside RM 7109
500mL, 1L, 2L beaker	RM 7109
Filter paper	RM 7109
Filter funnel	RM 7109
Magnetic stirrer	RM 7109
Centrifuge	Corridor outside RM 6115
Test tube	RM 7109
Shear Sandwich Clamp	RM 7109
Spin coater/spinner	RM 7109
Extrusion machine	RM 7106
Atomic force microscopy (AFM)	RM 7106
FTIR	RM 7106

### 3.6 Equipment for combining hemoglobin (Hb) with carboxyl graphene

Electrochemical workstation	RM 7109
Electrochemical cell consisted of a three electrode	RM 7109
Platinum wire	RM 7109

Magnetic stirrer	RM 7109
Scanning electron microscope	RM 7109
X-ray diffraction	RM 7109
ITO	RM 7109
X-ray photoelectron spectroscopy	RM 7106
Fourier transform infrared spectroscopy	RM 7106
Raman spectra	RM 7109
Electrochemical impedance spectroscopy	RM 7109
Amplitude	RM 7109
5 mL breaker	RM 7109

### 3.7 Equipment for preparation of arose coated activated carbon

diaphragm pumps	RM 7109
ultrapure water systems	RM 7109
constant temperature incubator shaker	RM 7109
ph meter	RM 7109
ultraviolet and visible spectrophotometer	RM 7109
Centrifuge	RM 7109
Filter	RM 7109
temperature controller	RM 7106
Thermostatic Water Bath	RM 7106
drying oven	RM 7109
100 ml breaker	RM 7109

### 3.8 preparations of 3D GO/biopolymer gels

Magnetic stirrer	RM 7109
Glass plate	RM 7109

Pipette	RM 7109
Vacuuming machine	RM 7109
Water bath machine	RM 7109

3.9 Equipment for preparation of poly (ether imides) (PEI) mixed matrix membranes (MMMs).

Spectrophotometry	RM 7109
pH meter	RM 7109
electron microscope	RM 7109
UV-vis absorbance	RM 7109
Spectroscopy	RM 7109
Breaker	RM 7109
Pipette	RM 7109
ultrasonic machine	RM 7109

3.10 Equipment for Biopolymer-Functionalized Graphene Oxide Nanosheet through Adhesive Dopamine

Breaker	RM 7109
Pipette	RM 7109
Ultrasonic machine	RM 7109
Magnetic stirrer	RM 7109
pH meter	RM 7109
Centrifuge	RM 7109
Refrigerator	RM 7109

3.11 Equipment for preparation of CS/CO gel

Breaker	RM 7109
Pipette	RM 7109
Ultrasonic machine	RM 7109
Magnetic stirrer	RM 7109
pH meter	RM 7109

Shaker	RM 7109
Refrigerator	RM 7109

### 3.12 Equipment for fabrication of mesoporous beads for hemoperfusion

Fume hood	RM 7109
Oven	Corridor outside RM 7109
500mL flask	RM 7109
500mL, 1L, 2L beaker	RM 7109
Centrifuge	Corridor outside RM 6115
filter paper	RM 7109
filter funnel	RM 7109
Magnetic stirrer	RM 7109
Heater	RM 7109
FTIR	RM 7106
Sphere mold	RM 7109

### 3.13 Equipment for coating of mesoporous beads for hemoperfusion

Fume hood	RM 7109
Oven	Corridor outside RM 7109
500mL, 1L, 2L beaker	RM 7109
Filter paper	RM 7109
Filter funnel	RM 7109
Magnetic stirrer	RM 7109
Centrifuge	Corridor outside RM 6115
Test tube	RM 7109
Atomic force microscopy (AFM)	RM 7106
FTIR	RM 7106

## **Section 4: Experimental Procedures:**

### **4.1 Synthesis of porous polystyrene beads**

(4.1.1) 0.16 g benzoyl peroxide, 4.0 g monomer (styrene and divinyl benzene), 1.0 g divinyl benzene, 0.2 g hexadecane and 1.6 g Span 80 (sorbitanmonooleate) were mixed to form the monomer phase

(4.1.2) 1.0 g poly (vinyl alcohol), 0.01 g hydroquinone, 0.02 g sodium sulfate, 0.015 g sodium dodecyl sulfate and 100 g water were mixed to form the aqueous phase.

(4.1.3) the emulsion was prepared by dispersing the monomer phase into the aqueous phase in a four – neck flask equipped with an anchor type agitator, a condenser, and a nitrogen inlet nozzle.

(4.1.4) the emulsion was bubble with nitrogen for 1 hour.

(4.1.5) the temperature was elevated to 75°C and held for 20 hours under a nitrogen atmosphere for the polymerization.

(4.1.6) the polymer particles were washed by water and ethanol 4 times.

(4.1.7) the impurities in particles were extracted by acetone for 24 hours.

(4.1.8) the particles were dried in vacuum at room temperature.

### **4.2 Synthesis of polystyrene suffocate beads**

(4.2.1) Concentrated sulfuric acid was placed in a 50 mL conical flask.

(4.2.2) Silver sulfate was added into the acid followed by careful stirring.

(4.2.3) Mixture was warmed to 90°C by steam bath.

(4.2.4) Polystyrene beads were added into the mixture.

(4.2.5) the flask was loosely stopped with a groove cork or one whole stopper, and placed on a steam bath for 2 hours with occasional stirring.

(4.2.6) the mixture was added into cold 6M sulfuric acid carefully.

(4.2.7) Mixture was then filtered, and the slurry was with distilled water for 5 times.

(4.2.8) the polymer was rinsed with anhydrous methanol for 2 times.

(4.2.9) the polymer was dried in a drying oven at 105°C for 10 – 15 min.

#### **4.3 Synthesis of cellulose acetate coated polystyrene sulfonate**

(4.3.1) Cellulose triacetate was dissolved in anhydrous acetone to make 10% solution.

(4.3.2) Amberlite 120H was added into the solution and stirred for 10 min.

(4.3.3) Polystyrene sulfonate was coated with the solution by using the fluidized bed coating equipment.

(4.3.4) the coated beads were dried at 70°C for 10 min.

#### **4.4 Synthesis of surface modified polystyrene samples**

(4.4.1) The samples are immersed in a 1 wt % solution of AEMA in a pH 9.2 Na<sub>2</sub>CO<sub>3</sub> buffer solution for 2 h, then rinse three times with Millipore grade distilled water and ethanol.

(4.4.2) Samples are then immersed for 2 h in 2 mL of a 2 wt % solution of glutaraldehyde in a pH 9.2 Na<sub>2</sub>CO<sub>3</sub> buffer, following by a 2 wt % solution of TEPA in a pH 9.2 Na<sub>2</sub>CO<sub>3</sub> buffer for 2 h.

#### **4.5 Modification of MCP**

(4.5.1) 1.36 g of DEDTC is dissolved in 12ml of dry ethanol, and then it is dropped into dry ethanol (20ml) containing MCP beads (4.5g).

(4.5.2) the resulting suspension was heated at 60°C under stirring for 12, 24, 36 and 48h, respectively.

(4.5.3) The MCP beads modified with iniferter (modified-MCP beads) were successively washed with double distilled water and methanol

(4.5.4) Dried at 40 ° C under vacuum overnight.

#### **4.6 Synthesis of porous polystyrene beads**

(4.6.1) 0.16 g benzoyl peroxide, 4.0 g monomer (styrene and divinyl benzene), 1.0 g divinyl benzene, 0.2 g hexadecane and 1.6 g Span 80 (sorbitan monooleate) were mixed to form the monomer phase

(4.6.2) 1.0 g poly (vinyl alcohol), 0.01 g hydroquinone, 0.02 g sodium sulfate, 0.015 g sodium dodecyl sulfate and 100 g water were mixed to form the aqueous phase.

(4.6.3) the emulsion was prepared by dispersing the monomer phase into the aqueous phase in a four – neck flask equipped with an anchor type agitator, a condenser, and a nitrogen inlet nozzle.

(4.6.4) the emulsion was bubble with nitrogen for 1 hour.

(4.6.5) the temperature was elevated to 75°C and held for 20 hours under a nitrogen atmosphere for the polymerization.

(4.6.6) after the polymerization, the polymer particles were washed by water and ethanol 4 times.

(4.6.7) the impurities in particles were extracted by acetone for 24 hours.

(4.6.8) the particles were dried in vacuum at room temperature.

#### **4.7 Synthesis of polystyrene sulfonate beads**

(4.7.1) Concentrated sulfuric acid was placed in a 50 mL conical flask. Silver sulfate was added into the acid followed by careful stirring.

(4.7.2) Mixture was warmed to 90°C by steam bath.

(4.7.3) Polystyrene beads were added into the mixture.

(4.7.4) the flask was loosely stopped with a groove cork or one whole stopper, and placed on a steam bath for 2 hours with occasional stirring.

(4.7.5) the mixture was added into cold 6M sulfuric acid carefully.

(4.7.6) Mixture was then filtered, and the slurry was with distilled water for 5 times.

(4.7.7) the polymer was rinsed with anhydrous methanol for 2 times. Finally, the polymer was dried in a drying oven at 105°C for 10 – 15 min.

#### **4.8 Synthesis of cellulose acetate coated polystyrene sulfonate**

(4.8.1) Cellulose triacetate was dissolved in anhydrous acetone to make 10% solution.

(4.8.2) Amberlite 120H was added into the solution and stirred for 10 min.

(4.8.3) Polystyrene sulfonate was coated with the solution by using the fluidized bed coating equipment.

(4.8.4) the coated beads were dried at 70°C for 10 min.

#### **4.9 Synthesis of polystyrene Chloromrthylation**

(4.9.1) Put 10 g polystyrene microspheres, 70 ml Chloromethyl methyl ether together in a 250 ml flask with stirring blade under 25 ° C thermostat for 1 hour, then 8 g anhydrous zinc were added in the solution, when the solution turns brown, begin to heat up to 50 ° C in oil bath reaction for 10 h.

(4.9.2) after reaction, suck filtrated the reaction mixture in the anhydrous state, then pouring the isolated solid into ice hydrochloric acid with stirring quickly

(4.9.3) filtered again and washed with deionized water until neutral, washed with ethanol and finally dried by anhydrous filtered, then dried in a vacuum oven

#### **4.10 Synthesis of chloromethylated polystyrene coupled PVA**

(4.10.1) 5g MCP beads were obtained with 50ml DMF to swell overnight, and then dissolved in 250 ml DMF solution of PVA22K; ensure that the reaction system PVA concentration is around 15 mg/ml

(4.10.2) 4.61g tetrabutylammonium iodide and 8.70g sodium hydroxide were successively added, stirred at 70 °C oil bath for 24 hours.

(4.10.3) the solid particles were filtered from hot solution, and used plenty of hot water to wash and remove the PVA adhered on the surface-modified polystyrene

(4.10.4) Filtered and vacuum dried the solids

### **4.11 Experimental procedures for preparing biopolymer functionalized material for blood perfusion**

#### **4.11.1 The preparation of Graphene oxide**

(4.11.1.1) 30 ml concentrated sulfuric acid (30 ml) was added to the mixture of K<sub>2</sub>S<sub>2</sub>O<sub>8</sub> (5 g), P<sub>2</sub>O<sub>5</sub> (5 g) and microwave-expanded graphite (1g), reacted at 90 °C for 4.5h

(4.11.1.2) the mixture above was added to excess DI water, and then washes the product with excess DI until the pH is ~5.5. Dry the graphite in air at 60°C for 3 hours.

(4.11.1.3) To the dried sample, concentrated sulfuric acid (100 ml) was added at 0 °C; followed by the addition of 30g KMnO<sub>4</sub> slowly. React at 35°C for 4 hours.

(4.11.1.4) Add the mixture to 1L DI water, stirred for 2 hours; then 50 ml of 30% H<sub>2</sub>O<sub>2</sub> was added to the solution slowly. Settled for 24 hours.

(4.11.1.5) Discard the supernatant, washed with a total of 1 L of 10% HCl solution then centrifuge; Wash the graphene oxide with excess DI water and centrifuge until the pH is about 7.

(4.11.1.6) Concentrate the final solution to 300ml. (a very viscous, brownish transparent solution with weight percent of 0.30% (w/w))

#### **4.11.2 The preparation of graphene oxide granules by direct granulation**

(4.11.2.1) Transfer 300 ml of graphene oxide solution on evaporating dish

(4.11.2.2) Dry the 50g of graphene oxide solution from the very viscous, brownish transparent solution to a brownish black crystal by oven

(4.11.2.3) Transfer Dried graphene oxide crystal from evaporating dish to mortar and grind to fine granule

(4.11.2.4) Weight and collect the graphene oxide granule into sampling bottles

#### **4.11.3 Preparation of biopolymer functionalized reduced graphene oxide**

(4.11.3.1) Add 200 mg of graphene oxide granule into 1 L of PBS solution (50mM, pH = 8.5) and dispersed by sonication for 20 min in an ice bath.

(4.11.3.2) adds 1g of dopamine hydrochloride into the mixture and sonicate it for another 5 min. Stir the solution vigorously at 60 °C for 12 h.

(4.11.3.3) Centrifuge the solution at 11000 g for 3 times to stop the reaction. Run the solution by dialysis in D.I. water for 2 days.

(4.11.3.4) Dry the solution to a brownish black crystal (pRGO) by oven.

(4.11.3.5) Transfer dried pRGO crystal from evaporating dish to mortar and grind to fine granule

(4.11.3.6) Weight and collect the pRGO into sampling bottles.

(4.11.3.7) Transfer 100mg of pRGO into 200 mL of PBS solution (50mM, pH = 8.5) followed by mild sonication for 10 min.

(4.11.3.8)Add 400 mg of pristine heparin or BSA (Bovine Serum Albumin) subsequently into the solution. Stir the solution vigorously at 25 °C for 24h.

(4.11.3.9) Centrifuge the solution at 14800 g for 3 times and wash it thoroughly with D.I. water. Dialyze the solution in D.I. water for 2 days.

(4.11.3.10) Dry the solution to a brownish black crystal (Hep-g-pRGO/BSA-g-pRGO) by oven.

(4.11.3.11) Transfer dried Hep-g-pRGO and BSA-g-pRGO crystal from evaporating dish to mortar and grind to fine granule.

(4.11.3.12) Weight and collect the Hep-g-pRGO and BSA-g-pRGO into sampling bottles.

(4.11.3.13) Collect adequate samples of different GOs derived above. Run AFM of GO, pRGO, Hep-g-pRGO and BSA-g-pRGO respectively.

## **4.12Experimental procedures for functionalizing polystyrene with cellulose acetate via dispersive precipitation**

### **4.12.1Dispersive precipitation of cellulose triacetate on polystyrene surface**

(4.12.1.1) Add 4 g cellulose triacetate into 196 g acetone to make a 2 wt. % solution

(4.12.1.2) Dry 1.8 g polystyrene in the oven for 15 minutes, then soak it into the solution prepared in step 4.1.1.1 for 2 hours

(4.12.1.3) Filter the above mixture in step 4.1.1.2 and dry the obtained solid in the oven for 0.5 hour

(4.12.1.4) Add 40 g ethyl alcohol into 60 ml water to make a 40 wt. % solution

(4.12.1.5) Soak the dried solid obtained in the step 4.1.1.3 into the ethyl alcohol aqueous solution for 2 hours

(4.12.1.6) Filter the above mixture, dry the obtained solid in the oven for 0.5 hour and then weight the final product

### **4.12.2Testing of absorbability of functionalized polystyrene towards bilirubin**

(4.12.2.1) Add 0.584 g bilirubin into 100 ml hexane to make a 0.01 M solution

(4.12.2.2) Add 0.5 g functionalized PS into the solution got from step 4.1.1.6 and stirring the mixture constantly; takes 1ml sample every 2 minutes until there are no observable color change in the mixture

(4.12.2.3) Samples are measured on a Beckman Coulter AU analyzer to determine the concentration of unreacted bilirubin

## **4.13Experimental procedures for emulsion polymerization and functionalization of styrene**

### **4.13.1Emulsion polymerization and functionalization**

(4.13.1.1) Add 0.15 g sodium dodecyl sulfate (SDS), 1 g alkylphenolpolyoxyethylene (OP-10), 12 g styrene, 0.04 g cellulose triacetate, 0.5 g acrylate polyethylene glycol monoester (APEG), 0.2g hexadecane and 0.275g azodiisobutyronitrile into 100 ml three-necked round bottom flask and stir the mixture for 0.5 hour to form emulsion

(4.13.1.2) Transfer the emulsion to a homogenizer at the speed of 4000 r/min for 10 min to form a miniemulsion in ice bath

- (4.13.1.3) Keep the miniemulsion mixture in argon atmosphere at 70 °C for 6 hours
- (4.13.1.4) Filter the above mixture, dry the obtained solid in the oven for 0.5 hour and then weight the final product

#### **4.13.2 Testing of adsorbability of functionalized polystyrene towards bilirubin**

- (4.13.2.1) Add 0.584 g bilirubin into 100 ml hexane to make a 0.01 M solution
- (4.13.2.2) Add 0.5 g functionalized PS into the solution got from step 4.2.1.4 and stirring the mixture constantly; takes 1ml sample every 2 minutes until there are no observable color change in the mixture
- (4.13.2.3) Samples are measured on a Beckman Coulter AU analyzer to determine the concentration of unreacted bilirubin

### **4.14 Experimental procedures for coating polystyrene with polyethyleneimine (PEI)**

#### **4.14.1 Partial oxidation of polystyrene**

- (4.14.1.1) Dissolve 20 g chromium (VI) oxide in 15 ml of water and then mix it with 100 ml of acetic acid
- (4.14.1.2) Dry 15 g polystyrene in the oven for 0.5 hour
- (4.14.1.3) set up a reflux system with a round-bottom flask, a condenser, a retort stand and a magnetic heater. Transfer the chromic solution prepared in step 4.3.1.1 into the flask and adds dried polystyrene, then reflux the mixture at 120°C for 3 hours
- (4.14.1.4) Dilute 118 g 37 wt.% hydrochloric acid with 125 ml water to make a 6M HCl solution, add 16 g NaOH into 200 ml water to make a 2M NaOH solution
- (4.14.1.5) Treat the mixture in step 4.3.1.3 with 6M HCl solution and 2M NaOH solution subsequently, with addition of several drops of 30% H<sub>2</sub>O<sub>2</sub> aqueous solution
- (4.14.1.6) Filter the mixture and dry the obtained solid

#### **4.14.2 Coating of PEI on partially oxidized polystyrene**

- (4.14.2.1) add 0.2M CuSO<sub>4</sub> into 100 ml water, mix it with the partially oxidized polystyrene obtained in step 4.3.1.6, stir the system for 0.5 hour and filter the mixture
- (4.14.2.2) Dilute 40 g PEI solution (50 wt.%) with 160 ml water to make a 10 wt.% aqueous solution, add the solid obtained in step 4.3.1.6, stir the system for 2 hours, and filter the mixture

(4.14.2.3) Dilute 40 g glutaric dialdehyde solution (50 wt.%) with 160 ml water to make a 10 wt.% aqueous solution, add the obtained solid in it, stir the mixture for 1 hour and filter it

(4.14.2.4) Dilute 118 g 37 wt.% hydrochloric acid with 125 ml water to make a 6M HCl solution, add 48 g NH<sub>3</sub> aqueous solution (28 wt.%) into 165 ml water to make a 4M NH<sub>3</sub> aqueous solution

(4.14.2.5) Treat the obtained solid in step 4.3.2.3 with 6M HCl solution and 4M NH<sub>3</sub> solution subsequently

(4.14.2.6) Filter the mixture, wash the obtained solid by enough DI water, dry the final product in the oven and weight it

#### **4.14.3 Testing of absorbability of functionalized polystyrene towards bilirubin**

(4.14.3.1) Add 0.584 g bilirubin into 100 ml hexane to make a 0.01 M solution

(4.14.3.2) Add 0.5 g functionalized PS into the solution got from step 4.3.2.6 and stirring the mixture constantly; takes 1ml sample every 2 minutes until there are no observable color change in the mixture

(4.14.3.3) Samples are measured on a Beckman Coulter AU analyzer to determine the concentration of unreacted bilirubin

### **4.15 General and Biomimetic Approach to Biopolymer-Functionalized Graphene Oxide Nanosheet through Adhesive Dopamine**

#### **4.15.1 The preparation of Graphene oxide**

(4.15.1.1) Graphene oxide (GO) was prepared from natural graphite flakes by a modified Hummers method. 2.25 g graphite and 1.875 g NaNO<sub>3</sub> were placed in a flask.

(4.15.1.2) Then, 75 mL H<sub>2</sub>SO<sub>4</sub> was added with stirring in an ice-water bath, and 10 g KMnO<sub>4</sub> were slowly added over about 1 h.

(4.15.1.3) the mixture was stirred in the ice water bath for 2 h, followed by a vigorously stirring for 3 days at room temperature.

(4.15.1.4) Then, the mixture was diluted with DI water (700 mL) slowly, and the excess KMnO<sub>4</sub> was decomposed by H<sub>2</sub>O<sub>2</sub> (30 wt. %, 15 mL).

(4.15.1.5) The insoluble precipitations were removed by centrifugation. The resulted GO solution was filtered and washed with HCl (10 wt. %, 1 L) and DI water for several times to remove the metal ions.

(4.15.1.6)the pristine brown GO solution was dialyzed with deionized water for 1 week before use to remove any residual salts and acids.

#### **4.15.2Synthesis of DA-g-Hep with 20 mol % grafting ratio:**

(4.15.2.1) 0.2 g of heparin and 0.05 g of dopamine were dissolved in 30 mL MES buffer (0.05M, pH 5.3, 0.1 M NaCl).

(4.15.2.2) After dissolving completely, 0.1915g EDC and 0.0575g NHS were added and the reaction mixture was vigorously stirred for 24 h under N<sub>2</sub> protection at room temperature (25 °C; caution: the reaction temperature should not lower than 20 °C, or else heparin gels will be formed)

(4.15.2.3)Maintain the pH at 5.3 by the addition of 1 M HCl.

(4.15.2.4)After the reaction was stopped, 3 mL of saturated NaCl solution and 60 mL of cold ethanol were sequentially added.

(4.15.2.5)After centrifugation at 1000 × g for 10 min, the precipitated dopamine grafted heparin (DA-g-Hep) conjugate was re-dissolved in 1 M NaCl solution, and ethanol was added again. The volume ratio of ethanol to NaCl solution was 10:1.

(4.15.2.5)This purification step was repeated three times to minimize the electrostatic interaction between the heparin and dopamine.

(4.15.2.6)The resultant DA-g-Hep conjugate was dialyzed against deionized water using a dialysis membrane (MWCO: 3.500) for 1 day under acidified water (pH 5, adjusted by 1 M HCl) to avoid catechol oxidation.

(4.15.2.7)The final product was obtained by using a freeze-dryer. The degree of the dopamine substitution was determined by using <sup>1</sup>H NMR spectroscopy (DRX 300,Bruker), and the substitution was calculated to be 20 ± 0.6 mol % by using the relative peak intensity ratio of the anomeric protons in heparin (5.1–5.3 ppm) to the aromatic protons in dopamine (6.7–7.1 ppm),

(4.15.2.8) Repeat the measurement three times to get a reliable value.

### **4.16Graphene Oxide Nanocomposite Incorporated Poly(ether imide) Mixed Matrix Membranes for in Vitro Evaluation of Its Efficacy in Blood Purification Applications**

#### **4.16.1 GO Preparation:**

(4.16.1.1) GO Preparation: Three grams of graphite powder was added to a round-bottom flask containing 70 mL of conc. H<sub>2</sub>SO<sub>4</sub> and stirred in an ice bath.

(4.16.1.2)Add 9 g of KMnO<sub>4</sub> slowly to ensure that the temperature was maintained lower than 15 °C.

(4.16.1.3) After 30 min, the flask was transferred into a 40 °C bath and vigorously stirred for 1 h.

(4.16.1.4) Then 150 mL of water was added dropwise, and the solution was maintained at 95 °C for 1 h.

(4.16.1.5) The solution changed color from dark brown to yellow when an excess 500 mL of water and 15 mL of H<sub>2</sub>O<sub>2</sub> (30%) was added.

(4.16.1.6) This solution was allowed to settle, and the solids were washed with dilute HCl (250 mL) to remove metal ions.

(4.16.1.7) The solution was filtered and centrifuged in hot conditions to remove the precipitates soluble in warm water.

(4.16.1.8) This yellowish brown residue was then ultrasonicated to get fully exfoliated GO.

(4.16.1.9) Next it was dried in a vacuum oven overnight and then used for further characterization and membrane preparation.

## 4.16.2 MMMs Preparation

(4.16.2.1) GO (0, 0.025, 0.050, 0.1, and 0.2 wt %) was sonicated in the solvent (NMP) for 1 h

(4.16.2.2) 2 wt % PVP-K90 was added and further homogenized by vigorous stirring for 2 h.

(4.16.2.3) To this, 16 wt % PEI was added, and a homogeneous dope solution was prepared by mechanical stirring for 24 h.

(4.16.2.4) The dope solution was then degassed by applying a vacuum.

(4.16.2.5) A semiautomatic casting unit was used to prepare these MMMs.

(4.16.2.6) The dope solution was casted on a dust free glass plate maintaining a thickness of 200 µm at a relative humidity (RH) of 25%.

(4.16.2.7) The glass plate was then immediately immersed in a water bath containing 0.2% solvent.

(4.16.2.8) The nascent membranes were washed with warm water (35 ± 2 °C) and then stored in distilled water until further testing.

## 4.17 Novel heparin-mimicking polymer brush grafted carbon nanotube/PES composite membranes for safe Biopolymer functionalized reduced graphene oxide with enhanced biocompatibility via mussel inspired coatings

#### **4.17.1 Preparation of biopolymer functionalized RGO**

(4.17.1.1) 200 mg GO was added into 1 L PBS solution (50 mM, pH 1/4 8.5)

(4.17.1.2) Dispersed by sonication for 20 min in an ice bath

(4.17.1.3) Then 1 g dopamine hydrochloride was added and sonicated for another 5 min.

(4.17.1.4) the solution was stirred vigorously at 60 C for 12 h

(4.17.1.5) the reduction reaction was stopped by centrifuging at 11 000 g 3 times

(4.17.1.6) Followed by dialysis in D.I. water for 2 days.

#### **4.17.2 Preparation of Hep-g-pRGO and BSA-g-pRGO**

(4.17.2.1) 100 mg pRGO was re-dispersed into 200 mL PBS solution (50 mM, pH 8.5) by mild sonication for 10 min

(4.17.2.2) 400 mg pristine heparin or BSA was added subsequently, and the heparin or BSA grafting reaction was carried out at 25 C for another 24 h with vigorous stirring to reach the maximum biopolymer grafting amounts.

(4.17.2.3) The solution was centrifuged and washed thoroughly with D.I. water at 14 800 g 3 times to remove the physically adsorbed heparin or BSA

(4.17.2.4) Dialyzed in D.I. water for 2 days to make sure the ions were removed completely.

### **4.18 Experimental procedures template for preparation of graphene based material for blood perfusion**

#### **4.18.1 Bioconjugations of CG-Hb**

(4.18.1.1) Adding 20 mg CG powder into NaOH solution (3 M, 5 mL) to obtain CG dispersion.

(4.18.1.2) The product above was dispersion bath-sonicated for 3 h to form homogeneous solution.

(4.18.1.3) Neutralize the pH value of homogenous solution to 7.0 by adding HCl solution (2.4 M, 11 mL) and purified by repeated washing and centrifuging at 5000 rpm for 10 min.

(4.18.1.4) Stir the resulting product in EDC and NHS for 2 hours. (Existed)

(4.18.1.5) The above product was centrifuged and washed in 7.0 PBS to remove redundant EDC and NHS.

(4.18.1.6) Adding Hb (2 mg , 400  $\mu$ L) into GC dispersion and stir overnight at 4 °C. (Existed)

(4.18.1.7) Centrifuge the resulting product at 5000 rpm for 20 min and washed 3 times with pH 7.4 PBS.

(4.18.1.8) Disperse the precipitates in pH 7.4 PBS to from 1 mg and stored in 4 °C refrigerator.

#### **4.18.2 Preparations of GCE/Au-NPs/CG-Hb**

(4.18.2.1) Polish the bare GCE (glassy carbon electrode) with abrasive paper and then with alumina (0.25 and 0.05  $\mu$ m) slurry on micro-cloth pads.

(4.18.2.2) Let the resulting product undergo ultrasonication in twice-distilled water for 30 s and dried in air.

(4.18.2.3) Deposit the Au-NPs on the surface of GCE by letting Au-NPs undergo cyclic voltammetry (CV) from 0.00 to 0.70 V for 40 cycles at the scan rate of 0.10 V s<sup>-1</sup> in 1.0 M KCl solution containing 0.50 mM HAuCl<sub>4</sub>. (Existed)

(4.18.2.4) Wash the Au-NPs modified GCE (GCE/Au-NPs) thoroughly with water to remove the un-reacted chemicals.

(4.18.2.5) Immerse the CE/Au-NPs electrode in the CG-Hb dispersion for 6 h.

(4.18.2.6) During this process, the CG-Hb dispersion should be bath-sonicated for 5 min for every 1 h.

(4.18.2.7) Store the resulting modified electrode, simply as “GCE/Au-NPs/CG-Hb” in 4 °C refrigerator. The synthesis procedure and possible mechanisms for formation of GCE/Au-NPs/CG-Hb were shown in Scheme.

#### **4.19 Experimental procedures for preparation of arose coated activated carbon**

(4.19.1) Add 0.6 agrose with 10 mL water

(4.19.2) Heat up the breaker in order to melt down the agrose

(4.19.3) Put the breaker under water bath.

(4.19.4) Adding 2g activated carbon into the breaker.

(4.19.5) Stir the mixture with rpm and adding 1.67 g Span 80 and 0.43 g Tween 80.

(4.19.6) Keep the temperature of mixture at 70 °C and 600 rpm for 30 mins.

(4.19.7) gradually decrease the temperature and rotating speed to 10°C and 180 rpm

(4.19.8) Use 50 mL ether to wash activated carbon for three times.

(4.19.9) Use 50 mL ethyl alcohol to wash activated carbon for three times.

(4.19.10) Use 50 mL deionized water to wash activated carbon for three times.

(4.19.11) Add 0.312 mL epichlorohydrin and 9.688 mL dimethyl sulfoxide into a 50 mL breaker and keep operation condition at 25 °C and 200 rpm

(4.19.12) Add 10 mL dimethyl sulfoxide, 1.2 g NaOH and 0.05 g NaBH4 into a 50 mL breaker.

(4.19.13) Add the coated activated carbon from procedure 10 into the 50 mL breaker. Keep the temperature at 45 °C for 6 hours.

(4.19.14) Use ethyl alcohol to wash resulting activated carbon for 3 times.

(4.19.15) Use deionized water to wash resulting activated carbon.

(4.19.16) Mix the activated carbon with dimethyl sulfoxide and undergo ultrasonic treatment for 15 mins.

## **4.20 Experimental procedures for preparation of 3D GO/biopolymer gels**

### **4.20.1 GO/BSA gel**

(4.20.1.1) Dissolve 4 g of bovine serum albumin (BSA) in 20 mL D.I. water and stirring overnight.

(4.20.1.2) Take 0.3 mL BSA solution (200 mg/mL) and add to 4 g GO concentrated solution (5 mg/g) and the mixture was shaken violently for 10 s to form a hydrogel.

(4.20.1.3) The formation of the hydrogel was confirmed by a tube inversion method.

(4.20.1.4) then the hydrogel was further treated by sonication for 3 min.

(4.20.1.5) Freeze-dried the hydrogel to obtain GO/BSA gel.

### **4.20.2 GO/DNA gel**

(4.20.2.1) Dissolve 400 mg of DNA in 20 mL D.I. water and stirring overnight.

(4.20.2.2) Take 1 mL DNA (200 mg/mL) solution and add to 4 g GO concentrated solution (5 mg/g) and the mixture was shaken violently for 10 s to form a hydrogel.

(4.20.2.3) the formation of the hydrogel was confirmed by a tube inversion method.

(4.20.2.4) then the hydrogel was further treated by sonication for 3 min.

(4.20.2.5) Freeze-dried the hydrogel to obtain GO/DNA gel.

### **4.20.3 GO/CS gel**

(4.20.3.1) Dissolve 400 mg of chitosan (CS) in 20 mL of 2.5% (v/v) aqueous acetic acid and stirring overnight.

(4.20.3.2) Take 0.4 mL (20 mg/g) CS solution and add to 4 g GO concentrated solution (5 mg/g) and the mixture was shaken violently for 10 s to form a hydrogel.

(4.20.3.3) the formation of the hydrogel was confirmed by a tube inversion method.

(4.20.3.4) then the hydrogel was further treated by sonication for 3 min.

(4.20.3.5) Freeze-dried the hydrogel to obtain GO/DNA gel.

### **4.20.4 Experimental procedures for preparation of poly (ether imide) (PEI) mixed matrix membranes (MMMs)**

(4.20.4.1) Sonicate the GO in the solvent (NMP) for one hour.

(4.20.4.2) Add 90 wt% PVP-K into the mixture and stir for 2 hours.

(4.20.4.3) Add 16 wt% PEI into mixture and stir for 24 hr to form dope solution.

(4.20.4.4) The dope solution is then degassed by applying vacuum.

(4.20.4.5) Cast the dope solution on a dust free glass plate maintaining a thickness of 200 $\mu$ m at a relative humidity (RH) of 25%.

(4.20.4.6) The glass plate was then immediately immersed in a water bath containing 0.2% solvent.

(4.20.4.7) Wash the membranes with warm water ( $35 \pm 2$  °C) and then stored in distilled water until further testing.

## **4.21 Experimental procedures for Biopolymer-Functionalized Graphene Oxide Nanosheet through Adhesive Dopamine**

### **4.21.1 Preparation of DA Grafted Heparin**

(4.21.1.1) Dissolve 91.8 mg of heparin and 28.5 mg of dopamine in 15 mL of MES buffer (0.05M, pH 5.3, 0.1 M NaCl).

(4.21.1.2) After complete dissolution, EDC (21.5 mg) were added and the reaction mixture was vigorously stirred for 2 h at room temperature while maintaining pH 4.75 by addition of 1 N HCl.

(4.21.1.3) Stop the reaction by adjusting pH to 7.0 with 1 M NaOH

(4.21.1.4) Add 3 mL of saturated NaCl solution and 60 mL of cold ethanol into mixture

(4.21.1.5) centrifugation at 1000 × g for 10 min

(4.21.1.6) Redissolve the precipitated heparin-dopamine conjugate in 1 M NaCl solution, and ethanol was added again. (The volume ratio of ethanol to NaCl solution was 10:1.)

(4.21.1.7) this purification step was repeated three times

#### **4.21.2 Preparation of Hep-a-GO and Hep-a-rGO.**

(4.21.2.1) Dissolve 40 mg DA-g-Hep in 20 mL of Tris buffer solution (10 mM, pH 8.5)

(4.21.2.2) 2 mg GO was added to the DA-g-Hep homogeneous solution.

(4.21.2.3) the solution was dispersed by sonication for 20 min and then vigorously stirred at 20 °C for 24 h.

(4.21.2.4) The obtained Hep-a-GO was centrifuged at 14 800g for three times, followed by dialysis in ultrapure water for 2 days to make sure the ions were removed completely.

(4.21.2.5) The Hep-a-rGO was prepared under the same condition as Hep-a-GO, except that the reaction temperature was changed to 60 °C.

### **4.22. Experimental procedures for preparation of heparin-modified chitosan/GO hybrid hydrogel**

#### **4.22.1 Preparation of CS/CO gel**

(4.22.1.1) 300 mg of CS was dispersed into 10 mL of 3 mg/mL GO suspension, and then 0.2 mL of acetic acid was added.

(4.22.1.2) vigorously stirred the mixture to dissolve the CS, and then the bubbles in the mixture were removed by vacuum degassing.

(4.22.1.3) Pour the mixture into a mold and freeze-dried under vacuum to form porous structure.

(4.22.1.4) the porous structures obtained were immersed in 0.5 M sodium hydroxide (NaOH) to remove the excess acid, and then thoroughly washed with deionized water. Notes: The resulting hydrogel was denoted as a CS/GO hydrogel (CS/GH).

## **4.22.2 Coupling of heparin on to CS/GH**

(4.22.2.1) 30 mg of heparin, 9 mg of NHS, and 30 mg of EDC/HCl were dissolved sequentially in 20 mL of phosphate buffer solution (50 mM, pH 5.5).

(4.22.2.2) Pour the mixture into a shaker for 1 hour.

(4.22.2.3) Adjust the pH value of solution to be 7.4.

(4.22.2.4) Incubate the solution with 150 mg of CS/GH (dry weight) overnight in the shaker.

(4.22.2.5) Excess reagents and physically bound heparin were removed by extensive washing with 2 M sodium chloride (NaCl) and deionized water.

(4.22.2.6) Toluidine blue staining was carried out to visualize the coupled heparin.

## **4.23 Experimental procedures for fabrication of mesoporous beads fpr hemoperfusion**

### **4.23.1 Membrane emulsion polymerization polystyrene**

(4.23.1.1) 3.9g styrene(St), 4.78g divinylbenzene(DVB) and 7g porogen containing 0.4g benzoyl peroxide(BPO) initiator and 0.7g lauryl alcohol as interface stabilizer was mixed as dispersed phase at room temperature;

(4.23.1.2) 1L aqueous solution of 9g polyvinyl alcohol(PVA), 0.45g sodium dodecyl sulfate (SDS, biochemical grade), 0.22g Na<sub>2</sub>SO<sub>4</sub> and 0.07g hydroquinone(HQ) inhibitor was used as continuous phase at room temperature;

(4.23.1.3) Turn on the nitrogen gas, continuously pressed the dispersed phase through the Shirasu Porous Glass(SPG) membrane with 2.8 μm pore size into the continuous aqueous solution;

(4.23.1.4) the obtained emulsion was transferred to a four-neck glass separator flask equipped with a semicircular anchor-type blade, a condenser and a nitrogen inlet nozzle;

(4.23.1.5) Bubble the emulsion with nitrogen gas for 1h;

(4.23.1.6) lifted the nitrogen nozzle and gradually heated the emulsion to 75 °C ;

(4.23.1.7) the polymerization reaction was carried out for 20h under the nitrogen atmosphere;

(4.23.1.8) Collected and washed the prepared PS microspheres with hot water and ethanol respectively for four times;

(4.23.1.9) Extracted the PS beads in a Sox let apparatus with acetone, and then dried under partial vacuum at 45 °C for 24 h;

#### **4.23.2. Preparation of chitosan/GO hybrid hydrogel**

(4.23.2.1) Dispersed 300mg chitosan(CS) into 10mL of 3mg/mL graphene oxide suspension;

(4.23.2.2) added 0.2mL of acetic acid, and vigorously stirred the mixture to dissolve the CS;

(4.23.2.3) Using vacuum degassing method to remove the bubbles in the mixture;

(4.23.2.4) poured the mixture into a sphere mold;

(4.23.2.5) Freeze-dried the spheres under vacuum;

(4.23.2.6) immersed the dried hydrogel into 0.5M sodium hydroxide (NaOH) to remove the excess acid;

(4.23.2.7) thoroughly washed the hydrogel with deionized water;

### **4.24. Experimental procedures for coating of mesoporous beads for hemoperfusion**

#### **4.24.1 Immerse and vacuum-dried coating method**

##### **4.24.1.1Coating of PS with polymethyl methacrylate(PMMA)**

(4.24.1.1.1) Dissolved the PMMA in ethyl acetate (1200mL of 2.5%, w/v);

(4.24.1.1.2) Dry PS beads were added into the prepared PMMA solution and shaken in a 2L beaker for 6h at 145rpm;

(4.24.1.1.3) decanted the solution and dried the beads under airflow in the hood for overnight;

(4.24.1.1.4) Furthered dried the beads in a vacuum oven at 80°C

##### **4.24.1.2. One-step coating of PS with the PMMA-heparin blend layer**

(4.24.1.2.1) dissolved the heparin sodium(50mg) in water (2.5 mL);

(4.24.1.2.2) Acetone (7.5 mL) was added to the heparin sodium solution to obtain a clear 0.5% (w/v) solution;

(4.24.1.2.3) Prepared PMMA in acetone as 5% (w/v) for 4 mL, and then slowly added to the heparin solution in order to form stable and off-white PMMA-heparin solution;

(4.24.1.2.4) separated the 14 mL PMMA-heparin solution into 16 mL and 8 mL;

(4.24.1.2.5) Added two batches of beads, weighing 2 and 1g, respectively to the 16 mL and 8 mL PMMA-heparin solution;

(4.24.1.2.6) Shook the beads and solutions at 180rpm for 5h;

(4.24.1.2.7) Decanted the solutions and dried the beads in a vacuum oven at 80°C

#### **4.24.1.3. Coating of PS with PMMA-chitosan**

(4.24.1.3.1) Chitosan was dissolved in 0.25% (w/w) aqueous acetic acid solution at a concentration of 120 mg/16 mL;

(4.24.1.3.2) Added the dry PMMA-coated PS beads (1.1 g) to chitosan solution (8 mL);

(4.24.1.3.3) the resulting mixture was shaken in three batches for 1, 3, and 5 h;

(4.24.1.3.4) the supernatant was decanted, and the beads were filtered under vacuum through Millipore filter paper using a Bucher funnel and rinsed with 0.1 N sodium hydroxide solutions;

(4.24.1.3.5) further rinsed the beads with water to remove residual sodium hydroxide;

(4.24.1.3.6) The PMMA–chitosan-coated beads were dried overnight in a vacuum oven at 80 °C;

#### **4.24.1.4. Immobilization of heparin on PMMA-chitosan-coated PS beads:**

(4.24.1.4.1) PMMA–chitosan-coated PS beads (0.3 g) were equilibrated in 2-(N-morpholino)ethanesulfonic acid (MES) buffer (0.05 M, pH 5.6) for 1 h;

(4.24.1.4.2) Added 1-ethyl-3-(3-dimethylaminopropyl) carbodiimide hydrochloride (EDC) and Nhydroxysuccinimide (NHS) to heparin solution [5 mL of 2% (w/w) in 0.05 M MES buffer at pH 5.60] at a molar ratio of EDC/NHS/heparin of 0.4:0.24:1.0;

(4.24.1.4.3) 10 min later, the 0.3g PS beads were added to the solution prepared in the previous step and shaken overnight at 180 rpm at room temperature;

(4.24.1.4.4) decanted the solution, and the beads were washed with deionized water for 24h with three changes of water;

(4.24.1.4.5) the heparin-coated beads were dried overnight in a vacuum oven at 40 °C;

#### **4.24.2 GO/biopolymer (BSA, DNA or chitosan) combination**

##### **4.24.2.1.GO/BSA (Bovine serum albumin) gel formation**

(4.24.2.1.1) Prepared a BSA stock solution by dissolving 4 g of BSA in 20 mL D.I. water, and stirring overnight;

(4.24.2.1.2) 0.3 mL BSA (200 mg/ mL) solution was added to 4 g GO concentrated solution (5 mg/g);

(4.24.2.1.3) violently shook the mixture solution for 10s to form a hydrogel, and observed the hydrogel formation by a tube inversion method;

(4.24.2.1.4) treated the hydrogel by sonication for 3 min;

(4.24.2.1.5) The final weight ratio of GO: BSA is 20 mg: 60 mg;

#### **4.24.2.2.GO/DNA gel formation**

(4.24.2.2.1) Prepared a DNA stock solution by dissolving 400mg of DNA in 20 mL D.I. water, and stirring overnight;

(4.24.2.2.2) 1 mL DNA (20mg/ mL) solution was added to 4 g GO concentrated solution (5 mg/g);

(4.24.2.2.3) violently shook the mixture solution for 10s to form a hydrogel, and observed the hydrogel formation by a tube inversion method;

(4.24.2.2.4) treated the hydrogel by sonication for 3 min;

(4.24.2.2.5) the final weight ratio of GO: DNA is 20 mg: 20 mg;

#### **4.24.2.3.GO/chitosan(CS) gel formation**

(4.24.2.3.1) Prepared a chitosan stock solution by dissolving 400mg of chitosan in 20 mL of 2.5%(v/v) aqueous acetic acid, and stirring overnight;

(4.24.2.3.2) 0.4 mL CS (20 mg/ mL) solution was added to 4 g GO concentrated solution (5 mg/g);

(4.24.2.3.3) violently shook the mixture solution for 10s to form a hydrogel, and observed the hydrogel formation by a tube inversion method;

(4.24.2.3.4) treated the hydrogel by sonication for 3 min;

(4.24.2.3.5) the final weight ratio of GO: CS is 20 mg: 8 mg;

## Section 5. Procedure Template

5.1 Synthesis of porous polystyrene beads		Procedure No.	Experimental Procedure Description	Scale (Mass/Volume)	Location	Method New or Existing
4.1.1	0.16 g benzoyl peroxide , 4.0 g monomer (styrene and divinyl benzene), 1.0 g divinyl benzene, 0.2 g hexadecane and 1.6 g Span 80 (sorbitanmonooleate) were mixed to form the monomer phase			0.16 g BPO 4.0 g DVB 0.2 g HD 1.6 g Span 80	(RM 7109, fume hood)	Existing
4.1.2	1.0 g poly(vinyl alcohol) , 0.01 g hydroquinone , 0.02 g sodium sulfate, 0.015 g sodium dodecyl sulfate and 100 g water were mixed to form the aqueous phase			1.0 g PVA 0.2 g SS 0.015 g SDS 100 g H <sub>2</sub> O	(RM 7109, fume hood)	Existing
4.1.3	The emulsion was prepared by dispersing the monomer phase into the aqueous phase in a four – neck flask equipped with an anchor type agitator, a condenser, and a nitrogen inlet nozzle			N/A	(RM 7109, fume hood)	Existing
4.1.4	The emulsion was bubble with nitrogen for 1 hour			N/A	(RM 7109, fume hood)	Existing
4.1.5	The temperature was elevated to 75°C and held for 20 hours under a nitrogen atmosphere for the polymerization			N/A	(Rm 7109, fume hood)	Existing
4.1.6	The polymer particles were washed by water and ethanol 4 times			N/A	(Rm 7109, fume hood)	Existing
4.1.7	The impurities in particles were extracted by acetone for 24 hours			300mL AC	(RM 7109, fume hood)	Existing
4.1.8	The particles were dried in vacuum at room temperature			N/A	(ENV service corridor)	Existing
5.2 Synthesis of porous polystyrene sulfonate beads		Procedure No.	Experimental Procedure Description	Scale (Mass/Volume)	Location	Method New or

			<b>Existing</b>
<b>Procedure No.</b>	<b>Experimental Procedure Description</b>	<b>Scale (Mass/Volume)</b>	<b>Method New or Existing</b>
4.2.1	Concentrated sulfuric acid was placed in a 50 mL conical flask	15 mL SA	(RM 7109, fume hood)
4.2.2	Silver sulfate was added into the acid followed by careful stirring	0.02 g SvS	(RM 7109, fume hood)
4.2.3	Mixture was warmed to 90°C by steam bath	N/A	(RM7109, fume hood)
4.2.4	Polystyrene beads were added into the mixture	1.0 g PSt	(RM7109, fume hood)
4.2.5	The flask was loosely stopped with a groove cork or one hole stopper, and placed on a steam bath for 2 hours with occasional stirring	N/A	(RM7109, fume hood)
4.2.6	The mixture was added into cold 6M sulfuric acid carefully	100 mL 6M SA	(RM7109, fume hood)
4.2.7	Mixture was filtered, and the slurry was with distilled water for 5 times	10 mL H <sub>2</sub> O	(RM7109, fume hood)
4.2.8	The polymer was rinsed with anhydrous methanol for 2 times	10 mL Mtol	(RM7109, fume hood)
4.2.9	The polymer was dried in a drying oven at 105°C for 10 – 15 min	N/A	(RM7109)
<b>5.3 Synthesis of cellulose acetate coated polystyrene sulfonate</b>			
<b>Procedure No.</b>	<b>Experimental Procedure Description</b>	<b>Scale (Mass/Volume)</b>	<b>Location</b>
4.3.1	Cellulose triacetate was dissolved in anhydrous acetone to make 10% solution	1 g CT 11.38 ml AC	(RM 7109, fume hood)
4.3.2	Amberlite 120H was added into the solution and stirred for 10 min	10 mL A120H	(RM 7109, fume hood)
4.3.3	Polystyrene sulfonate was coated with the solution by using the fluidized bed coating equipment	N/A	(RM 7109, fume hood)
4.3.4	The coated beads were dried at 70°C for 10 min	N/A	(RM 7109)
<b>5.4 Synthesis of surface modified polystyrene samples</b>			
<b>Procedure No.</b>	<b>Experimental Procedure Description</b>	<b>Scale (Mass/Volume)</b>	<b>Method New or</b>

Procedure No.	Experimental Procedure Description	Scale (Mass/Volume)	Location	Method New or Existing
4.4.1	The samples are immersed in a 1 wt % solution of AEMA in a pH 9.2 Na <sub>2</sub> CO <sub>3</sub> buffer solution for 2 h	1 wt% AEMA pH 9.2 Na <sub>2</sub> CO <sub>3</sub> buffer	(RM 7109, fume hood)	Existing
4.4.2	rinse three times with Millipore grade distilled water and ethanol	N/A	(RM 7109, fume hood)	Existing
4.4.3	immersed for 2 h in 2 mL of a 2 wt % solution of glutaraldehyde in a pH 9.2 Na <sub>2</sub> CO <sub>3</sub> buffer	2 mL of a 2 wt % solution of glutaraldehyde pH 9.2 Na <sub>2</sub> CO <sub>3</sub> buffer	(RM 7109, fume hood)	Existing
4.4.4	Following by a 2 wt % solution of TEPA in a pH 9.2 Na <sub>2</sub> CO <sub>3</sub> buffer for 2 h.	2 wt % solution of TEPA pH 9.2 Na <sub>2</sub> CO <sub>3</sub> buffer	(RM 7109)	Existing
<b>5.5 Synthesis of surface modified polystyrene samples</b>				
Procedure No.	Experimental Procedure Description	Scale (Mass/Volume)	Location	Method New or Existing
4.5.1	1.36 g of DEDTC is dissolved in 12ml of dry ethanol	1.36 g DEDTC 12ml dry ethanol	(RM 7109, fume hood)	Existing
4.5.2	The samples are dropped into dry ethanol (20ml) containing MCP beads (4.5g)	4.5g MCP beads 20ml dry ethanol	(RM 7109, fume hood)	Existing
4.5.3	The resulting suspension was heated at 60°C under stirring for 12, 24, 36 and 48h, respectively	N/A	(RM 7109, fume hood)	Existing
4.5.4	The samples are washed with double distilled water and methanol, and then dried at 40 ° C under vacuum overnight.	N/A	(RM 7109)	Existing
<b>5.6 Synthesis of porous polystyrene beads</b>				
Procedure No.	Experimental Procedure Description	Scale (Mass/Volume)	Location	Method New or Existing
4.6.1	0.16 g benzoyl peroxide , 4.0 g monomer (styrene and divinyl benzene), 1.0 g divinyl benzene, 0.2 g hexadecane and 1.6 g	0.16 g BPO 4.0 g DVB	(RM 7109, fume hood)	Existing

Procedure No.	Experimental Procedure Description	Scale (Mass/Volume)	Location	Method New or Existing
4.7.1	Concentrated sulfuric acid was placed in a 50 mL conical flask	15 mL SA	(RM 7109, fume hood)	Existing
4.6.1	Span 80 (sorbitan monooleate) were mixed to form the monomer phase	0.2 g HD 1.6 g Span 80		
4.6.2	1.0 g poly(vinyl alcohol), 0.01 g hydroquinone , 0.02 g sodium sulfate, 0.015 g sodium dodecyl sulfate and 100 g water were mixed to form the aqueous phase	1.0 g PVA 0.2 g SS 0.015 g SDS 100 g H <sub>2</sub> O	(RM 7109, fume hood)	Existing
4.6.3	The emulsion was prepared by dispersing the monomer phase into the aqueous phase in a four – neck flask equipped with an anchor type agitator, a condenser, and a nitrogen inlet nozzle	N/A	(RM7109, fume hood)	Existing
4.6.4	The emulsion was bubble with nitrogen for 1 hour	N/A	(RM 7109, fume hood)	Existing
4.6.5	The temperature was elevated to 75°C and held for 20 hours under a nitrogen atmosphere for the polymerization	N/A	(Rm 7109, fume hood)	Existing
4.6.6	The polymer particles were washed by water and ethanol 4 times	N/A	(Rm 7109, fume hood)	Existing
4.6.7	The impurities in particles were extracted by acetone for 24 hours	300 mL AC	(RM 7109, fume hood)	Existing
4.6.8	The particles were dried in vacuum at room temperature	N/A	(ENV service corridor)	Existing
<b>5.7 Synthesis of porous polystyrene sulfonate beads</b>				

4.7.2	Silver sulfate was added into the acid followed by careful stirring	0.02 g SvS	(RM 7109, fume hood)	Existing
4.7.3	Mixture was warmed to 90°C by steam bath	N/A	(RM 7109, fume hood)	Existing
4.7.4	Polystyrene beads were added into the mixture	1.0 g PSt	(RM 7109, fume hood)	Existing
4.7.5	The flask was loosely stopped with a groove cork or one hole stopper, and placed on a steam bath for 2 hours with occasional stirring	N/A	(RM 7109, fume hood)	Existing
4.7.6	The mixture was added into cold 6M sulfuric acid carefully	100 mL 6M SA	(RM 7109, fume hood)	Existing
4.7.7	Mixture was filtered, and the slurry was with distilled water for 5 times	10 mL H <sub>2</sub> O	(RM 7109, fume hood)	Existing
4.7.8	The polymer was rinsed with anhydrous methanol for 2 times	10 mL Mtol	(RM 7109, fume hood)	Existing
4.7.9	The polymer was dried in a drying oven at 105°C for 10 – 15 min	N/A	(RM 7109)	Existing
<b>5.8 Synthesis of cellulose acetate coated polystyrene sulfonate</b>				
Procedure No.	Experimental Procedure Description	Scale (Mass/Volume)	Location	Method New or Existing
4.8.1	Cellulose triacetate was dissolved in anhydrous acetone to make 10% solution	1 g CT 11.38 ml AC	(RM 7109, fume hood)	Existing
4.8.2	Amberlite 120H was added into the solution and stirred for 10	10 mL A120H	(RM 7109, fume	Existing

	min		hood)	
4.8.3	Polystyrene sulfonate was coated with the solution by using the fluidized bed coating equipment	N/A	(RM 7109, fume hood)	Existing
4.8.4	The coated beads were dried at 70°C for 10 min	N/A	(RM 7109)	Existing

### 5.9 Synthesis of polystyrene Chloromethylatation

Procedure No.	Experimental Procedure Description	Scale (Mass/Volume)	Location	Method New or Existing
4.9.1	10g polystyrene ,70ml Chloromethyl methyl ether were mixed in 250ml flask	10g PS 70ml Chloromethyl methyl ether	(RM 7109, fume hood)	Existing
4.9.2	8g anhydrous zinc were added in the solution	8g anhydrous zinc	(RM 7109, fume hood)	Existing
4.9.3	filtrated the reaction mixture in the anhydrous state,	N/A	(RM 7109, fume hood)	Existing
4.9.4	isolated solid into ice hydrochloric	N/A	(RM 7109)	Existing
4.9.5	filtered again and washed with deionized water until neutral ,then washed with ethanol	N/A	(RM 7109)	Existing

### 5.10 Synthesis of chloromethylated polystyrene coupled PVA

Procedure No.	Experimental Procedure Description	Scale (Mass/Volume)	Location	Method New or Existing
4.10.1	5g MCP beads were obtained with 50ml DMF to swell overnight	5g MCP beads 50ml DMF	(RM 7109, fume hood)	Existing

4.10.2	dissolved in 250ml DMF solution of PVA22K	250ml DMF PVA22K	(RM 7109, fume hood)	Existing
4.10.3	4.61g tetrabutylammonium iodide and 8.70g sodium hydroxide were successively added	4.61g tetrabutylammonium iodide, 8.7 sodium hydroxide	(RM 7109, fume hood)	Existing
4.10.4	stirred at 70 ° C oil bath for 24 hours.	N/A	(RM 7109)	Existing
<b>5.11 Procedure template for preparation of biopolymer functionalized material for blood perfusion</b>				
Experimental	Experimental Procedure	Scale	Location	Method
Procedure No.	Description	(Mass/Volume) (Fumehood,bencet op,etc)	New or Existing	
4.11.1.1	Concentrated sulfuric acid was added to the mixture of K <sub>2</sub> S <sub>2</sub> O <sub>8</sub> , P <sub>2</sub> O <sub>5</sub> and graphite, reacted at 90 °C for 4.5h.	30 ml Concentrated H <sub>2</sub> SO <sub>4</sub> , 5g K <sub>2</sub> S <sub>2</sub> O <sub>8</sub> , 5g P <sub>2</sub> O <sub>5</sub> and 1g graphite	Fume hood(7109)	Existing
4.11.1.2	Filtrate and wash the product with excess DI until the pH is ~5.5.	1L DI water	Fume hood(7109)	Existing
4.11.1.3	To the dried sample, concentrated sulfuric acid and KMnO <sub>4</sub> was added, react at 35°C for 4 hours	100 ml Concentrated H <sub>2</sub> SO <sub>4</sub> , 30g KMnO <sub>4</sub>	Fume hood(7109)	Existing
4.11.1.4	Add the mixture to excess DI water, stirred for 2 hours; then H <sub>2</sub> O <sub>2</sub> was added to the solution.	1L DI water, 50mL 30% H <sub>2</sub> O <sub>2</sub>	Fume hood(7109)	Existing
4.11.1.5	Wash with HCl and excess DI water until the pH is about 7.	1 L of 10% HCl, 1L DI water	Fume hood(7109)	Existing
4.11.1.6	Concentrate the final solution		Fume hood(7109)	Existing
4.11.2.1	Transfer 50g of graphene oxide solution on evaporating dish		Fume hood(7109)	Existing

4.11.2.2	Dry the graphene oxide solution from the very viscous, brownish transparent solution to a brownish black crystal by oven	300ml of graphene oxide solution	Oven (corridor outside 7109)	Existing
4.11.2.3	Transfer Dried graphene oxide crystal from evaporating dish to mortar and grind to fine granule	300ml of graphene oxide solution	Fume hood(7109)	Existing
4.11.2.4	Weight and collect the graphene oxide granule into sampling bottles		Fume hood(7109)	Existing
4.11.3.1	Add 200mg of graphene oxide granule into 1L of PBS solution and dispersed by sonication for 20 min in an ice bath.	200mg of graphene oxide granule, 1L of PBS solution (50mM, pH=8.5), 1L of DI water	Fume hood(7109)	Existing
4.11.3.2	Add 1g of dopamine hydrochloride into the mixture and sonicate it for another 5 min. Stir the solution vigorously at 60 °C for 12 h.	1g of dopamine hydrochloride	Fume hood(7109)	Existing
4.11.3.3	Centrifuge the solution at 11000 g for 3 times to stop the reaction. Run the solution by dialysis in D.I. water for 2 days	1L of DI water	Fume hood(7109)	Existing
4.11.3.4	Dry the solution to a brownish black crystal by oven.	1L of pRGO solution	Oven(corridor outside 7109)	Existing
4.11.3.5	Transfer dried pRGO crystal from evaporating dish to mortar and grind to fine granule.		Fume hood(7109)	Existing
4.11.3.6	Weight and collect the pRGO into sampling bottles.		Fume hood(7109)	Existing
4.11.3.7	Transfer 100mg of pRGO into 200mL of PBS solution followed by mild sonication for 10 min.	100mg of pRGO, 200mL of 50mM PBS solution (50mM, pH=8.5)	Fume hood(7109)	Existing

4.11.3.8	Add 400mg of pristine heparin or BSA (Bovine Serum Albumin) subsequently into the solution. Stir the solution vigorously at 25 °C for 24h	400mg of pristine heparin or 400mg of BSA	Fume hood(7109)	Existing
4.11.3.9	Centrifuge the solution at 14800 g for 3 times and wash it thoroughly with D.I. water. Dialyze the solution in D.I. water for 2 days.	1L of DI water	Fume hood(7109)	Existing
4.11.3.10	Dry the solution to a brownish black crystal by oven.	200mL of Hep-g-pRGO solution or 200mL of BSA-g-pRGO solution	Oven (corridor outside 7109)	Existing
4.11.3.11	Transfer dried Hep-g-pRGO and BSA-g-pRGO crystal from evaporating dish to mortar and grind to fine granule.		Fume hood(7109)	Existing
4.11.3.12	Weight and collect the Hep-g-pRGO and BSA-g-pRGO into sampling bottles.		Fume hood(7109)	Existing
4.11.3.13	Collect adequate samples of different GOs derived above. Run AFM of GO, pRGO, Hep-g-pRGO and BSA-g-pRGO respectively.	50mg of GO, 50mg of pRGO, 50mg of Hep-g-pRGO, 50mg of BSA-g-pRGO	Fume hood(7106)	Existing
<b>5.12 Procedure template for functionalizing polystyrene with cellulose acetate via dispersive precipitation</b>				
Experimental Procedure No.	Experimental Procedure Description	Scale (Mass/Volume)	Location (Fumehood,bench op,etc)	Method New or Existing
4.12.1.1	Add 4 g cellulose triacetate into 196 g acetone to make a 2 wt.% solution	4 g cellulose triacetate 196 g acetone	Fume hood(7109)	Existing

Experimental	Experimental Procedure	Location	Method
4.12.1.2	Dry 1.8 g polystyrene in the oven for 15 minutes, then soak it into the solution prepared in step 4.1.1.1 for 2 hours	1.8 g polystyrene Oven (corridor outside 7109) Fume hood(7109)	Existing
4.12.1.3	Filter the above mixture in step 4.1.1.2 and dry the obtained solid in the oven for 0.5 hour	Fume hood(7109)	Existing
4.12.1.4	Add 40 g ethyl alcohol into 60 ml water to make a 40 wt.% solution	40 g ethyl alcohol 60 ml water Fume hood(7109)	Existing
4.12.1.5	Soak the dried solid obtained in the step 4.1.1.3 into the ethyl alcohol aqueous solution for 2 hours	Fume hood(7109)	Existing
4.12.1.6	Filter the above mixture, dry the obtained solid in the oven for 0.5 hour and then weight the collected final product	Fume hood(7109) Over (corridor outside 7109)	Existing
4.12.2.1	Add 0.584 g bilirubin into 100 ml hexane to make a 0.01 M solution	0.584 g bilirubin 100 ml hexane Fume hood(7109)	Existing
4.12.2.2	Add 0.5 g functionalized PS into the solution got from step 4.1.1.6 and stirring the mixture constantly; take 1ml sample every 2 minutes until there are no observable color change in the mixture	0.5 g functionalized polystyrene Fume hood(7109)	Existing
4.12.2.3	Samples are measured on a Beckman Coulter AU analyzer to determine the concentration of unreacted bilirubin	Fume hood(7109)	Existing
<b>5.13 Procedure template for emulsion polymerization and functionalization of styrene</b>			

Procedure No.	Description	(Mass/Volume) op,etc)	(Fumehood,benc top,etc)	New or Existing
4.13.1.1	Add 0.15 g sodium dodecyl sulfate (SDS), 1 g alkylphenolpolyoxyethylene (OP-10), 12 g styrene, 0.04 g cellulose triacetate, 0.5 g acrylate polyethylene glycol monoester (APEG), 0.2g hexadecane and 0.275g azodiisobutyronitrile into 100 ml three-necked round bottom flask and stir the mixture for 0.5 hour to form emulsion	0.15 g sodium dodecyl sulfate 1 g alkylphenolpolyoxyethylene 0.5 g acrylate polyethylene glycol monoester 0.2g hexadecane 0.275g azodiisobutyronitrile 12 g styrene	Fume hood(7109)	Existing
4.13.1.2	Transfer the emulsion to a homogenizer at the speed of 4000 r/min for 10 min to form a miniemulsion in ice bath		Fume hood(7109)	Existing
4.13.1.3	Keep the miniemulsion mixture in argon atmosphere at 70 °C for 6 hours		Glove box(7109)	Existing
4.13.1.4	Filter the above mixture, dry the obtained solid in the oven for 0.5 hour and then weight the collected final product		Fume hood(7109) Over (corridor outside 7109)	Existing
4.13.2.1	Add 0.584 g bilirubin into 100 ml hexane to make a 0.01 M solution	0.584 g bilirubin 100 ml hexane	Fume hood(7109)	Existing
4.13.2.2	Add 0.5 g functionalized PS into the solution got from step 4.2.1.4 and stirring the mixture constantly; take 1ml sample every 2 minutes until there are no observable color change in the mixture	0.5 g functionalized polystyrene	Fume hood(7109)	Existing
4.13.2.3	Samples are measured on a Beckman Coulter AU analyzer to determine the concentration of unreacted bilirubin		Fume hood(7109)	Existing

**5.14 Procedure template for coating polystyrene with polyethyleneimine (PEI)**

Experimental	Experimental Procedure	Scale	Location	Method
Procedure No.	Description	(Mass/Volume)	(Fumehood,bench op,etc)	New or Existing
4.14.1.1	Dissolve 20 g chromium (VI) oxide in 15 ml of water and then mix it with 100 ml of acetic acid	20 g chromium (VI) oxide 15 ml water 100 ml acetic acid	Fume hood(7109)	Existing
4.14.1.2	Dry 15 g polystyrene in the oven for 0.5 hour	15 g polystyrene	Oven (corridor outside 7109)	Existing
4.14.1.3	Set up a reflux system with a round-bottom flask, a condenser, a retort stand and a magnetic heater. Transfer the chromic solution prepared in step 4.3.1.1 into the flask and add dried polystyrene, reflux the mixture at 120 °C for 3 hours		Fume hood(7109)	Existing
4.14.1.4	Dilute 118 g 37 wt.% hydrochloric acid with 125 ml water to make a 6M HCl solution, add 16 g NaOH into 200 ml water to make a 2M NaOH solution	118 g 37 wt.% hydrochloric acid 125 ml water 16 g NaOH 200 ml water	Fume hood(7109)	Existing
4.14.1.5	Treat the mixture in step 4.3.1.3 with 6M HCl solution and 2M NaOH solution subsequently, with addition of several drops of 30% H <sub>2</sub> O <sub>2</sub> aqueous solution	30% H <sub>2</sub> O <sub>2</sub> aqueous solution	Fume hood(7109)	Existing
4.14.1.6	Filter the mixture and dry the obtained solid		Fume hood(7109) Over (corridor	Existing

			outside 7109	
4.14.2.1	Add 0.2M CuSO <sub>4</sub> into 100 ml water, mix it with the partially oxidized polystyrene obtained in step 4.3.1.6, stir the system for 0.5 hour and filter the mixture	0.2M CuSO <sub>4</sub> 100 ml water	Fume hood(7109)	Existing
4.14.2.2	PEI solution (50 wt.%) into 160 ml water to make a 10 wt.% solution, add the solid obtained in step 4.3.1.6, stir the mixture 2 hours, and filter the mixture	40 g PEI solution (50 wt.%) 160 ml water	hood(7109)	Existing
4.14.2.3	Dilute 40 g glutaric dialdehyde solution (50 wt.%) with 160 ml water to make a 10 wt.% aqueous solution, add the obtained solid in it, stir the mixture for 1 hour and filter it	40 g glutaric dialdehyde solution (50 wt.%) 160 ml water	Fume hood(7109)	Existing
4.14.2.4	Dilute 118 g 37 wt.% hydrochloric acid with 125 ml water to make a 6M HCl solution, add 48 g NH <sub>3</sub> aqueous solution (28 wt.%) into 165 ml water to make a 4M NH <sub>3</sub> aqueous solution (28 wt.%)	118 g 37 wt.% hydrochloric acid 125 ml water 48 g NH <sub>3</sub> aqueous solution (28 wt.%) 165 ml water	Fume hood(7109)	Existing
4.14.2.5	Treat the obtained solid in step 4.3.2.3 with 6M HCl solution and 4M NH <sub>3</sub> solution subsequently		Fume hood(7109)	Existing
4.14.2.6	Filter the mixture, wash the obtained solid by enough DI water, dry the final product in the oven and weight it	DI Water	Fume hood(7109) Over (corridor outside 7109)	Existing
4.14.3.1	Add 0.584 g bilirubin into 100 ml hexane to make a 0.01 M solution	0.584 g bilirubin 100 ml hexane	Fume hood(7109)	Existing

4.14.3.2	Add 0.5 g functionalized PS into the solution got from step 4.3.2.6 and stirring the mixture constantly; take 1ml sample every 2 minutes until there are no observable color change in the mixture	0.5 g functionalized polystyrene	Fume hood(7109)	Existing
4.14.3.3	Samples are measured on a Beckman Coulter AU analyzer to determine the concentration of unreacted bilirubin	Fume hood(7109)	Existing	
<b>5.15 General and Biomimetic Approach to Biopolymer-Func5onalized Graphene Oxide Nanosheet through Adhesive Dopamine</b>				
Experimental Procedure	Description	Scale (Mass/Volume)	Location (Fumehood,benc top,etc)	Method New or Existing
Procedure No.				
4.15.1.1	Graphene oxide (GO) was prepared from natural graphite flakes by a modified Hummers method. 2.5 g graphite and 1.875 g NaNO <sub>3</sub> were placed in a flask.	2.5g Graphite 1.875g NaNO <sub>3</sub>	Fume hood(7109)	Existing
4.15.1.2	75 mL H <sub>2</sub> SO <sub>4</sub> was added with stirring in an ice-water bath, and 10 g KMnO <sub>4</sub> were slowly added over about 1 h.	75ml H <sub>2</sub> SO <sub>4</sub> 10g KMnO <sub>4</sub>	Fume hood(7109)	Existing
4.15.1.3	Mixture was stirred in the ice water bath for 2 h, followed by a vigorously stirring for 3 days at room temperature.	N/A	Fume hood(7109)	Existing
4.15.1.4	Diluted the mixture with DI water (700 mL) slowly, and the excess KMnO <sub>4</sub> was decomposed by H <sub>2</sub> O <sub>2</sub> (30 wt. %, 15 mL).	15ml 30wt% H <sub>2</sub> O <sub>2</sub>	Fume hood(7109)	Existing
4.15.1.5	The insoluble precipitations were removed by centrifugation. The resulted GO solution was filtered and washed with HCl	1L 10 wt% HCl	Fume hood(7109)	Existing

	(10 wt %, 1 L) and DI water for several times to remove the metal ions.		
4.15.1.6	The pristine brown GO solution was dialyzed with deionized water for 1 week before use to remove any residual salts and acids.	N/A	Fume hood(7109)
<b>5.16 Graphene Oxide Nanocomposite Incorporated Poly(ether imide) Mixed Matrix Membranes for in Vitro Evaluation of Its Efficacy in Blood Purification Applications</b>			
<b>5.16.1 GO Preparation</b>			
P4.16.1.1	Three grams of graphite powder was added to a round-bottom flask containing 70 mL H <sub>2</sub> SO <sub>4</sub> and stirred in an ice bath.	70ml H <sub>2</sub> SO <sub>4</sub> 3g Graphite	Fume hood(7109)
4.16.1.2	Add 9 g of KMnO <sub>4</sub> slowly to ensure that the temperature was maintained lower than 15 °C.	9 g KMnO <sub>4</sub>	Fume hood(7109)
4.16.1.3	After 30 min, the flask was transferred into a 40 °C bath and vigorously stirred for 1 h.	N/A	Fume hood(7109)
4.16.1.4	150 mL of water was added dropwise, and the solution was maintained at 95 °C for 1 h	Water	Fume hood(7109)
4.16.1.5	The solution changed color from dark brown to yellow when an excess 500 mL of water and 15 mL of H <sub>2</sub> O <sub>2</sub> (30%) was added.	15ml H <sub>2</sub> O <sub>2</sub> (30 wt%)	Fume hood(7109)
4.16.1.6	Allow solution to settle, the solids were washed with dilute HCl (250 mL) to remove metal ions	250 ml diluted HCl	Fume hood(7109)
4.16.1.7	Filter and centrifuged solution in hot conditions to remove the precipitates soluble in warm water	N/A	Fume hood(7109)
4.16.1.8	Ultrasonicate yellowish brown residue	N/A	Fume hood(7109)

4.16.1.9	Dry in vacuum overnight	N/A	Fume hood(7109)	Existing
<b>Synthesis of DA-g-Hep with 20 mol % grafting ratio</b>				
Experimental	Experimental Procedure	Scale (Mass/Volume)	Location (Fumehood,benc top,etc)	Method
Procedure No.	Description			
4.16.1.10	0.2 g of heparin and 0.05 g of dopamine were dissolved in 30 mL MES buffer (0.05M, pH 5.3, 0.1 M NaCl).	0.2g niti	Fume hood(7109)	Existing
4.16.1.11	0.1915g EDC and 0.0575g NHS were added and the reaction mixture was vigorously stirred for 24 h under N2 protection at room temperature	0.1915g EDC 0.0575g NHS	Fume hood(7109)	Existing
4.16.1.12	Maintain the pH at 5.3 by the addition of 1 M HCl	1M HCl	Fume hood(7109)	Existing
4.16.1.13	3 mL of saturated NaCl solution and 60 mL of cold ethanol were sequentially added.	3ml saturated NaCl 60 ml cold ethanol	Fume hood(7109)	Existing
4.16.1.14	After centrifugation at 1000 × g for 10 min, the precipitated dopamine grafted heparin (DA-g-Hep) conjugate was redissolved in 1 M NaCl solution, and ethanol was added again. The volume ratio of ethanol to NaCl solution was 10:1.	1M NaCl solution Cold ethanol NaCl:Ethanol=10:1	Fume hood(7109)	Existing
4.16.1.15	This purification step was repeated three times to minimize the electrostatic interaction between the heparin and dopamine.	N/A	Fume hood(7109)	Existing
4.16.1.16	Dialyzed against deionized water using a dialysis membrane (MWCO:3,500) for 1 day under acidified water (pH 5, adjusted by 1 M HCl) to avoid catechol oxidation.	pH 5, 1M HCl	Fume hood(7109)	Existing

4.16.1.17	The final product was obtained by using a freeze-dryer.	N/A	Fume hood(7109)	Existing
4.16.1.18	Repeat the measurement three times to get a reliable value	N/A	Fume hood(7109)	Existing
<b>4.16.2 MMMs Preparation</b>				
Experimental	Experimental Procedure	Scale	Location	Method
Procedure No.	Description	(Mass/Volume) (top,etc)	(Fumehood,benc top,etc)	New or Existing
4.16.2.1	GO (0, 0.025, 0.050, 0.1, and 0.2 wt %) was sonicated in the solvent (NMP) for 1 h	Graphine Oxides NMP	Fume hood(7109)	Existing
4.16.2.2	2 wt % PVP-K90 was added and further homogenized by vigorous stirring for 2 h.	2 wt% PVP-K90	Fume hood(7109)	Existing
4.16.2.3	16 wt % PEI was added, and a homogeneous dope solution was prepared by mechanical stirring for 24 h.	16 wt% PEI	Fume hood(7109)	Existing
4.16.2.4	The dope solution was then degassed by applying a vacuum	N/A	Fume hood(7109)	Existing
4.16.2.5	A semiautomatic casting unit was used to prepare these MMMs	N/A	Fume hood(7109)	Existing
4.16.2.6	The dope solution was casted on a dust free glass plate maintaining a thickness of 200 $\mu$ m at a relative humidity (RH) of 25%	N/A	Fume hood(7109)	Existing
4.16.2.7	The glass plate was then immediately immersed in a water bath containing 0.2% solvent.	N/A	Fume hood(7109)	Existing
4.16.2.8	The nascent membranes were washed with warm water (35 ± 2 °C) and then stored in distilled water until further testing	N/A	Fume hood(7109)	Existing

### 5.17.1 Preparation of biopolymer functionalized RGO

Experimental	Experimental Procedure	Scale (Mass/Volume)	Location	Method
Procedure No.	Description	(Fumehood,benc top,etc)		New or Existing
4.17.1.1	200 mg GO was added into 1 L PBS solution (50 mM, pH 1/4 8.5)	200mg GO 1 L PBS	Fume hood(7109)	Existing
4.17.1.2	Dispersed by sonication for 20 min in an ice bath	N/A	Fume hood(7109)	Existing
4.17.1.3	Then 1 g dopamine hydrochloride was added and sonicated for another 5 min	1g Dopamine	Fume hood(7109)	Existing
4.17.1.4	The solution was stirred vigorously at 60 C for 12 h	N/A	Fume hood(7109)	Existing
4.17.1.5	The reduction reaction was stopped by centrifuging at 11 000 g 3 times	N/A	Fume hood(7109)	Existing
4.17.1.6	Followed by dialysis in D.I. water for 2 days.	N/A	Fume hood(7109)	Existing
<b>5.17.2 Preparation of Hep-g-pRGO and BSA-g-pRGO</b>				
Experimental	Experimental Procedure	Scale (Mass/Volume)	Location	Method
Procedure No.	Description	(Fumehood,benc top,etc)		New or Existing
4.17.2.1	100 mg pRGO was re-dispersed into 200 mL PBS solution (50 mM, pH 8.5) by mild sonication for 10 min	100mg pRGO 200ml PBS	Fume hood(7109)	Existing
4.17.2.2	400 mg pristine heparin or BSA was added subsequently, and the heparin or BSA grafting reaction was carried out at 25 C	400 mg Pristine heparin or BSA	Fume hood(7109)	Existing

	for another 24 h with vigorous stirring to reach the maximum biopolymer grafting amounts.			
4.17.2.3	The solution was centrifuged and washed thoroughly with D.I. water at 14 800 g 3 times to remove the physically adsorbed heparin or BSA	N/A	Fume hood(7109)	Existing
4.17.2.4	Dialyzed in D.I. water for 2 days to make sure the ions were removed completely.	N/A	Fume hood(7109)	Existing
<b>5.18 Procedure template for preparation of graphene based material for blood perfusion</b>				
Experimental	Experimental Procedure	Scale (Mass/Volume)	Location (Fumehood,benc top,etc)	Method New or Existing
Procedure No.	Description			
4.18.1.1	Add CG powder into NaOH solution.	20 mg CG powder,NaOH solution (3 M, 5 mL)	Fume hood(7109)	Existing
4.18.1.2	Bath-sonicated the resulting product for 3 h to form homogeneous solution		Fume hood(7109)	Existing
4.18.1.3	Neutralize the pH value of homogenous solution to 7.0 by adding HCl solution	HCl solution (2.4 M, 11 mL)	Fume hood(7109)	Existing
4.18.1.4	Purify the homogenous solution by repeated washing and centrifuging at 5000 rpm for 10 min.		Fume hood(7109)	Existing
4.18.1.5	Stir the resulting product in EDC and NHS for 2 hours.	100 Mm EDC (1-(3-	Fume hood(7109)	Existing

	Dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride; 100           NHS Hydroxysuccinimide)		
4.18.1.6	Centrifuge and wash the above product in 7.0 Phosphate buffer solutions (PBS).	Fume hood(7109)	Existing
4.18.1.7	Adding Hb into GC dispersion and stir overnight at 4 °C.	Hb (2 mg mL <sup>-1</sup> , 400 µL)	Fume hood(7109)
4.18.1.8	Centrifuge the resulting product at 5000 rpm for 20 min and washed 3 times with pH 7.4 PBS.	Fume hood(7109)	Existing
4.18.1.9	Disperse the precipitates in pH 7.4 PBS and stored the resulting product in 4 °C refrigerator.	Fume hood(7109)	Existing
4.18.2.1	Polish the bare GCE (glassy carbon electrode) with abrasive paper and then with alumina slurry on micro-cloth pads.	alumina (0.25 and 0.05 µm)	Fume hood(7109)
4.18.2.2	Undergo ultrasonication in twice-distilled water for 30 s and dried in air.		Fume hood(7109)
4.18.2.3	Let Au-NPs undergo cyclic voltammetry (CV) from 0.00 to 0.70 V for 40 cycles at the scan rate of 0.10 V s <sup>-1</sup> in KCl solution containing HAuCl4.	5.1 M (KCl) HAuCl4(0.50 Mm)	Fume hood(7109) Existing
4.18.2.4	Wash the Au-NPs modified GCE (GCE/Au-NPs) thoroughly		Fume hood(7109) Existing

	with water		
4.18.2.5 to 4.18.2.7	Immerse the CE/Au-NPs electrode in the CG-Hb dispersion for 6 h and during process, the CG-Hb dispersion should be bath-sonicated for 5 min for every 1 h.	Fume hood(7109)	Existing
4.18.2.8	Store the resulting modified electrode in 4 °C refrigerator	Fume hood(7109)	Existing
<b>5.19 Procedure templateforpreparation of agrose coated activated carbon</b>			
Experimental	Experimental Procedure	Scale (Mass/Volume)	Location (Fumehood,benc top,etc) New or Existing Method
Procedure No.	Description		
4.19.1.1	Add agrose with water into a breaker	0.6 g agrose; 10 mL water	Fume hood(7109) Existing
4.19.1.2	Heat up the breaker		Fume hood(7109) Existing
4.19.1.3	Water bath.		Fume hood(7109) Existing
4.19.1.4	Adding activated carbon into the breaker.	2g activated carbon	Fume hood(7109) Existing
4.19.1.5	Add Span 80 and Tween 80 into breaker.	1.67 g Span; 0.43 g Tween 80.	Fume hood(7109) Existing
4.19.1.6	Stir the mixture		Fume hood(7109) Existing
4.19.1.7	Stir the mixture		Fume hood(7109) Existing
4.19.1.8	use ether to wash activated carbon	50 mL ether	Fume hood(7109) Existing

4.19.1.9	use ethyl alcohol to wash activated carbon	50 mL ethyl alcohol	Fume hood(7109)	Existing
4.19.1.10	use deionized water to wash activated carbon	50 mL deionized water	Fume hood(7109)	Existing
4.19.1.11	Add epichlorohydrin and dimethyl sulfoxide into a 50 mL breaker	0.312 g epichlorohydrin ; 9.688 mL dimethyl sulfoxide	Fume hood(7109)	Existing
4.19.1.12	Add dimethyl sulfoxide, NaOH and NaBH4 into breaker.	10 mL dimethyl sulfoxide;1.2 g NaOH; 0.05 g NaBH4	Fume hood(7109)	Existing
4.19.1.13	Add the coated activated carbon from procedure 10 into the breaker.	coated activated carbon	Fume hood(7109)	Existing
4.19.1.14	Use ethyl alcohol to wash resulting activated carbon.	ethyl alcohol	Fume hood(7109)	Existing
4.19.1.15	Use deionized water to wash resulting activated carbon.	deionized water	Fume hood(7109)	Existing
4.19.1.16	Mix the activated carbon with dimethyl sulfoxide and undergo ultrasonic treatment for 15 mins.	dimethyl sulfoxide	Fume hood(7109)	Existing
<b>5.20 Procedure template for preparation of 3D GO/biopolymer gels</b>				
Experimental	Experimental Procedure	Scale (Mass/Volume)	Location (Fumehood,benc op,etc)	Method
Procedure No.	Description			New or Existing
4.20.1.1	Dissolve BSA in D.I. water and stirring overnight.	4 g bovine serum albumin 20 mL D.I. water	Fume hood(7109)	Existing

4.20.1.2	Add the mixture to GO concentrated solution	0.3 mL BSA solution 4 g GO concentrated solution	Fume hood(7109)	Existing
4.20.1.3	Test the formation of hydrogel		Fume hood(7109)	Existing
4.20.1.4	Treat sonication		Fume hood(7109)	Existing
4.20.1.5	Freeze-dried the hydrogel		Fume hood(7109)	Existing
4.20.2.1	Dissolve DNA in D.I. water and stirring overnight.	400 mg DNA; 20 mL D.I. water	Fume hood(7109)	Existing
4.20.2.2	Add mixture to GO concentrated solution	0.1 mL DNA solution 4 g GO concentrated solution	Fume hood(7109)	Existing
4.20.2.3	Test the formation of hydrogel		Fume hood(7109)	Existing
4.20.2.4	Treat sonication		Fume hood(7109)	Existing
4.20.2.5	Freeze-dried the hydrogel		Fume hood(7109)	Existing
4.20.3.1	Dissolve chitosan in D.I. water and stirring overnight.	400 mg chitosan; 20 mL D.I. water	Fume hood(7109)	Existing
4.20.3.2	Add mixture to GO concentrated solution	0.4 mL CS solution 4 g GO concentrated solution	Fume hood(7109)	Existing
4.20.3.3	Test the formation of hydrogel		Fume hood(7109)	Existing
4.20.3.4	Treat sonication		Fume hood(7109)	Existing

4.20.3.5	Freeze-dried the hydrogel		Fume hood(7109)	Existing
4.20.4.1	Employing GO colloidal suspension with freeze-drying,	5 mg/g GO	Fume hood(7109)	Existing
4.20.4.2	Sonicate the GO in the solvent (NMP) for one hour.	0.2 wt %GO	Fume hood(7109)	Existing
4.20.4.3	Add PVP-K into the mixture	90 wt% PVP-K	Fume hood(7109)	Existing
4.20.4.4	Add PEI into mixture	16 wt% PEI	Fume hood(7109)	Existing
4.20.4.5	Degassed by applying vacuum.		Fume hood(7109)	Existing
4.20.4.6	Cast the dope solution on a dust free glass plate maintaining a thickness of 200 $\mu$ m at a relative humidity (RH) of 25%.		Fume hood(7109)	Existing
4.20.4.7	Immersed the glass plate in a water bath containing 0.2% solvent.		Fume hood(7109)	Existing
4.20.4.8	Wash the membranes with warm water ( $35 \pm 2$ °C) and stored in distilled water		Fume hood(7109)	Existing
<b>5.21 Procedure template for preparation of Biopolymer-Functionalized Graphene Oxide Nanosheet through Adhesive Dopamine.</b>				
Experimental	Experimental Procedure	Scale (Mass/Volume)	Location	Method
Procedure No.	Description		Fume hood(7109)	Existing
4.21.1.1	Dissolve heparin and dopamine in of MES buffer (0.05M, pH 5.3, 0.1 M NaCl).	91.8 mg of heparin; 28.5 mg of dopamine;	Fume hood(7109)	Existing

		15 mL of MES buffer		
4.21.1.2	Add EDC into mixture and maintaining the pH by addition of 1 N HCl	EDC (21.5 mg); HCl (1 N)	Fume hood(7109)	Existing
4.21.1.3	Stop the reaction by adjusting pH to 7.0 with 1 M NaOH	NaOH (1 M)	Fume hood(7109)	Existing
4.21.1.4	Add saturated NaCl solution and cold ethanol into mixture	3 mL of saturated NaCl; 60 mL of cold ethanol	Fume hood(7109)	Existing
4.21.1.5	centrifugation at 1000 × g for 10 min		Fume hood(7109)	Existing
4.21.1.6	Redisolve the precipitated heparin-dopamine conjugate NaCl solution, and ethanol was added again. (The volume ratio of ethanol to NaCl solution was 10:1.)	1 M NaCl and ethanol (The volume ratio of ethanol to NaCl solution was 10:1.)	Fume hood(7109)	Existing
4.21.1.7	Repeat purification step three times		Fume hood(7109)	Existing
4.21.2.1	Dissolve 40 mg DA-g-Hep in 20 mL of Tris buffer solution	40 mg DA-g-Hep ; 20 mL of Tris buffer solution (10 mM, pH 8.5)	Fume hood(7109)	Existing
4.21.2.2	2 mg GO was added to the DA-g-Hep homogeneous solution.	2 mg GO	Fume hood(7109)	Existing

4.21.2.3	Sonication for 20 min and then vigorously stirred at 20 °C for 24 h.		Fume hood(7109)	Existing
4.21.2.4	The obtained Hep-a-GO was centrifuged at 14 800g for three times		Fume hood(7109)	Existing
4.21.2.5	The Hep-a-rGO was prepared under the same condition as Hep-a-GO, except that the reaction temperature was changed to 60 °C.		Fume hood(7109)	Existing
<b>5.22 Procedure template for preparation of CS/CO gel</b>				
Experimental	Experimental Procedure	Scale (Mass/Volume)	Location	Method
Procedure No.	Description			
4.22.1.1	CS was dispersed into 10 mL of GO suspension, and then acetic acid was added.	300 mg chitosan(CS) 10 mL of 3 mg/mL GO 0.2 mL of acetic acid	Fume hood(7109)	Existing
4.22.1.2	stirred the mixture		Fume hood(7109)	Existing
4.22.1.3	Pour the mixture into a mold and freeze-dried under vacuum		Fume hood(7109)	Existing
4.22.1.4	Immersed the product in 0.5 M sodium hydroxide (NaOH)		Fume hood(7109)	Existing
4.22.2.1	Heparin, NHS, and EDC/HCl were dissolved sequentially in phosphate buffer solution.	30 mg of heparin; 9 mg of NHS;	Fume hood(7109)	Existing

		30 mg of EDC; 20 mL of phosphate buffer solution (50 mM, pH 5.5).	
4.22.2.2	Shake the solution		Fume hood(7109) Existing
4.22.2.3	Adjust the pH value of solution		Fume hood(7109) Existing
4.22.2.4	Incubate the solution with CS/GH	150 mg of CS/GH(dry weight)	Fume hood(7109) Existing
4.22.2.5	Washing with sodium chloride and deionized water.	2 M NaCl; D.I. water	Fume hood(7109) Existing
4.22.2.6	Testing the product with toluidine blue	toluidine blue	Fume hood(7109) Existing
<b>5.23 Procedure template for fabrication of mesoporous beads for hemoperfusion:</b>			
Experimental procedure No.	Experimental Procedure Description	Scale (Mass/Volume)	Location Method (New or existing)
4.23.1.1	3.9g styrene(St), 4.78g divinylbenzene(DVB) and 7g porogen containing 0.4g benzoyl peroxide(BPO) initiator and 0.7g lauryl alcohol as interface stabilizer was mixed as dispersed phase at room temperature	3.9g styrene(St), 4.78g divinylbenzene(DVB), 7g porogen containing 0.4g benzoyl peroxide(BPO) initiator and 0.7g lauryl alcohol	Fume hood (7109) Existing
4.23.1.2	1L aqueous solution of 9g Polyvinyl alcohol(PVA), 0.45g sodium dodecyl sulfate (SDS, biochemical grade), 0.22g Na <sub>2</sub> SO <sub>4</sub> and 0.07g hydroquinone(HQ) inhibitor was used as continuous phase at room temperature	9g Polyvinyl alcohol(PVA), 0.45g sodium dodecyl sulfate (SDS, biochemical grade), 0.22g	Fume hood (7109) Existing

		Na <sub>2</sub> SO <sub>4</sub> , 0.07g hydroquinone(HQ)		
4.23.1.3	Turn on the nitrogen gas, continuously pressed the dispersed phase through the Shirasu Porous Glass(SPG) membrane with 2.8 $\mu$ m pore size into the continuous aqueous solution	Nitrogen gas	Fume hood (7109)	Existing
4.23.1.4	The obtained emulsion was transferred to a four-neck glass separator flask equipped with a semicircular anchor-type blade, a condenser and a nitrogen inlet nozzle;	Nitrogen gas	Fume hood (7109)	Existing
4.23.1.5	Bubble the emulsion with nitrogen gas for 1h;	Nitrogen gas	Fume hood (7109)	Existing
4.23.1.6	Lifted the nitrogen nozzle and gradually heated the emulsion to 75 °C ;	NIL	Fume hood (7109)	Existing
4.23.1.7	The polymerization reaction was carried out for 20h under the nitrogen atmosphere;	NIL	Fume hood (7109)	Existing
4.23.1.8	Collected and washed the prepared PS microspheres with hot water and ethanol respectively for four times;	Hot water, ethanol	Fume hood (7109)	Existing
4.23.1.9	Extracted the PS beads in a Soxhlet apparatus with acetone, and then dried under partial vacuum at 45 °C for 24 h;	Acetone	Fume hood (7109), Oven(Corridor outside 7190)	Existing

4.23.2.1	Dispersed 300mg chitosan(CS) into 10mL of 3mg/mL graphene oxide suspension;	300mg chitosan(CS) , 10mL of 3mg/mL graphene oxide suspension	Fume hood (7109)	Existing
4.23.2.2	Added 0.2mL of acetic acid, and vigorously stirred the mixture to dissolve the CS;	0.2mL of acetic acid	Fume hood (7109)	Existing
4.23.2.3	Using vacuum degassing method to remove the bubbles in the mixture;	NIL	Fume hood (7109)	Existing
4.23.2.4	Poured the mixture into a sphere mold;	NIL	Fume hood (7109)	Existing
4.23.2.5	Freeze-dried the spheres under vacuum;	NIL	Fume hood (7109)	Existing
5.23.2.6	Immersed the dried hydrogel into 0.5M sodium hydroxide (NaOH) to remove the excess acid;	0.5M sodium hydroxide (NaOH)	Fume hood (7109)	Existing
4.23.2.7	Thoroughly washed the hydrogel with deionized water;	D.I.water	Fume hood (7109)	Existing
<b>5.24 Procedure template for coating of mesoporous beads for hemoperfusion:</b>				
Experimental procedure No.	Experimental Procedure Description	Scale (Mass/Volume)	Location	Method (New or existing)
4.24.1.1.1	Dissolved the PMMA in ethyl acetate (1200mL of 2.5%, w/v) 2.5%, w/v)	PMMA, ethyl acetate (1200mL of 2.5%, w/v)	Fume hood (7109)	Existing

4.24.1.1.2	Dry PS beads were added into the prepared PMMA solution and shaken in a 2L beaker for 6h at 145rpm	PMMMA solution	Fume hood (7109)	Existing
4.24.1.1.3	Decanted the solution and dried the beads under airflow in the hood for overnight	NIL	Fume hood (7109)	Existing
4.24.1.1.4	Furthered dried the beads in a vacuum oven at 80°C	NIL	Oven (Corridor outside 7109)	Existing
4.24.1.2.1	Dissolved the heparin sodium(50mg) in water (2.5 mL)	Heparin sodium(50mg), water (2.5 mL)	Fume hood (7109)	Existing
4.24.1.2.2	Acetone (7.5 mL) was added to the heparin sodium solution to obtain a clear 0.5% (w/v) solution	Acetone (7.5 mL), heparin sodium solution to obtain a clear 0.5% (w/v) solution	Fume hood (7109)	Existing
4.24.1.2.3	Prepared PMMA in acetone as 5% (w/v) for 4 mL, and then slowly added to the heparin solution in order to form stable and off-white PMMA-heparin solution	PMMA, acetone as 5% (w/v) for 4 mL, heparin solution	Fume hood (7109)	Existing
4.24.1.2.4	Separated the 14 mL PMMA-heparin solution into 16 mL and 8 mL	14 mL PMMA-heparin solution	Fume hood (7109)	Existing
4.24.1.2.5	Added two batches of beads, weighing 2 and 1g, respectively to the 16 mL and 8 mL PMMA-heparin solution	16 mL and 8 mL PMMA-heparin solution	Fume hood (7109)	Existing
4.24.1.2.6	Shook the beads and solutions at 180rpm for 5h	NIL	Fume hood (7109)	Existing
4.24.1.2.7	Decanted the solutions and dried the beads in a vacuum oven at 80°C	NIL	Fume hood (7109)	Existing

4.24.1.3.1	Chitosan was dissolved in 0.25% (w/w) aqueous acetic acid solution at a concentration of 120 mg/16 mL	Chitosan, 0.25% (w/w) aqueous acetic acid solution	Fume hood (7109)	Existing
4.24.1.3.2	Added the dry PMMA-coated PS beads (1.1 g) to chitosan solution (8 mL)	PMMA-coated PS beads (1.1 g), chitosan solution (8 mL)	Fume hood (7109)	Existing
4.24.1.3.3	The resulting mixture was shaken in three batches for 1, 3, and 5 h	NIL	Fume hood (7109)	Existing
4.24.1.3.4	The supernatant was decanted, and the beads were filtered under vacuum through Millipore filter paper using a Bucher funnel and rinsed with 0.1 N sodium hydroxide solution	0.1 N sodium hydroxide solution	Fume hood (7109)	Existing
4.24.1.3.5	Further rinsed the beads with water to remove residual sodium hydroxide	water	Fume hood (7109)	Existing
4.24.1.3.6	The PMMA–chitosan-coated beads were dried overnight in a vacuum oven at 80 °C	NIL	Fume hood (7109)	Existing
4.24.1.4.1	PMMA–chitosan-coated PS beads (0.3 g) were equilibrated in 2-(N-morpholino)ethanesulfonic acid (MES) buffer (0.05 M, pH 5.6) for 1 h	2-(N-morpholino)ethanesulfonic acid (MES) buffer (0.05 M, pH 5.6)	Fume hood (7109)	Existing
4.24.1.4.2	Added 1-ethyl-3-(3-dimethylaminopropyl) carbodiimide hydrochloride (EDC) and Nhydroxysuccinimide (NHS) to heparin solution [5 mL of 2% (w/w) in 0.05 M MES buffer at pH 5.60] at a molar ratio of EDC/NHS/heparin of 0.4:0.24:1.0	1-ethyl-3-(3-dimethylaminopropyl) carbodiimide hydrochloride (EDC), Nhydroxysuccinimide (NHS), heparin	Fume hood (7109)	Existing
4.24.1.4.3	10 min later, the 0.3g PS beads were added to the solution prepared in the previous step and shaken overnight at 180 rpm at room temperature	NIL	Fume hood (7109)	Existing

4.24.1.4.4	Decanted the solution, and the beads were washed with deionized water for 24h with three changes of water	D.I. water (7109)	Fume hood (7109)	Existing
4.24.1.4.5	The heparin-coated beads were dried overnight in a vacuum oven at 40 °C	NIL	Fume hood (7109)	Existing
4.24.2.1.1	Prepared a BSA stock solution by dissolving 4 g of BSA in 20 mL D.I. water, and stirring overnight;	4 g BSA , 20 mL D.I. water (7109)	Fume hood (7109)	Existing
4.24.2.1.2	0.3 mL BSA (200 mg/ mL) solution was added to 4 g GO concentrated solution (5 mg/g);	0.3 mL BSA (200 mg/ mL) 4 g GO concentrated solution (5 mg/g);	Fume hood (7109)	Existing
4.24.2.1.3	Violently shook the mixture solution for 10s to form a hydrogel, and observed the hydrogel formation by a tube inversion method;	NIL	Fume hood (7109)	Existing
4.24.2.1.4	Treated the hydrogel by sonication for 3 min;	NIL	Fume hood (7109)	Existing
4.24.2.1.5	The final weight ratio of GO: BSA is 20 mg: 60 mg;	NIL	Fume hood (7109)	Existing
4.24.2.2.1	Prepared a DNA stock solution by dissolving 400mg of DNA in 20 mL D.I. water, and stirring overnight;	400mg DNA in 20 mL D.I. water (7109)	Fume hood (7109)	Existing
4.24.2.2.2	1 mL DNA (20mg/ mL) solution was added to 4 g GO concentrated solution (5 mg/g);	1 mL DNA, 4g GO concentrated solution(5mg/g) (7109)	Fume hood (7109)	Existing

4.24.2.2.3	Violently shook the mixture solution for 10s to form a hydrogel, and observed the hydrogel formation by a tube inversion method;	NIL	Fume hood (7109)	Existing
4.24.2.2.4	Treated the hydrogel by sonication for 3 min;	NIL	Fume hood (7109)	Existing
4.24.2.2.5	The final weight ratio of GO: DNA is 20 mg: 20 mg;	NIL	Fume hood (7109)	Existing
4.24.2.3.1	Prepared a chitosan stock solution by dissolving 400mg of chitosan in 20 mL of 2.5%(v/v) aqueous acetic acid, and stirring overnight;	400mg of chitosan , 20 mL 2.5%(v/v) aqueous acetic acid	Fume hood (7109)	Existing
4.24.2.3.2	0.4 mL CS (20 mg/ mL) solution was added to 4 g GO concentrated solution (5 mg/g);	0.4 mL CS (20 mg/ mL), 4g GO concentrated solution (5mg/g)	Fume hood (7109)	Existing
4.24.2.3.3	Violently shook the mixture solution for 10s to form a hydrogel, and observed the hydrogel formation by a tube inversion method;	NIL	Fume hood (7109)	Existing
4.24.2.3.4	Treated the hydrogel by sonication for 3 min;	NIL	Fume hood (7109)	Existing
4.24.2.3.5	The final weight ratio of GO: CS is 20 mg: 8 mg;	NIL	Fume hood (7109)	Existing

## Section 6.Hazard and Operability Analysis (HAZOP)

NO	HAZARD	HAZARD EFFECT	SEV ERI TY	PROBA BILITY	RISK	MINIMISE RISK BY	RESIDUAL RISK
4.1.1	Benzoyl peroxide	Cause eye, skin and respiratory irritation	M(2)	L(1)	M(2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L(1)
	Styrene	Cause eye and skin irritation; Flammable	M(2)	L(1)	M(2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L(1)
	Divinyl benzene	Cause eye and skin irritation; Flammable	M(2)	L(1)	M(2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L(1)
	Hexadecane	Cause eye, skin and respiratory irritation	M(2)	L(1)	M(2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L(1)
	Sorbitanmonooleate	Cause eye, skin and respiratory irritation	M(2)	L(1)	M(2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L(1)
	Hydroquinone	Cause eye, skin and respiratory irritation	M(2)	L(1)	M(2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L(1)
	Sodium dodecyl sulfate	Cause eye, skin and respiratory irritation; Flammable	M(2)	L(1)	M(2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.  Keep away from heat source or ignition.	L(1)

4.1.3	No associated hazard	N/A	N/A	N/A	N/A	N/A	N/A
4.1.4	No associated hazard	N/A	N/A	N/A	N/A	N/A	N/A
4.1.5	High temperature	Cause skin burning	M(2)	L(1)	M(2)	Wear lab coat, goggles and proper gloves. Avoid direct contact with the hot object	L(1)
4.1.6	Ethanol	Cause eye, skin and respiratory irritation; Flammable	M(2)	L(1)	M(2)	Wear lab coat, goggles and proper gloves and work in fume cupboard. Keep away from heat source or ignition.	L(1)
4.1.7	Acetone	Cause eye, skin and respiratory irritation; Flammable	M(2)	L(1)	M(2)	Wear lab coat, goggles and proper gloves and work in fume cupboard. Keep away from heat source or ignition.	L(1)
4.1.8	No associated hazard	N/A	N/A	N/A	N/A	N/A	N/A
4.2.1	Sulfuric acid	Cause eye, skin and respiratory irritation; Corrosive	M(2)	L(1)	M(2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L(1)
4.2.2	Silver sulfate	Cause eye, skin and respiratory irritation; Corrosive	M(2)	L(1)	M(2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L(1)
	Sulfuric acid	Cause eye, skin and respiratory irritation; Corrosive	M(2)	L(1)	M(2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L(1)
4.2.3	High temperature	Cause skin burning	M(2)	L(1)	M(2)	Wear lab coat, goggles and proper	L(1)

4.2.4	No associated hazard	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4.2.5	No associated hazard	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4.2.6	Sulfuric acid	Cause eye, skin and respiratory irritation; Corrosive	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L (1)	
4.2.7	Acidic mixture	Cause eye, skin and respiratory irritation; Corrosive	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L (1)	
4.2.8	Methanol	Cause eye, skin and respiratory irritation; Flammable	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard. Keep away from heat source or ignition.	L (1)	
4.2.9	High temperature	Cause skin burning	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves. Avoid direct contact with the hot object. Keep away from heat source or ignition.	L (1)	
4.3.1	No associated hazard	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Acetone	Cause eye, skin and respiratory irritation; Flammable	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard. Keep away from heat source or	L (1)	

4.3.2	Amberlite 120H	Cause eye irritation	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.
4.3.3	Polystyrene sulfonate	Cause eye and skin irritation	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.
4.3.4	High temperature	Cause skin burning	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves. Avoid direct contact with the hot object
4.4.1	AEMA	Cause eye, skin and respiratory irritation; Corrosive	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.
	Na <sub>2</sub> CO <sub>3</sub> buffer	Serious Eye Damage/Eye Irritation Skin Corrosion/Irritation	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.
		Acute toxicity - Inhalation				
4.4.2	No associated hazard	N/A	N/A	N/A	N/A	N/A
4.4.3	glutaraldehyde	Inhalation, Skin absorption, Skin contact, Eye Contact, Ingestion	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.
	Na <sub>2</sub> CO <sub>3</sub> buffer	Serious Eye Damage/Eye Irritation Skin Corrosion/Irritation	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.
		Acute toxicity - Inhalation				
4.4.4	Na <sub>2</sub> CO <sub>3</sub> buffer	Serious Eye Damage/Eye Irritation Skin Corrosion/Irritation	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.
		ignition.				

		Acute toxicity - Inhalation					
	TEPA	Cause eye, skin and respiratory irritation; Corrosive	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L (1)
4.5.1	DEDTC	Cause eye, skin and respiratory irritation; Corrosive	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L (1)
	Ethanol	Cause eye, skin and respiratory irritation; Flammable	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.  Keep away from heat source or ignition.	L (1)
4.5.2	Ethanol	Cause eye, skin and respiratory irritation; Flammable	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves. Avoid direct contact with the hot object. Keep away from heat source or ignition.	L (1)
4.5.3	High temperature	Cause skin burning	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.  Keep away from heat source or ignition.	L (1)
4.5.4	No associated hazard	N/A	N/A	N/A	N/A	N/A	N/A
4.6.1	Benzoyl peroxide	Cause eye, skin and respiratory irritation	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L (1)
	Styrene	Cause eye and skin irritation;	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper	L (1)

		Flammable				gloves and work in fume cupboard.	
						Keep away from heat source or ignition.	
Divinylbenzene	Cause eye and skin irritation; Flammable	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L (1)	
Hexadecane	Cause eye, skin and respiratory irritation	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L (1)	
Sorbitan monooleate	Cause eye, skin and respiratory irritation	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L (1)	
4.6.2	Hydroquinone	Cause eye, skin and respiratory irritation	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L (1)
Sodium dodecyl sulfate	Cause eye, skin and respiratory irritation; Flammable	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L (1)	
4.6.3	No associated hazard	N/A	N/A	N/A	N/A	N/A	N/A
4.6.4	No associated hazard	N/A	N/A	N/A	N/A	N/A	N/A
4.6.5	High temperature	Cause skin burning	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves. Avoid direct contact with	L (1)

4.6.6	Ethanol	Cause eye, skin and respiratory irritation; Flammable	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard. Keep away from heat source or ignition.		L (1)	
4.6.7	Acetone	Cause eye, skin and respiratory irritation; Flammable	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard. Keep away from heat source or ignition.		L (1)	
4.6.8	No associated hazard	N/A	N/A	N/A	N/A			N/A	N/A
4.7.1	Sulfuric acid	Cause eye, skin and respiratory irritation; Corrosive	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.		L (1)	
4.7.2	Silver sulfate	Cause eye, skin and respiratory irritation; Corrosive	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.		L (1)	
	Sulfuric acid	Cause eye, skin and respiratory irritation; Corrosive	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.		L (1)	
4.7.3	High temperature	Cause skin burning	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves. Avoid direct contact with the hot object. Keep away from heat source or ignition.		L (1)	

4.7.4	No associated hazard	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4.7.5	No associated hazard	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4.7.6	Sulfuric acid	Cause eye, skin and respiratory irritation; Corrosive	M (2) L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.		L (1)	
4.7.7	Acidic mixture	Cause eye, skin and respiratory irritation; Corrosive	M (2) L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.		L (1)	
4.7.8	Methanol	Cause eye, skin and respiratory irritation; Flammable	M (2) L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	Keep away from heat source or ignition.	L (1)	
4.7.9	High temperature	Cause skin burning	M (2) L (1)	M (2)	Wear lab coat, goggles and proper gloves. Avoid direct contact with the hot object. Keep away from heat source or ignition.		L (1)	
4.8.1	No associated hazard	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Acetone	Cause eye, skin and respiratory irritation; Flammable	M (2) L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	Keep away from heat source or ignition.	L (1)	
4.8.2	Amberlite 120H	Cause eye irritation	M (2) L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.		L (1)	

4.8.3	Polystyrene sulfonate	Cause eye and skin irritation	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L (1)
4.8.4	High temperature	Cause skin burning	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves. Avoid direct contact with the hot object. Keep away from heat source or ignition.	L (1)
4.9.1	Chloromethyl methyl ether	Cause eye, skin and respiratory irritation; Corrosive	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L(1)
4.9.2	No associated hazard	N/A	N/A	N/A	N/A	N/A	N/A
4.9.3	No associated hazard	N/A	N/A	N/A	N/A	N/A	N/A
4.9.4	ice hydrochloric	Cause eye, skin and respiratory irritation; Corrosive	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L (1)
4.9.5	Ethanol	Cause eye, skin and respiratory irritation; Flammable	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard. Keep away from heat source or ignition.	L (1)
4.10.1	DMF	Cause eye, skin and respiratory irritation;	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L (1)
4.10.2	DMF	Cause eye, skin and respiratory irritation;	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L (1)
	PVA	Cause eye, skin and respiratory irritation;	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper	L (1)

		Flammable					
4.10.3	tetrabutylammonium iodide	Cause eye, skin and respiratory irritation;	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L (1)
	sodium hydroxide	Cause eye, skin and respiratory irritation; Corrosive	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L (1)
4.10.4	No associated hazard	N/A	N/A	N/A	N/A	N/A	N/A
4.11.1.1	Concentrated sulfuric acid	Corrosive	H	L	H	Carefully control. Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
	K <sub>2</sub> S <sub>2</sub> O <sub>8</sub>	Irritant & Oxidative	H	L	M	Wear protective gloves/protective clothing/eye protection/face protection	L
	P <sub>2</sub> O <sub>5</sub>	Irritant	H	L	M	Ensure adequate ventilation. Wear lab coat, goggles and proper gloves and work in fume cupboard. Avoid dust formation.	L
	Graphite	Irritant	L	L	L	Keep away from heat. Keep away from sources of ignition. Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
4.11.1.2	No associated hazard						
4.11.1.3	Concentrated sulfuric acid	Corrosive & Oxidative	H	L	H	Minimize the amount used. Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
	KMnO <sub>4</sub>	Corrosive & Oxidative	M	L	M	Minimize the amount used. Wear lab coat, goggles and proper gloves and	L

4.11.1.4		H <sub>2</sub> O <sub>2</sub>		Irritant & Corrosive	M	L	M	Wear lab coat, goggles and proper gloves and work in fume cupboard.
4.11.1.5	Hydrochloric acid		Irritant		H	L	M	Wear protective gloves/protective clothing/eye protection/face protection
4.11.1.6	No associated hazard							L
4.11.2.1	Graphene oxide solution		Irritant		L	M	M	Wear lab coat, goggles and proper gloves and work in fume cupboard.
4.11.2.2	High temperature Graphene oxide solution		Irritant		L	M	M	Wear lab coat, goggles and proper gloves and work in fume cupboard.
4.11.2.3	Directly contact with nanomaterial Graphene oxide		Irritant		L	M	M	Wear lab coat, goggles and proper gloves and work in fume cupboard.
4.11.2.4	Graphene oxide granule		Irritant		L	M	M	Wear lab coat, goggles and proper gloves and work in fume cupboard.
4.11.3.1	Graphene oxide granule		Irritant		L	M	M	Wear lab coat, goggles and proper gloves and work in fume cupboard.
	PBS solution		Irritant		L	M	M	Wear lab coat, goggles and proper gloves and work in fume cupboard.
4.11.3.2	Graphene oxide solution		Irritant		L	M	M	Wear lab coat, goggles and proper gloves and work in fume cupboard.
	PBS solution		Irritant		L	M	M	Wear lab coat, goggles and proper gloves and work in fume cupboard.
	Dopamine hydrochloride		Irritant		L	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard.
4.11.3.3	pRGO solution		Irritant		L	M	M	Wear lab coat, goggles and proper gloves and work in fume cupboard.
4.11.3.4	pRGO solution at high temperature		Irritant		L	M	M	Wear lab coat, goggles and proper gloves and work in fume cupboard.
4.11.3.5	Directly contact with nanomaterial pRGO		Irritant		L	M	M	Wear lab coat, goggles and proper gloves and work in fume cupboard.
4.11.3.6	pRGO granule		Irritant		L	M	M	Wear lab coat, goggles and proper gloves and work in fume cupboard.
	pRGO granule		Irritant		L	M	M	Wear lab coat, goggles and proper L

4.11.3.7	PBS solution	Irritant	L	M	M		gloves and work in fume cupboard.	L
4.11.3.8	pRGO solution	Irritant	L	M	M		Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
	PBS solution	Irritant	L	M	M		Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
4.11.3.9	Hep-g-pRGO solution	Irritant	L	M	M		Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
	BSA-g-pRGO solution	Irritant	L	L	L		Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
4.11.3.10	Hep-g-pRGO solution at high temperature	Irritant	L	M	M		Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
	BSA-g-pRGO solution at high temperature	Irritant	L	M	M		Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
4.11.3.11	Directly contact with nanomaterial Hep-g-pRGO	Irritant	L	M	M		Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
	Directly contact with nanomaterial BSA-g-pRGO	Irritant	L	M	M		Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
4.11.3.12	Hep-g-pRGO granule	Irritant	L	M	M		Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
	BSA-g-pRGO granule	Irritant	L	M	M		Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
4.11.3.13	No associated hazard						Keep away from heat source or ignition.	L
4.12.1.1	Acetone	Flammable, irritation	H	M	H	Wear protective gloves/protective clothing/eye protection/face protection	L	
4.12.1.2	Polystyrene	Combustible	M	L	M	Keep away from heat source or ignition. Wear lab coat, goggles and proper gloves and work in fume cupboard.	L	

4.12.1.3	Drying		Hot surface	M	H	H	Wear heat insulation gloves	L
4.12.1.4	Ethyl alcohol	Flammable		H	M	H	Keep away from heat source or ignition. Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
4.12.1.5	No associated hazard							
4.12.1.6	Drying	Hot surface	M	H	H	Wear heat insulation gloves	L	
4.12.2.1	Bilirubin Hexane	Possible skin, eye, and respiratory tract irritation  Highly inflammable	H	M	M	Keep away from heat source or ignition. Wear protective gloves/protective clothing/eye protection/face protection, work in fume cupboard.	L	
4.12.2.2	No associated hazard							
4.12.2.3	No associated hazard							
4.13.1.1	Sodium dodecyl sulfate Alkylphenolpolyoxyethylene Styrene Acrylate polyethylene glycol monoester Hexadecane Azodiisobutyronitrile	Toxic; skin and eye irritation	M	M	M	Wear protective gloves/protective clothing/eye protection/face protection, work in fume cupboard	L	
4.13.1.2	Homogenizer	High spinning speed	M	L	M	Adjust the homogenizer gradually from low speed up to the speed stated in the literature	L	
4.13.1.3	Heating	High temperature	H	M	H	Wear heat insulation gloves	L	
4.13.1.4	Drying	Hot surface	M	M	M	Wear heat insulation gloves	L	
4.13.2.1	Bilirubin Hexane	Possible skin, eye, and respiratory tract irritation  Highly inflammable	H	M	M	Keep away from heat source or ignition. Wear protective gloves/protective clothing/eye protection/face protection, work in fume cupboard	L	

4.13.2.2	No associated hazard							L
4.13.2.3	No associated hazard							L
4.14.1.1	Chromium trioxide	Flammable, toxic	H	M	H	Keep away from heat source or ignition.		L
4.14.1.2	Drying	High temperature	M	H	H	Wear protective gloves/protective clothing/eye protection/face protection, work in fume cupboard		L
4.14.1.3	Heating Reflux set-up	Hot surface Gas pressure variation (e.g. building up) Leaking	H	H	H	Wear heat insulation gloves Wear heat insulation gloves Ventilation Double check the connections of reflux system before reaction begins		L
4.14.1.4	HCl NaOH	Corrosive; eye or skin irritation	H	H	H	Wear protective gloves/protective clothing/eye protection/face protection, work in fume cupboard		L
4.14.1.5	HCl NaOH H <sub>2</sub> O <sub>2</sub>	Corrosive; eye or skin irritation	H	H	H	Wear protective gloves/protective clothing/eye protection/face protection, work in fume cupboard		L
4.14.1.6	No associated hazard							L
4.14.2.1	CuSO <sub>4</sub>	Toxic; skin irritation	H	M	H	Wear protective gloves/protective clothing/eye protection/face protection, work in fume cupboard		L
4.14.2.2	PEI	Respiratory, skin or eye irritation	H	M	H	Wear protective gloves/protective clothing/eye protection/face protection, work in fume cupboard Ventilation		L
4.14.2.3	Glutaric dialdehyde	Corrosive, toxic; Respiratory, skin or eye	H	M	H	Wear protective gloves/protective		L

		irritation				clothing/eye protection/face protection, work in fume cupboard Ventilation	L
4.14.2.4	HCl NH <sub>3</sub>	Corrosive; eye or skin irritation	H	H	H	Wear protective gloves/protective clothing/eye protection/face protection, work in fume cupboard	L
4.14.2.5	HCl NH <sub>3</sub>	Corrosive; eye or skin irritation	H	H	H	Wear protective gloves/protective clothing/eye protection/face protection, work in fume cupboard	L
4.14.2.6	Drying	Hot surface	M	M	M	Wear heat insulation gloves	L
4.14.3.1	Bilirubin Hexane	Possible skin, eye, and respiratory tract irritation Highly inflammable	H	M	M	Keep away from heat source or ignition. Wear protective gloves/protective clothing/eye protection/face protection, work in fume cupboard	L
4.14.3.2	No associated hazard						L
4.14.3.3	No associated hazard						L
4.15.1.1	Drying	Hot temperature	L	M	M	Wear heat insulation gloves	L
	Graphene oxide	Irritant	L	L	L	Ventilation Wear lab coat, goggles and proper gloves and work in fume cupboard	L

4.15.1.2	Propylene glycol alginate sodium sulfate	Irritant	M	L	L	Keep away from heat. Keep away from sources of ignition.	L
	Graphene oxide	Irritant	L	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
4.15.1.3	Extrusion	Hot temperature	M	M	M	Ventilation. Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
	Graphene oxide	Irritant	L	L	L	Ventilation. Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
4.15.1.4	Graphene oxide	Irritant	L	L	L	Ventilation. Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
4.15.2.1	Drying	Hot temperature	M	M	M	Wear heat insulation gloves	L
	Ethanol	Flammable	H	L	H	Lower drying temperature Keep away from heat source or ignition. Wear lab coat, goggles and proper gloves and work in fume cupboard.	L

	Graphene oxide	Irritant	L	L	L	Ventilation. Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
4.15.2.2	Graphene oxide	Irritant	L	L	L	Ventilation. Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
4.15.2.3	PEG	Irritant	L	L	L	Keep away from heat and ignition. Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
	Ethanol	Flammable	H	L	M	Lower drying temperature. Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
4.15.2.4	Ultra-high-molecular-weight	Flammable	M	L	L	Keep away from heat and ignition. Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
	Polyethylene PEG	Irritant	L	L	L	Keep away from heat and ignition. Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
	Ethanol	Flammable	H	L	M	Lower drying temperature Keep away from heat source or ignition. Wear lab coat, goggles and proper gloves and work in fume cupboard	L
4.15.2.5	PEG	Irritant	L	L	L	Keep away from heat and ignition.	L
	Ethanol	Flammable	H	L	M	Lower drying temperature Keep away from fire source	L

4.15.2.6	PEG	Irritant	L	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
	Ethanol	Flammable	H	L	M	Keep away from heat and ignition. Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
4.15.2.7	Drying	Hot temperature	M	M	M	Lower drying temperature Keep away from heat source or ignition. Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
4.15.3.1	Ethanol	Flammable	M	M	M	Lower drying temperature Keep away from heat source or ignition. Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
	Graphene oxide	Irritant	L	L	L	Ventilation Wear lab coat, goggles and proper gloves and work in fume cupboard	L
4.15.3.2	Graphene oxide	Irritant	L	L	L	Ventilation Wear lab coat, goggles and proper gloves and work in fume cupboard	L
4.15.3.3	Ethanol	Flammable	M	L	M	Keep away from heat source or ignition. Wear lab coat, goggles and proper gloves and work in fume cupboard	L

	HEMA	Irritant	L	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard
4.15.3.4	Ethanol	Flammable	M	L	M	Keep away from heat source or ignition.
	HEMA	Irritant	L	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard
	Graphene Oxide	Irritant	L	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard
4.15.3.5	Ethanol	Flammable	M	L	M	Keep away from heat source or ignition..
	HEMA	Irritant	L	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard
	Graphene Oxide	Irritant	L	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard
4.15.3.6	Ethanol	Flammable	M	L	M	Keep away from heat source or ignition.
	HEMA	Irritant	L	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard
	Graphene Oxide	Irritant	L	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard
4.15.3.7	Drying	Hot temperature	M	M	M	Wear heat insulation gloves

	Graphene Oxide	Irritant	L	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard	L
4.15.4.1	Graphene Oxide	Irritant	L	L	L	Keep away from heat source or ignition.	L
	Ethanol	Flammable	M	L	M	Wear lab coat, goggles and proper gloves and work in fume cupboard	L
4.15.4.2	Graphene oxide	Irritant	L	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard	L
4.15.4.3	Polyethylene	Flammable	M	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard. Keep away from heat source or ignition	L
	Hexane	Flammable	M	L	M	Keep away from heat source or ignition.	L
	Calcium carbonate masterbatch	Irritant	L	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard	L
4.15.4.4	Polyethylene	Flammable	M	L	L	Keep away from heat source or ignition. Wear lab coat, goggles and	L

							proper gloves and work in fume cupboard.	
Hexane	Flammable	M	L	M	Keep away from heat source or ignition. Wear lab coat, goggles and proper gloves and work in fume cupboard.	L		
Calcium carbonate masterbatch	Irritant	L	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L		
4.15.4.5	Polyethylene	Flammable	M	L	Keep away from heat source or ignition. Wear lab coat, goggles and proper gloves and work in fume cupboard.	L		
Hexane	Flammable	M	L	M	Keep away from heat source or ignition. Wear lab coat, goggles and proper gloves and work in fume cupboard.	L		
Calcium carbonate masterbatch	Irritant	L	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L		
4.15.4.6	Graphene oxide	Irritant	L	L	Ventilation Wear lab coat, goggles and proper gloves and work in fume cupboard.	L		
Polyethylene	Flammable	M	L	L	Keep away from heat source or ignition. Wear lab coat, goggles and proper gloves and work in fume cupboard.	L		

	Hexane	Flammable	M	L	M	Keep away from heat source or ignition.	L
						Wear lab coat, goggles and proper gloves and work in fume cupboard.	
Calcium carbonate masterbatch	Irritant		L	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
4.15.4.7	Drying	Hot temperature	M	M	M	Wear heat insulation gloves	L
	Graphene oxide	Irritant	L	L	L	Ventilation	L
4.16.1.1	Sulfuric Acid	Cause eye, skin and respiratory irritation; Corrosive	M(2)	L(1)	M(2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L(1)
4.16.1.2	Potassium Permanganate	Corrosive & Oxidative	M	L	M	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
4.16.1.3	No associated hazard	N/A	N/A	N/A	N/A	Minimize the amount used and wear glove	N/A
4.16.1.4	No associated hazard	N/A	N/A	N/A	N/A	N/A	N/A
4.16.1.5	Hydrogen Peroxide	Irritant & Corrosive	M	L	M	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
4.16.1.6	Hydrochloric Acid	Irritant	H	L	M	Wear protective gloves/protective clothing/eye protection/face protection	L
4.16.1.7	No associated hazard	N/A	N/A	N/A	N/A	N/A	N/A
4.16.1.8	No associated hazard	N/A	N/A	N/A	N/A	N/A	N/A
4.16.1.9	No associated hazard	N/A	N/A	N/A	N/A	N/A	N/A

4.16.1.10	No associated hazard	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4.16.1.11	EDC	Flammable and Explosive	H	L	H	Keep away from heat and ignition	L	N/A
	NHS	Irritant	M	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L	
4.16.1.12	Sulfuric Acid	Cause eye, skin and respiratory irritation; Corrosive	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L (1)	
4.16.1.13	Ethanol	Cause eye, skin and respiratory irritation; Flammable	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard. Keep it away from any sources of ignition.	L (1)	
4.16.1.14	Ethanol	Cause eye, skin and respiratory irritation; Flammable	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard. Keep it away from any sources of ignition.	L (1)	
4.16.1.15	No associated hazard	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4.16.1.16	Sulfuric Acid	Cause eye, skin and respiratory irritation; Corrosive	M (2)	L (1)	M (2)	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L (1)	
4.16.1.17	No associated hazard	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4.16.1.18	No associated hazard	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4.16.2.1	Graphite Oxide	Irritant	L	L	L	Ventilation	L	
4.16.2.2	No associated hazard	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4.16.2.3	PEI	Respiratory, skin or eye irritation	H	M	H	Wear protective gloves/protective clothing/eye protection/face	L	

							protection, work in fume cupboard
						Ventilation	
4.16.2.4	No associated hazard	N/A	N/A	N/A	N/A	N/A	N/A
4.16.2.5	No associated hazard	N/A	N/A	N/A	N/A	N/A	N/A
4.16.2.6	No associated hazard	N/A	N/A	N/A	N/A	N/A	N/A
4.16.2.7	No associated hazard	N/A	N/A	N/A	N/A	N/A	N/A
4.16.2.8	No associated hazard	N/A	N/A	N/A	N/A	N/A	N/A
4.17.1.1	Graphite Oxide	Irritant	L	L	Ventilation		L
4.17.1.2	No associated hazard	N/A	N/A	N/A	N/A	Wear lab coat, goggles and proper gloves and work in fume cupboard	N/A
4.17.1.3	Dopamine	N/A	N/A	N/A	N/A		N/A
4.17.1.4	No associated hazard	N/A	N/A	N/A	N/A		N/A
4.17.1.5	No associated hazard	N/A	N/A	N/A	N/A		N/A
4.17.2.1	PBS	Irritant	L	M	Wear lab coat, goggles and proper gloves and work in fume cupboard.		L
	p-RGO	Irritant	L	M	Wear lab coat, goggles and proper gloves and work in fume cupboard.		L
4.17.2.2	Pristine heparin	Respiration hazard	L	L	Work in ventilated area; Properly wear mask		L
	BSA	Irritant	L	L	Wear goggle, glove and lab coat		L

4.17.2.3	No associated hazard		N/A	N/A	N/A	N/A	N/A	N/A
4.17.2.4	No associated hazard		N/A	N/A	N/A	N/A	N/A	N/A
4.18.1.1	NaOH	Corrosive	H	L	H	Carefully control, wear goggle and glove and lab coat, work in fume cupboard	L	
	Graphite powder	Irritant	L	L	L	Ventilation. Keep away from sources of ignition	L	
4.18.1.2	No associated hazard							
4.18.1.3	HCl	Corrosive	L	L	H	Carefully control, wear goggle and glove and lab coat, work in fume cupboard	L	
4.18.1.4	No associated hazard							
4.18.1.5	EDC	Flammable and explosive	H	L	H	Keep away from heat and ignition Wear lab coat, goggles and proper gloves	L	

	NHS	irritant	M	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
4.18.1.6	Phosphate buffer solution	Irritant	M	L	M	Carefully control, wear goggle and glove and lab coat, work in fume cupboard	L
4.18.1.7	Hemoglobin	penetrate into skin	L	M	L	Carefully control, wear glove and lab coat and goggle, work in fume cupboard	L
4.18.1.8	Phosphate buffer solution	Irritant	M	L	M	wear goggle and glove and lab coat, work in fume cupboard	L
4.18.1.9	No associated hazard						
4.18.2.1	Alumina	Irritant	M	L	L	Carefully control, wear goggle and glove and lab coat, work in fume cupboard.	L
4.18.2.2	No associated hazard						
4.18.2.3	KCl	Irritation and caused vomiting	M	L	M	Carefully control, wear goggle and glove and lab coat, work in fume cupboard.	L

	HAuCl <sub>4</sub>	cause serious and volatile	M	L	M	Carefully control, wear goggle and glove and lab coat, work in fume cupboard.	L
4.18.2.4	No associated hazard						
4.18.2.5	No associated hazard						
4.18.2.6	No associated hazard						
4.19.1.1	Agrose	Irritant and slightly flammable	H	L	H	Carefully control, wear goggle and glove and lab coat, work in fume cupboard.  Keep away from heat. Keep away from sources of ignition	L
4.19.1.2	No associated hazard						
4.19.1.3	No associated hazard						
4.19.1.4	activated carbon	irritant	M	L	M	Keep away from heat and ignition Wear lab coat, goggles and proper gloves	L
4.19.1.5	Tween 80	Irritant	M	L	M	Keep away from heat and ignition Wear lab coat, goggles and proper gloves	L
	Span 80	Irritant	M	L	M	Keep away from heat and ignition Wear lab coat, goggles and proper gloves	L

4.19.1.6	No associated hazard						
4.19.1.7	No associated hazard						
4.19.1.8	Ether	Irritant and permeator	H	L	H	Keep away from heat and ignition Carefully control, wear goggle and glove and lab coat, work in fume cupboard	L
4.19.1.9	ethyl alcohol	Flammable and irritant	H	L	H	Keep away from heat and ignition Carefully control, wear goggle and glove and lab coat, work in fume cupboard.	L
4.19.1.10	No associated hazard						
4.19.1.11	Epichlorohydrin	Irritant, corrosive and flammable	H	L	H	Keep away from heat and ignition Carefully control, wear goggle and glove and lab coat, work in fume cupboard.	L
	dimethyl sulfoxide	Combustible and irritant	H	L	H	Keep away from heat and ignition Carefully control, wear goggle and glove and lab coat, work in fume cupboard.	L

4.19.1.12	dimethyl sulfoxide	Combustible and irritant	H	L	H	Keep away from heat and ignition Carefully control, wear goggle and glove and lab coat, work in fume cupboard.	L
	NaOH	Corrosive	H	L	H	Carefully control, wear goggle and glove and lab coat, work in fume cupboard.	L
	NaBH4	Irritant, corrosive, flammable	H	M	H	Keep away from heat and ignition Carefully control, wear goggle and glove and lab coat, work in fume cupboard.	L
4.19.1.13	coated activated carbon	Irritant	L	L	L	Keep away from heat and ignition Wear lab coat, goggles and proper gloves	L
4.19.1.14	ethyl alcohol	Flammable and irritant	H	L	H	Keep away from heat and ignition Wear lab coat, goggles and proper gloves	L
4.19.1.15	No associated hazard						
4.19.1.16	dimethyl sulfoxide	Combustible and irritant	H	L	H	Keep away from heat and ignition Carefully control, wear goggle and glove and lab coat, work in fume cupboard.	L

4.20.1.1	Bovine serum albumin	Irritant	L	L	L	Wear goggle, glove and lab coat, work in fume cupboard	L
4.20.1.2	Bovine serum albumin	Irritant	L	L	L	Wear goggle, glove and lab coat, work in fume cupboard	L
	GO concentrated solution	High toxicity, eye and respiratory irritation	M	L	L	Wear goggle, glove, lab coat and mask, work in fume cupboard.	L
4.20.1.3	No associated hazard						
4.20.1.4	No associated hazard						
4.20.1.5	No associated hazard						
4.20.2.1	Double-stranded DNA from salmon milt	Irritant	H	L	H	Carefully control, wear goggle and glove and lab coat, work in fume cupboard.	L
4.20.2.2	Double-stranded DNA from salmon milt	Irritant	H	L	H	Carefully control, wear goggle and glove and lab coat, work in fume cupboard.	L
	GO concentrated solution	High toxicity, eye and respiratory irritation	M	L	M	Wear goggle, glove, lab coat and mask, work in fume cupboard.	L
4.20.2.3	No associated hazard						

4.20.2.4	No associated hazard							
4.20.2.5	No associated hazard							
4.20.3.1	Chitosan	Acute aquatic toxicity	H	L	H	Carefully control, wear goggle and glove and lab coat, work in fume cupboard.	L	
4.20.3.2	GO concentrated solution	High toxicity, eye and respiratory irritation	H	L	H	Carefully control, wear goggle and glove and lab coat, work in fume cupboard.	L	
	Chitosan	Acute aquatic toxicity	H	L	H	Carefully control, wear goggle and glove and lab coat, work in fume cupboard.	L	
4.20.3.3	No associated hazard							
4.20.3.4	No associated hazard							
4.20.3.5	No associated hazard							
4.20.4.1	GO	Irritant	L	L	L	Keep away from sources of ignition	L	
4.20.4.2	polyvinylpyrrolidone	Irritant, combustible	M	L	M	Keep away from heat. Keep away from sources of ignition, wear goggle and glove and lab coat, work in fume cupboard.	M	
4.20.4.3	Poly(ether imides)	Flammable and irritant	M	L	M	Keep away from heat. Keep away	L	

						from sources of ignition, wear goggle and glove and lab coat, work in fume cupboard.
4.20.4.4	No associated hazard					
4. 20.4.5	No associated hazard					
4. 20.4.6	No associated hazard					
4. 20.4.7	No associated hazard					
4.21.1.1	Heparin	Irritant	L	L	Wear goggle and glove and lab coat, work in fume cupboard.	L
	Dopamine	Irritant	L	L	Wear goggle and glove and lab coat, work in fume cupboard.	L
	MES buffer	Combustible and irritant	H	L	Keep away from heat. Keep away from sources of ignition, wear goggle and glove and lab coat, work in fume cupboard.	L
4. 21.1.2	1-ethyl-3-(3- dimethylaminopropyl) carbodiimide hydrochloride (EDC)	Combustible and irritant	H	L	Keep away from heat. Keep away from sources of ignition, wear goggle and glove and lab coat, work in fume cupboard.	L

	HCl	Corrosive and irritant	H	L	H	Carefully control, wear goggle and glove and lab coat, work in fume cupboard.	L
4. 21.1.3	NaOH	Corrosive and oxidized	H	L	H	Carefully control, wear goggle and glove and lab coat, work in fume cupboard.	L
4. 21.1.4	NaCl	Irritant	L	L	L	wear goggle and glove and lab coat, work in fume cupboard.	L
	Ethanol	Irritant and flammabl	M	L	M	Carefully control, wear goggle and glove and lab coat, work in fume cupboard.	L
4. 21.1.5	No associated hazard						
4. 21.1.6	NaCl	Irritant	L	L	L	wear goggle and glove and lab coat, work in fume cupboard.	L
	Ethanol	Irritant and flammable	M	L	M	Carefully control, wear goggle and glove and lab coat, work in fume cupboard.	L
4. 21.2.1	DA-g-Hep	Irritant	M	L	M	Carefully control, wear goggle and glove and lab coat, work in fume cupboard.	L
	Tris buffer solution	Irritant	L	L	L	wear goggle and glove and lab coat, work in fume cupboard.	L
4. 21.2.2	GO	Irritant	L	L	L	Ventilation. Keep away from sources of ignition	L

4. 21.2.3	No associated hazard							
4. 21.2.4	No associated hazard							
4. 21.2.5	No associated hazard							
4.22.1.1	Chitosan	Acute aquatic toxicity	H	L	H	Carefully control, wear goggle and glove and lab coat, work in fume cupboard.	L	
	GO	Irritant	L	L	L	Ventilation. Keep away from sources of ignition	L	
	Acetic acid	Irritant and corrosive	M	L	M	Carefully control, wear goggle and glove and lab coat, work in fume cupboard.	L	
4.22.1.2	No associated hazard							
4.22.1.3	No associated hazard							
4.22.1.4	Sodium hydroxide	Corrosive and irritant	H	L	H	Carefully control, wear goggle and glove and lab coat, work in fume cupboard.	L	
	heparin	Irritant	M	L	M	Wear goggle and glove and lab coat, work in fume cupboard.	L	
N-hydroxysuccinimide	Combustible and irritant		M	L	M	Keep away from heat. Carefully control, wear goggle and	L	

	1-ethyl-3-(3-dimethylaminopropyl) carbodiimide hydrochloride (EDC)	Combustible and irritant	M	L	M	Keep away from sources of ignition Carefully control, wear goggle and glove and lab coat, work in fume cupboard		L	
4.22.2.2	Phosphate buffer solution	Irritant	L	L	L	. Carefully control, wear goggle and glove and lab coat, work in fume cupboard.		L	
4.22.2.3	No associated hazard								
4.22.2.4	CS/GH	Irritant	H	L	H	Wear goggle and glove and lab coat, work in fume cupboard.		L	
4.22.2.5	NaCl	Irritant	L	L	L	Wear goggle and glove and lab coat, work in fume cupboard.		L	
4.22.2.6	Toluidine blue	Combustible and irritant	M	L	M	Keep away from heat. Keep away from sources of ignition. Carefully control, wear goggle and glove and lab coat, work in fume cupboard.		L	
4.23.1.1	Styrene	Irritant	L	M	M	Wear protective gloves/protective clothing/eye protection/face protection, work in fume cupboard.		L	
	Divinylbenzene	Irritant	M	L	M	Wear lab coat, goggles and proper gloves and work in fume cupboard.		L	
	Benzoyl peroxide	Irritant,	H	L	H	Wear protective gloves/protective		L	

		Exposition				clothing/eye protection/face
						protection, work in fume cupboard. Check the storage information, and properly discard it
Lauryl alcohol	Irritant	M	L	M		L
4.23.1.2 Polyvinyl alcohol	Irritant	L	L	L	Wear protective gloves/protective clothing/eye protection/face protection, work in fume cupboard.	L
Sodium dodecyl sulfate	Irritant	L	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
Na2SO4	Irritant (respiration track)	L	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
Hydroquinone	Irritant, oxidative	M	L	M	Store in dry and ventilated area	L
4.23.1.3 Nitrogen gas	Respiration hazard	L	L	L	Wear protective gloves/protective clothing/eye protection/face protection	L
4.23.1.4 Four-neck glass separator flask	Skin or eye hurt	M	L	M	Work in ventilated area Carefully handle; Wear protective gloves/protective clothing/eye protection/face protection, work in fume cupboard.	L
Semicircular anchor-type blade	Skin hurt	M	L	M	Carefully handle; Wear protective gloves/protective clothing/eye protection/face protection, work in fume cupboard.	L
Nitrogen inlet nozzle	Respiration hazard	L	L	L	Work in ventilated area	L
4.23.1.5 Nitrogen gas	Respiration hazard	L	L	L	Work in ventilated area	L
4.23.1.6 Heater						
4.23.1.7 Nitrogen gas	Respiration hazard	L	L	L	Work in ventilated area	L
4.23.1.8 Hot water	Skin burn	L	L	L	Carefully handle; Properly wear gloves	L
Ethanol	Flammable,	L	M	M	Work in ventilated area;	L

		Combustible				Keep away from heat. Keep away from sources of ignition	
4.23.1.9	Acetone	Highly flammable, Explosive	M	L	M	Work in ventilated area; Keep away from heat. Keep away from sources of ignition	L
4.23.2.1	Chitosan	Irritant	L	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
4.23.2.2	Acetic acid	Irritant	L	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
4.23.2.3	Vacuum degassing	Skin burn	M	L	M	Strictly follow the operation regulations	L
4.23.2.4	No associated hazard						
4.23.2.5	Vacuum	Suction	L	L	L	Strictly follow the operation regulations	L
4.23.2.6	Sodium hydroxide	Corrosive	M	M	M	Wear protective gloves/protective clothing/eye protection/face protection, work in fume cupboard.	L
4.23.2.7	No associated hazard						
4.24.1.1.1	PMMA	Toxicity; Carcinogenicity; Irritation/corrosion; Combustibility	H	M	H	Carefully control, wear goggle, glove and lab coat; Keep away from heat. Keep away from sources of ignition Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
4.24.1.1.2	Ethyl acetate	Irritant	L	L	L	Wear protective gloves/protective clothing/eye protection/face protection, work in fume cupboard.	L
4.24.1.1.2	PMMA	Toxicity; Carcinogenicity; Irritation/corrosion; Combustibility	H	M	H	Carefully control, wear goggle, glove and lab coat, work in fume cupboard. Keep away from heat. Keep away from sources of ignition	L



	Heparin	Respiration hazard	L	L	L	Keep away from sources of ignition	L
4.24.1.2.6	No associated hazard					Wear lab coat, goggles and proper gloves and work in fume cupboard.	
4.24.1.2.7	Vacuum oven	Skin burn	M	L	M	Strictly follow the operation regulations	L
4.24.1.3.1	Chitosan	Irritant	L	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
	Acetic acid	Irritant	L	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
4.24.1.3.2	PMMA	Toxicity; Carcinogenicity; Irritation/corrosion; Combustibility	H	M	H	Carefully control, wear goggle, glove and lab coat, work in fume cupboard. Keep away from heat. Keep away from sources of ignition	L
	Chitosan	Irritant	L	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L
4.24.1.3.3	No associated hazard					Strictly follow the operation regulations	L
4.24.1.3.4	Vacuum	Skin burn	M	L	M	Wear protective gloves/protective clothing/eye protection/face, work in fume cupboard.	L
	Sodium hydroxide	Corrosive	M	M	M	Wear protective gloves/protective clothing/eye protection/face, work in fume cupboard.	L
4.24.1.3.5	Sodium hydroxide	Corrosive	M	M	M	Wear protective gloves/protective clothing/eye protection/face	L
4.24.1.3.6	Vacuum oven	Skin burn	M	L	M	Wear protective gloves/protective clothing/eye protection/face, work in fume cupboard.	L
4.24.1.4.1	2-(N-morpholino)	Irritant	M	L	M	Wear protective gloves/protective clothing/eye protection/face	L

	ethanesulfonic acid							clothing/eye protection/face protection, work in fume cupboard.
4.24.1.4.2	1-ethyl-3-(3-dimethylaminopropyl) carbodiimide hydrochloride (EDC) N-Hydroxysuccinimide (NHS)	Irritant	M	L	M	Wear protective gloves/protective clothing/eye protection/face protection, work in fume cupboard.	L	
	Heparin	Respiration hazard	L	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard. Work in ventilated area; Properly wear mask	L	
4.24.1.4.3	No associated hazard					Strictly follow the operation regulations	L	
4.24.1.4.4	No associated hazard					Wear lab coat, goggles and proper gloves and work in fume cupboard.	L	
4.24.1.4.5	Vacuum oven	Skin burn	M	L	M	Work in ventilated area;	L	
4.24.2.1.1	Bovine serum albumin	Irritant	L	L	L	Wear protective gloves/protective clothing/eye protection/face protection, work in fume cupboard.	L	
4.24.2.1.2	GO concentrated solution	Irritant	M	L	M	Strictly follow the operation regulations	L	
4.24.2.1.3	No associated hazard							
4.24.2.1.4	Sonication	Electrical injuries	L	L	L			
4.24.2.2.5	No associated hazard							
4.24.2.2.1	DNA	Ingestion and inhalation hazard	L	M	M	Wear protective gloves/protective clothing/eye protection/face protection, work in fume cupboard. No eat or drink in the lab	L	
4.24.2.2.2	GO concentrated solution	Irritant	M	L	M	Work in ventilated area; Wear protective gloves/protective clothing/eye protection/face	L	

4.24.2.2.3	No associated hazard								protection, work in fume cupboard.
4.24.2.2.4	Sonication	Electrical injuries	L	L	L	Strictly follow the operation regulations	L		
4.24.2.3.5	No associated hazard	Irritant	L	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L		
4.24.2.3.1	Chitosan	Irritant	L	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L		
	Acetic acid	Irritant	L	L	L	Wear lab coat, goggles and proper gloves and work in fume cupboard.	L		
4.24.2.3.2	GO concentrated solution	Irritant	M	L	M	Work in ventilated area; Wear protective gloves/protective clothing/eye protection/face protection, work in fume cupboard.	L		
4.24.2.3.3	No associated hazard								
4.24.2.3.4	Sonication	Electrical injuries	L	L	L	Strictly follow the operation regulations	L		
4.24.2.3.5	No associated hazard								
OVERALL ASSESSMENT: L									

Remark: Severity–L=Low (Minor injuries, first aid); M=Medium (Hospitalization, medical leave); H=High (Serious injuries, fatality)

Probability–L=Low (Unlikely); M=Medium (Possible); H=High (Very Likely)

Note: Severity x Probability = Risk [e.g. LxL=L; LxM=M; LxH=H; HxM=H; the product follows the higher severity or probability]

AEMA: 2-aminoethyl methacrylate hydrochloride

TEPA: tetra ethylenepent amine

DEDTC: diethyl dithiocarbamate sodium

## Section 7: Services List

1. Compressed air
2. Nitrogen gas
3. DI water
4 Electricity
5. Scanning electron microscope (surface features of polymer microsphere)
6. Mercury porosimetry (porosity of microsphere)
7. Laser diffractometry (particle size)
8. NMR Spectroscopy and Kinetics (compound identification)
9. Dynamic light scattering (size distribution)
10. Atomic force microscopy (AFM)
11. ATR-FTIR Spectroscopy
12. Centrifuge equipment
13. Magnetic Stirrer
14. Sonication Device
15. UV-Vis Spectroscopy
16. Ramen Spectroscopy
17. XRD
18. Blood Coagulation Analyzer
19. Cell-counting Kit
20. Optical microscopy
21. FE-SEM, AFM image
22. X-ray photoelectron spectroscopy
23. Fourier transform infrared spectroscopy (FTIR)
24. UV-Vis absorption spectroscopy, Hitachi 902 analyzer

25.Column chromatography separation
26. An optical contact angle measuring device
27. Prothrombin time (PT)
28. Beckman Coulter AU analyzer
29. Breaker
30. Pipette
31. Ultrasonic machine
32. pH meter
33. Shaker
34. Temperature controller
35. Thermostatic Water Bath
36. Diaphragm pumps
37. Ultraviolet and visible spectrophotometer
38. Drying oven
39. Vacuuming machine
40. Refrigerator
41. Raman spectra
42. Electrochemical impedance spectroscopy
43. Amplitude
44. Electrochemical workstation
45. Electrochemical cell consisted of a three electrode
46. Platinum wire
47. X-ray diffraction

## Section 8: Chemical List

### 8.1 Chemical list for preparation of graphene based material for blood perfusion

Chemical Name	Quality/Quantity	MSDS Sheet
Concentrated sulfuric acid(H <sub>2</sub> SO <sub>4</sub> )	98%	Attached
Potassium peroxodisulfate (K <sub>2</sub> S <sub>2</sub> O <sub>8</sub> )	>99%	Attached
Phosphorus oxide (P <sub>2</sub> O <sub>5</sub> )	>99%	Attached
Graphite	>99%	Attached
Potassium permanganate (KMnO <sub>4</sub> )	>99%	Attached
Hydrogen peroxide (H <sub>2</sub> O <sub>2</sub> )	30 wt%	Attached
Hydrochloric acid (HCl)	37%	Attached
Urea	>99%	Attached
Creatinine	≥98%	Attached
Sodium chloride	≥99%	Attached
Glucose	≥99.5%	Attached

### 8.2 Chemical list for coating of graphene based material for blood perfusion

Chemical Name	Quality/Quantity	MSDS Sheet
Graphene oxide	1000ml	Attached
PEG solution	350ml	Attached
95 % ethanol	1000ml	Attached
HEMA solution	350ml	Attached
Propylene glycol alginate sodium sulfate	150g	Attached
Ultra-high-molecular-weight polyethylene	350g	Attached
Polyethylene	200g	Attached

Hexane	400ml	Attached
Calcium Carbonate Masterbatch	200g	Attached

### 8.3 Chemical list for functionalizing polystyrene with cellulose acetate via dispersive precipitation

Chemical Name	Quality/Quantity	MSDS Sheet
Cellulose triacetate	4g	Attached
Acetone	>99.9% /196g	Attached
Polystyrene	1.8g	Attached
Ethyl alcohol	80.7% / 40g	Attached
Water	100%	Attached
Bilirubin	>98%	Attached
Hexane	95%	Attached

### 8.4 Chemical list for emulsion polymerization and functionalization of styrene

Chemical Name	Quality/Quantity	MSDS Sheet
Sodium dodecyl sulfate	0.15g	Attached
Alkylphenolpolyoxyethylene	1g	
Acrylate polyethylene glycol monoester	0.5g	
Hexadecane	0.2g	Attached
Azodiisobutyronitrile	0.275g	
Styrene	99% / 12g	Attached
Bilirubin	>98%	Attached
Hexane	95%	Attached
Water	100%	Attached

### 8.5 Chemical list for coating polystyrene with polyethyleneimine (PEI)

Chemical Name	Quality/Quantity	MSDS Sheet
Chromium(VI) oxide	>95% / 20g	Attached
Water	100%	Attached
Acetic acid	100% / 100ml	Attached
Polystyrene	15g	Attached
Hydrochloric acid	37 wt.% / 118 g	Attached
NaOH	99% / 16g	Attached
H <sub>2</sub> O <sub>2</sub> solution	30%	Attached
CuSO <sub>4</sub>	100% / 32g	Attached
Polyethyleneimine solution	50 wt.% / 40g	Attached
Glutaric dialdehyde solution	50 wt.% / 40g	Attached
NH <sub>3</sub> aqueous solution	28 wt.% / 48g	Attached
Bilirubin	>98%	Attached
Hexane	95%	Attached

#### 8.6 Chemical list for combining hemoglobin with carboxyl graphene

Chemical Name	Quality/Quantity	MSDS Sheet
Carboxyl graphene (CG, which was carrying 5% carboxyl groups)	>99%	Attached
1-(3-Dimethylaminopropyl)-3-ethylcarbodiimide hydrochloride, EDC	>99%	Attached
HAuCl <sub>4</sub> ·4H <sub>2</sub> O (Au > 48%)	>99%	Attached
Potassium ferrocyanide	>99%	Attached
hydrogen peroxide	30 wt%	Attached
disodium hydrogen phosphate	0.2 M	Attached
sodium dihydrogen phosphate	0.2 M	Attached

oxygen-free distilled water		Attached
NaOH solution	3 M	Attached
HCl	2.4 M	Attached
N-Hydroxysuccinimide	>99.5%	Attached
Alumina	0.25 and 0.05 µm	Attached
KCl	5.1 M	Attached

### 8.7 Chemical list for preparation of agrose coated activated carbon

Chemical Name	Quality/Quantity	MSDS Sheet
activated carbon	>99%	Attached
Epichlorohydrin	>99%	Attached
Agrose	>99%	Attached
EDC	>99%	Attached
Tween 80	>99%	Attached
Span 80	>99%	Attached
Papain	>99%	Attached
Ninhydrin	>99%	Attached
sodium thiosulfate	>99%	Attached
KCl	5.1 M	Attached

### 8.8 Chemical list for preparation of 3D GO/biopolymer gels

Chemical Name	Quality/Quantity	MSDS Sheet
Double-stranded DNA from salmon milt (Na salt, molecular weight: 5 *10^6)	>99%	Attached
Bovine serum albumin	>99%	Attached
Chitosan	>99%	Attached

Graphene oxide	>99%	Attached
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#### 8.9 Chemical list for preparation of poly (ether imide) (PEI) mixed matrix membranes

Chemical Name	Quality/Quantity	MSDS Sheet
GO	0.2 wt%	Attached
PVP-K	90 wt%	Attached
PEI	16 wt%	Attached

#### 8.10 Chemical list for Biopolymer-Functionalized Graphene Oxide Nanosheet through Adhesive Dopamine

Chemical Name	Quality/Quantity	MSDS Sheet
heparin	>99%	Attached
dopamine	>99%	Attached
MES buffer	(0.05 M, pH 5.3, 0.1 M NaCl)	Attached
EDC	>99%	Attached
HCl	1 N	Attached
NaOH	1 M	Attached
NaCl solution	1 M	Attached
ethanol	The volume ratio of ethanol to NaCl solution was 10:1	Attached
Tris buffer solution	10 mM, pH 8.5	Attached
GO	>99%	Attached

#### 8.11 Chemical list for preparation of CS/CO gel

Chemical Name	Quality/Quantity	MSDS Sheet
chitosan	>99%	Attached

GO	>99%	Attached
NaOH	0.5 M	Attached
heparin	>99%	Attached
NHS	>99%	Attached
EDC	>99%	Attached
phosphate buffer solution	50 mM	Attached
NaCl	2M	Attached

#### 8.12 Chemical list for fabricaiton of mesoporous beads for hemoperfusion

Chemical Name	Quality/Quantity	MSDS Sheet
Styrene(St)	3.9g	Attached
Divinylbenzene(DVB)	4.78g	Attached
Porogen	7g	Attached
Benzoyl peroxide(BPO)	0.4g	Attached
Lauryl alcohol	0.7g	Attached
Polyvinyl alcohol(PVA)	9g	Attached
Sodium dodecyl sulfate(SDS)	0.45g	Attached
Na <sub>2</sub> SO <sub>4</sub>	0.22g	Attached
Hydroquinone(HQ)	0.07g	Attached
Ethanol	>99%	Attached
Acetone	>99%	Attached
Chitosan	300mg	Attached
Graphene oxide(GO)	3mg/mL	Attached
Acetic acid	>99%	Attached
Sodium hydroxide(NaOH)	0.5M	Attached

#### 8.13 Chemical list for coating of mesoporous beads for hemoperfusion

Chemical Name	Quality/Quantity	MSDS Sheet
PMMA	>99%	Attached
Ethyl acetate	2.5% w/v	Attached
Heparin sodium	50mg	Attached
Acetone	>99%	Attached
Chitosan	0.25% w/w	Attached
Sodium hydroxide	0.1M	Attached
2-(N-morpholino)ethanesulfonic acid (MES) buffer	0.05M, pH 5.6	Attached
1-ethyl-3-(3-dimethylaminopropyl) carbodiimide hydrochloride (EDC)	>99%	Attached
Nhydroxysuccinimide (NHS)	>99%	Attached
Bovine serum albumin(BSA)	>99%	Attached
GO concentrated solution	5mg/g	Attached
DNA	400mg	Attached
Acetic acid	>99%	Attached
Agarose	>99%	Attached

## Section 9 Summary of Relevant Hazards and Incompatibilities

Concentrated sulfuric acid	Skin corrosion, severe burns.
Phosphorus(V) oxide (P <sub>2</sub> O <sub>5</sub> )	Skin corrosion, severe burns.
Graphite	Skin contact (irritant), of eye contact (irritant), of ingestion, of Inhalation
Potassium permanganate (KMnO <sub>4</sub> )	Acute toxicity (oral), contact with combustible material may cause fire, adverse effect in the aquatic environment.
Hydrogen peroxide (H <sub>2</sub> O <sub>2</sub> )	serious eye damage, acute toxicity (oral)
Potassium peroxodisulfate (K <sub>2</sub> S <sub>2</sub> O <sub>8</sub> )	Specific target organ toxicity, acute toxicity (oral), contact with combustible material may cause fire, eye irritation, respiratory sensitization.
Hydrochloric acid (HCl)	Skin corrosion , eye irritation
95 % ethanol	Flammable
Hexane	Flammable
Graphene oxide	Eye Irritation
Sodium chloride	Skin contact (irritant), of eye contact (irritant), of ingestion, of inhalation.
Urea	Skin contact (irritant), of eye contact (irritant), of ingestion, of inhalation.
Glucose	Skin contact (irritant), of eye contact (irritant), of ingestion, of inhalation.
Creatinine	Skin contact (irritant), of eye contact (irritant), of ingestion, of inhalation.
Multi-meter	Electrical current
Drying	High temperature
Propylene glycol alginate sodium sulfate	Skin contact (irritant), of eye contact (irritant), of ingestion, of inhalation.
Extrusion	Hot temperature

PEG	Skin corrosion , eye irritation
Ultra-high-molecular-weight Polyethylene	Skin corrosion
Polyethylene	Skin corrosion
HEMA	Eye irritation
Calcium carbonate masterbatch	Skin corrosion
Acetone	Flammable, irritation
Polystyrene	Combustible
Ethyl alcohol	Flammable
Sodium dodecyl sulfate Alkylphenolpolyoxyethylene Styrene Acrylate polyethylene glycol monoester Hexadecane Azodiisobutyronitrile	Toxic; skin and eye irritation
Homogenizer	High spinning speed
Heating	High temperature

Chromium trioxide	Flammable, toxic
Dopamine hydrochloride	Eye irritation
Heparin	Skin contact (irritant), of eye contact (irritant),
Styrene Lauryl alcohol Polyvinyl alcohol Sodium dodecyl sulfate Na <sub>2</sub> SO <sub>4</sub> Chitosan Acetic acid Heparin sodium 2-(N-morpholino) ethanesulfonic acid 1-ethyl-3-(3- dimethylaminopropyl) carbodiimide hydrochloride (EDC) N-Hydroxysuccinimide (NHS) Bovine serum albumin GO concentrated solution	Irritant
DNA	Ingestion and inhalation hazard
Heating Reflux set-up	Hot surface Gas pressure variation (e.g. building up) Leaking
HCl NaOH	Corrosive; eye or skin irritation

Bilirubin	Possible eye, skin or respiratory irritation
Divinylbenzene	Irritant, low toxicity
Benzoyl peroxide	Irritant, exposition
Hydroquinone	Irritant, oxidative
Sodium hydroxide	Corrosive
Na <sub>2</sub> SO <sub>4</sub> Nitrogen gas Nitrogen inlet nozzle	Respiration hazard
Four-neck glass separator flask Semicircular anchor-type blade Hot water Vacuum degassing Vacuum oven	Skin hurt or eye hurt
Vacuum	Suction
PMMA	Toxicity, carcinogenicity, irritation/corrosion, combustibility

Sonication	Electrical injuries
Sorbitanmonooleate	Irritant
Poly(vinyl alcohol)	
Sodium dodecyl sulfate	Flammable, Corrosive, Irritant, Toxic, Environmental Hazard
Sulfuric acid	Corrosive, Irritant, Toxic
Silver sulfate	Corrosive, Environmental Hazard
Methanol	Flammable, Toxic
Amberlite 120H	Corrosive
Cellulose triacetate	

## Section 10. Waste list

Diluted sulfuric acid solution	Inorganic Acids container
Diluted NaOH solution	Alkalies container
Diluted KMnO4 solution	Metal Solutions containers
Hydrochloric acid (HCl)	Inorganic Acids container
Mixture of water ,sodium chloride salt, glucose, creatinine and urea	Organic alkalis container
PEG solution	Organic waste
HEMA solution	Organic waste
Hexane	Organic waste
NH3 solution	Alkalies container
Chromium oxide solution	Metal Solutions containers
KCl solution	Metal Solutions containers
H2O2 solution	Inorganic Acids container
Cellulose triacetate solution	Organic waste
Ethyl alcohol	Organic waste
Mixture of sodium dodecyl sulfate, akylphenolpolyoxyethylene, cellulose triacetate, acrylate polyethylene glycol monoester, hexadecane and azodiisobutyronitrile	Organic waste
PEI solution	Organic waste
Glutaricdialdehyde solution	Organic waste
Bilirubin	Organic waste
Disodium hydrogen phosphate	Organic waste
Sodium dihydrogen phosphate	Organic waste
Potassium ferrocyanide	Alkalies container
Epichlorohydrin	Organic waste
Agrose;EDC; NHS; ethanol; Tween 80; Span 80; papain; ninhydrin; double-stranded DNA from salmon milt; bovine serum albumin (BSA); chitosan	Organic waste
Dopamine	Organic waste
Styrene(St)	Organic waste
Divinylbenzene(DVB)	Organic waste
Porogen	Organic waste
Benzoyl peroxide(BPO)	Organic waste
Lauryl alcohol	Organic waste
Polyvinyl alcohol(PVA)	Organic waste
Sodium dodecyl sulfate(SDS)	Inorganic waste
Na2SO4	Inorganic waste
Hydroquinone(HQ)	Organic waste

Acetone	Organic waste
PMMA	Organic waste
Ethyl acetate	Organic waste
Heparin sodium	Organic waste
Acetic acid	Organic waste

## **Section 11. Assessment of Significant Risks**

The use of concentrated sulfuric acid, bilirubin, hexane, chromium trioxide, PMMA, benzoyl peroxide, heparin sodium, and multiple oxidizing agents should be proceeded with extreme caution.

## **Section 12. Safety Precautions**

Personal protective equipment: Goggles, laboratory coat, gloves. No specific training required.

## **Section 13. Action in Case of Abnormal or Emergency Situations**

- Service failure

For electricity failure: Stop furnace, voltage supply

For fume hood failure: Stop any experiment inside the fume hood immediately.

For water supply failure: Stop the furnace of heating under reflux set up

- Action in case of fire or explosion

For a fire discovered: Sound the alarm. Dial 8999 to report to Security Control Centre and inform SEPO. Shut down procedure including experimental apparatus, gases and electricity as quickly as possible without endangering life.

- First aid measure

If chemicals are sputtered into eyes or contacted by skin, flush eyes or skin with plenty of water for at least 15 min immediately. Loosen tight clothing. If chemicals are swallowed, wash out mouth with amount of water to dilute it and ask for the medical help as soon as possible.

- Waste handling and accidental spillage

If solid chemicals are dropped onto the floor, appropriate tools must be used to sweep up and then place them in a plastic bag and hold for waste disposal carefully. And then transfer them into a covered container carefully. In addition, the hazardous wastes including solid and liquid phase should follow standard disposal procedure. If the toxic liquid or volatile liquid was leaking, inform others in the lab and activate the alarm system which is connecting to the security center.

- Abnormal operation of the instrument

When there is something wrong with the instrument, equipment's power should be cut off immediately. And then contact the technician for checking the problem. Not try to repair alone.

- Fire and gas leakage

If you notice the gas leakage or fire occurs, you should evacuate the people in the room as soon as possible and activate the alarm system inform the SEPO and the campus security or inform them by dialing 8999.