POLYACRYLAMIDE HYDROGEL GRAFTED ONTO POLYETHYLENE TEREPHTHALATE TEXTILE VIA ULTRAVIOLET LIGHT-EMITTING DIODE PHOTOGRAFTING FOR OIL/WATER SEPARATION

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Special dedication to:

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ABSTRACT

This study was invented to provide a cheaper alternative filter material for oil/water separation application. Polyethylene terephthalate (PET) textiles with diameter of 4.5 cm were chemically grafted with a thin layer of polyacrylamide (PAAm) hydrogel via UV LED photopolymerisation system. From the grammages that were tested, 85 gsm PET was the most favourable to be used as a matrix. Based on the weight loss data the alkali treatment was optimised under the following condition *i.e.* 2 hours of treatment with 10 wt % of NaOH at 60 ºC. For the grafting process, the effects of UV curing time (5-30 minutes), positioning of filter paper as a spacer (M1 representing the filter paper at the bottom side only and M2 representing the filter papers at both top and bottom sides) as well as technique of grafting (immersion and dipping) were also taken into the account. The obtained samples were characterised using the basic characteristics such as the degree of grafting (DG) and Fourier transformed infrared spectroscopy (FTIR). The DG values for immersed samples were significantly higher (190 % for M1 and 160 % for M2) than dipped samples (90 % for M1 and 60 % for M2). The obtained samples were also characterised in terms of surface morphology by field emission scanning electron microscopy (FESEM), oil fouling, pure water permeability and oil/water permeability test. The results indicated that, the oil/water separation performance of the hydrogel-grafted filter materials (PAAm-*g*-HPET) were strongly influenced by the DG of grafted PAAm hydrogel. However, the immersion grafting technique was found not suitable to be used for commercialisation purposes because of the low water permeability due to hydrogel grafting inside pores as evidenced by FESEM images. The dipping grafting method with the positioning of M2 was selected to be the best method to deal with filtration in oil/water separation. Different UV curing time influenced the oil fouling behaviour of filter samples. Data concluded that 20 minutes of curing was the optimum time for hydrogel grafting. Wettability data indicated that the filter materials after undergoing alkali treatment as well as after being grafted with PAAm hydrogel changed from hydrophobic to hydrophilic. To some extent, this innovation has shown in the near future as promising device for oil/water separation.

ABSTRAK

Kajian ini telah dijalankan bagi menyediakan alternatif bahan penapis yang lebih murah dalam aplikasi pemisahan air/minyak. Tekstil polietilena tereftalat (PET) dengan diameter 4.5 cm telah dicantumkan secara kimia dengan lapisan hidrogel poliakrilamida (PAAm) yang nipis melalui sistem cahaya UV LED. Antara semua jumlah berat tekstil PET yang telah diuji, tekstil PET dengan jumlah berat 85 gsm adalah yang terbaik untuk digunakan sebagai matrik. Berdasarkan data penurunan berat, keadaan rawatan alkali yang optimum adalah; pada masa 2 jam dengan kepekatan NaOH sebanyak 10 wt% pada suhu 60 °C. Sementara itu, bagi proses pencantuman pula, kesan terhadap masa pematangan UV (5-30 minit), kedudukan kertas turas sebagai pemisah; M1 mewakili kertas turas pada sebelah bawah sahaja dan M2 mewakili kertas turas pada kedua-dua belah bahagian atas dan bawah serta teknik pencantuman (rendaman dan celupan) turut diambil kira. Sampel yang diperoleh kemudiannya dinilai dengan menggunakan ciri-ciri asas seperti darjah cantuman (DG) dan spektroskopi jelmaan Fourier infra-merah (FTIR). Nilai DG bagi sampel rendaman adalah lebih tinggi (190% untuk M1 dan 160% untuk M2) berbanding sampel yang dicelup (90% untuk M1 dan 60% untuk M2). Seterusnya, sampel yang diperoleh ini juga turut dicirikan dari segi morfologi permukaan menggunakan medan pelepasan elektron mikroskop pengimbas (FESEM), ujian kotoran minyak, kebolehtelapan air tulen, kebolehtelapan minyak dan ujian penolakan minyak. Keputusan menunjukkan bahawa prestasi bahan penapis yang dihasilkan melalui pencantuman hidrogel dalam pemisahan minyak/air sangat dipengaruhi oleh darjah cantuman PAAm hidrogel. Walau bagaimanapun, teknik pencantuman rendaman tidak sesuai digunakan pada peringkat komersil kerana kadar kebolehtelapan air rendah disebabkan oleh pencantuman hidrogel dalam pori-pori seperti yang ditunjukkan oleh gambar FESEM. Oleh itu, teknik pencantuman secara celupan dengan kedudukan kertas turas M2 telah dipilih untuk menjadi kaedah terbaik dan sangat sesuai untuk digunakan dalam penapisan bagi pemisah air/minyak. Selain itu, masa pematangan UV yang berbeza memberi impak ke atas sifat kotoran minyak terhadap sampel penapis. Setakat ini, tempoh pematangan selama 20 minit adalah masa yang optimum untuk hidrogel dicantumkan. Data yang diperolehi daripada kebolehbasahan menunjukkan bahan penapis selepas menjalani rawatan alkali serta dicantumkan dengan hidrogel berubah menjadi hidrofilik. Adalah dijangkakan, inovasi ini mempunyai kegunaan yang cerah sebagai bahan penapis yang baik untuk pemisahan minyak/air pada masa hadapan.

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LIST OF SYMBOLS AND ABBREVIATIONS

%	-	Percent
>	-	More than
^{o}C	-	Celsius degree
µm	-	Micrometre
cm	-	Centimetre
-g-	-	Grafted
gsm	-	gram per metre square
mL	-	millimetre
3D	-	Three dimensional
AA	-	Acrylic acid
AAm	-	Acrylamide
AMPS	-	2-acrylamido-2-methyl-1-propansulfonic acid
AAS	-	Atomic absorption spectrometer
BP	-	Benzophenone
C_F	-	Concentration feed
C_P	-	Concentration permeates
CAs	-	Contact Angle
COD	-	Chemical oxygen demand
DG	-	Degree of grafting
FESEM	-	Field Emission Scanning Electron Microscopy
FO	-	Forward osmosis
FTIR	-	Fourier Transform Infrared Spectroscopy
LED	-	Light-emitting diode
LCST	-	Lower critical solution temperature
MBAAm	-	*N,N'*-methylenebisacrylamide
MMC	-	Monolithic macroporous carbon

MW	-	Molecular weight
NaOH	-	Sodium hydroxide
NC	-	Nanocomposites
OMMT	-	Organo-montmorillonite
PAAm	-	Polyacrylamide
PDMS	-	Polydimethysiloxane
PDMAPAAm	-	Poly(*N*,*N*-dimethylaminopropyl acrylamide)
PEG	-	Poly(ethylene glycol)
PET	-	Polyethylene terephthalate
PEGDA	-	Poly(ethylene glycol)diacrylate
PES	-	Polyethersulfone
PHEMA	-	poly (2-hydroxyethylmethacrylate)
PI	-	Photoinitiator
PP	-	Polypropylene
PTFE	-	Polytetrafluoroethylene
PU	-	Polyurethane
PVA	-	Poly(vinyl alcohol)
PVDF	-	Polyvinylidene fluoride
RO	-	Reverse osmosis
SP	-	Smart Polymer
UV	-	Ultraviolet
W_1	-	Initial weight of PET textiles
W_2	-	After modification weight of PET textiles
W_s	-	Weight of hydrogel in swollen state
W_d	-	Weight of hydrogel in dry state
w/v	-	Weight per volume
wt	-	Weight

CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, tremendous attention have been paid towards development of functional hydrogels (Kumar *et al.*, 2007; Yang *et al.*, 2011; Wandera *et al.*, 2010; Chirani *et al.*, 2015). Many researchers are interested in exploring the potential application of hydrogel in various fields such as drug delivery, tissues engineering, biomedical, artifical tissue (Ahmed 2013) and recently in bioseparation field e.g. oil/ water separation (Xue *et al.*, 2011; Wu *et al.*, 2012; Adrus, 2012; Liang *et al.*, 2012; Xue *et al.*, 2013; Yuan *et al.*, 2015), protein mixture (Gunavadhi *et al.*, 2012; Wang *et al.*, 2013) and many more.

Hydrogels are highly hydrophilic polymeric matrices that built up of three-dimensional network (Adrus, 2012). Hydrogels are also unique because they have self-cleaning (Wang *et al.*, 2011) and oil-fouling resistance (Sagle & Freeman 2009) properties. In addition, due to their hydrophilicity, hydrogels have the ability to retain high water content and minimize the foulant contact such as adsorption of protein (Charles *et al.*, 2009), adhesion of cells or bacteria (Kunz *et al.*, 1999) as well as oil-repellent property (Yoshida and Okano 2010).

Furthermore, research that related to hydrogel is still very active due to the great attention with regard to its outstanding properties. Polyacrylamide (PAAm) hydrogel is one of the frequently used hydrogel. In the literature, PAAm hydrogel was mainly used in electrophoresis application for protein and DNA separation (Lin *et al.,* 2004). But recently, the research on hydrogels have focused on oil/water separation field due to their oil-repelling characteristics (Kumar *et al.,* 2007 and Stuart *et al.,* 2010). According to Xue *et al.,* (2011) and Feng *et al.,* (2012), PAAm hydrogel-coated mesh shows special wettability with both underwater superoleophobic and low oil-adhesion characteristics in oil/water/solid three phase systems. This is because, it consist of rough nanostructured hydrogel coatings and micro scale porous substrate. Similarly, Gao *et al.,* (2013) also had synthesized such hydrophilic and oleophobic molecules by using TiO_2 and it successfully applied for the separation crude oil/water mixtures.

In order to assess the surface wettability of hydrogels, it is highly recommended to use hydrogels as a grafted layer on the polymer substrate as compared to bulk hydrogels (Adrus and Ulbricht, 2012). Engineering polymer such as PET, polyurethane (PU), polyethersulfone (PES) and polyvinylidene fluoride (PVDF) are commonly employed as polymer substrates. In recent times, PET textiles have been broadly used in various applications by using different types of textile namely woven and nonwoven. Those include medical (Rahman and East, 2006), filter, geotextiles (East and Rahman, 1999) and many more. On top of that, PET is much cheaper, have good mechanical properties that comparable with metals, easy to handle as well as user-friendly amongst other polymeric materials.

In this work, the formation of hydrogel layers onto the polymer substrates could further be enhanced by photopolymerization using UV LED system. To the best of our knowledge, hydrogel grafting for oil/water separation using photopolymerization is limited. Most of the studies were reported to use physical grafting only. So, photografting technique was preferred in this study. In recent years, the UV-initiated grafting or copolymerization is progressively proposed for an effective surface modification as it offers unique ability to tune and to manipulate surface properties without damaging the bulk materials (Praschak *et al.*, 2000; Bahners *et al.,* 2004). Therefore, the aim of this work was to graft PAAm hydrogels onto PET textiles surfaces (which was direct activated with photoinitiator) via UV LED photografting and to characterize the grafted textiles (PAAm-*g*-HPET) from degree of grafting (DG), Fourier transformed infrared spectroscopy (FTIR), field emission scanning electron microscopy (FESEM), surface wettability by contact angle, pure water permeability test and oil/water separation measurement. The hydrogel grafted PET textiles were envisioned to have oil-repelling properties due to the synergistic of combining hydrophilic hydrogel onto PET textiles surfaces. Thus, this innovation would have bright vision in the near future as effective materials for oil/water separation.

1.2 Problem Statement

To date, oily wastewater, polluted ocean water and frequent oil spill accident have becoming a main worldwide problem. According to the previous studies (Benfer *et al.*, 2001; Inagaki *et al.*, 2002; Huang & Lim, 2006), various approaches have been used to overcome these problems such as removal oil by kapok fibre, adsorption of oil by using activated carbon, separation by gravity and separation by ceramic membrane. Although those materials exhibited high adsorption capacity up to 99%, but there are limitations occur for a large scale fabrication of such adsorber materials and for practical application. This ascribed to the high prices of the materials, complex fabrication procedures, low stability and flexibility, difficult practical condition, lead to the oil fouling as well as poor selectivity and recyclability (Guvendiren *et al.*, 2009). In response to the problems stated above, it was therefore, worthwhile to investigate the simple and necessary way to overcome the limitation of previous innovation.

Previously, there were several studies reported that hydrogels including PAAm were usually coated onto stainless steels mesh and successfully employed for oil/water separation (Xue *et al.*, 2011). However, stainless steel mesh did not have a functional group to be grafted with hydrogel. As a result, it directed the hydrogels only attached by physical coating. This event would lead to the short lifetime and low stability. The use of engineering PET as a substrate could be good alternative as PET has also outstanding mechanical properties similar to metal. Two years later, a superhydrophobic and superoleophilic material was developed by Xue *et al.*, (2013).

Sol-gel was coated onto PET textiles. Since the obtained material is designed to be superhydrophobic and superoleophilic, the probability for pores of the textiles to be clogged with oil is very high. As a result, post-treatment is needed which directed in higher cost. Moreover, in 2014, Yuan and co-workers have developed polysulfone membrane clicked with poly (ethylene glycol) (PEG) of high density and uniformity for oil/water emulsion purification. Although the membrane shows superior oil/water emulsion separation performance, but due to its complicated fabrication, this study is not feasible to be scale up.

Although PET was widely used in numerous applications such as used as a filter device, bottles and apparels, it has limitations with regard to their surface properties. This is because PET is less hydrophilic in nature. Therefore pre-treatment is a must process to modify its surfaces. Here, the non-woven PET textiles were grafted with a thin layer of PAAm hydrogel via photografting approached for oil/water separation. PET textiles were chosen as substrate for this research because it was much cheaper, easy to handle and environmentally friendly as compared to other polymeric materials, stainless steels and ceramics.

Additionally, the curing of hydrogels was mostly focused on conventional ultraviolet-A (UVA) system. However, as the conventional UVA lamp has high energy consumption and takes time to warming up (as the emitting lamps for UVA curing are typically from mercury sources), thus UV LED was used instead. The development of UV LED light source for hydrogels curing is promising technology that can be used to replace conventional UVA system (Ayub *et al.*, 2017) . To the best of our knowledge, UV LED has not yet been reported as a source to irradiate or cure the hydrogels.

1.3 Objectives of the Research

The ultimate aim of this study was to produce highly efficient filters for oil/water separation where they were cheaper, easier to fabricate as well as environmentally friendly. The sub objectives could be further divided into:

i. To study the effect of alkali treatment on the hydrophilicity of PET textiles with various grammage (17-120 gsm), different concentrations of NaOH (4 and 10 wt%), times of treatment (2, 4 and 8 hours) and temperatures of treatment (30 and 60 ºC).
ii. To synthesize the PAAm hydrogel grafted onto PET textiles surfaces (PAAm-*g*-HPET) with different times of irradiation (5-30 minutes) via UV LED photopolymerization, method of grafting (immersion and dipping) and also different positioning of filter paper (M1 and M2)
iii. To characterize the PAAm-*g*-HPET samples via DG, FTIR, oil fouling test, water permeability, FESEM, surface wettability and the performance of PAAm-*g*-HPET samples towards oil/water separation.

1.4 Scope of the Research

In general, this project was divided into three tasks. The first task started with alkali treatment of PET textiles. The purpose of this process was to improve i) the hydrophilicity of PET as it is hydrophobic in nature, ii) performance of PET textiles and iii) to eliminate the dirt as well as other contamination. The concentration of NaOH, time of treatment and temperature were varied in order to determine the optimum conditions for alkali treatment towards the PET textiles.

Meanwhile, the second task of this research involved the study regarding the photografting process of PAAm-*g*-HPET via UV LED system. Primarily, both surfaces of pure and alkali-treated PET textiles were activated using type II photoinitiator (benzophenone, BP). At first, PAAm hydrogel was grafted onto PET textiles without using any spacers. Later, the same process was deliberated using filter paper as a spacer with different positioning. Moreover, the photografting was carried out either via immersion or dipping method. These two methods were studied to investigate the effect of grafting onto the PET textiles as well as the performance of the samples towards oil/water separation. The samples were exposed to different times of curing in order to find the best UV time for grafting. Then, the grafted PET textile samples were soaked in the distilled water to wash out the residual chemicals and unreacted monomer before being dried in the oven.

Finally, all the designated samples were characterized using the basic polymer characterization process such as DG and FTIR. In addition, FESEM, oil fouling test, pure water permeability, and surface wettability using contact angle as well as oil/water separation measurement were also conducted to study the ability of PAAm-*g*-HPET samples to separate oil and water.

REFERENCES

Adebajo, M. O., Frost, R. L., Kloprogge, J. T., Carmody, O. and Kokot, S. J. (2003). Porous Materials for Oil Spill Cleanup: A Review of Synthesis and Absorbing Properties. *Porous Material*. 10(3): 159-170.

Adrus, N. (2012). Stimuli-Responsive Hydrogels and Hydrogel Pore-Filled Composite Membranes. *Dissertation Universitat Duisburg-Essen*. 1–183.

Adrus, N. and Ulbricht, M. (2012). Novel Hydrogel Pore-Filled Composite Membranes With Tunable And Temperature-Responsive Size-Selectivity. *Journal of Materials Chemistry*, 22(7): 3088.

Adrus, N. and Ulbricht, M. (2013). Rheological Studies on PNIPAAm Hydrogel Synthesis via in situ Polymerization and On Resulting Viscoelastic Properties. *Reactive and Functional Polymers*, 73(1): 141–148.

Ahmed, E.M. (2015). Hydrogel : Preparation , Characterization and Applications : A review. *Journal of Advanced Research*, 6(2): 105–121.

Ahmed, E.M. (2013). Hydrogel: Preparation, Characterization and Applications. *Journal of Advanced Research*.

Akin, H., Hasirci, V.N. & Hasirci, N. (1990). Permeability Properties Of Charged Hydrogel-Carrying Membranes. *Polymer*, 31(2): 270–275.

Augé, A. and Zhao, Y. (2016). What Determines The Volume Transition Temperature of UCST Acrylamide–Acrylonitrile Hydrogels? *RSC Adv.*, 6(74): 70616–70623.

Ayub, N.F., Hashim, S., Jamaluddin, J. and Adrus, N. (2017). New UV LED Curing Approach for Polyacrylamide and Poly(N-isopropylacrylamide) Hydrogels. *New Journal of Chemistry*.

Begam, T., Nagpal, A.K. and Singhal, R. (2003). A Comparative Study of Swelling Properties of Hydrogels Based on Poly (acrylamide- co -methyl methacrylate) Containing Physical and Chemical Crosslinks. *Journal of applied Polymer Science*, 89(3): 779–786.

Benfer, S., Popp, U., Richter, H., Siewert, C. and Tomandl, G. (2001). Development And Characterization of Ceramic Nanofiltration Membranes. *Separation and Purification Technology*, 22-23: 231–237.

Bisson, I., Kosinski, M., Ruault, S., Gupta, B., Hilborn, J., Wurm, F. and Frey, P. (2002). Acrylic Acid Grafting and Collagen Immobilization on Poly(ethylene terephthalate) Surfaces for Adherence and Growth of Human Bladder Smooth Muscle Cells. *Biomaterials*, 23: 3149–3158.

Brown, P.S., Atkinson, O.D.L.A. and Badyal, J.P.S. (2014). Ultrafast Oleophobic-hydrophilic Switching Surfaces for Antifogging, Self-cleaning, And Oil-water Separation. *ACS Applied Materials and Interfaces*, 6(10): 7504–7511.

Brown, P.S. and Bhushan, B. (2015). Mechanically Durable, Superomniphobic Coatings Prepared by Layer-by-Layer Technique for Self-Cleaning And Anti-Smudge. *Journal of Colloid and Interface Science*, 456: 210–218.

Bruening, M. and Dotzauer, D. (2009). Polymer Films: Just spray it. *Nature Materials*, 8(6): 449–450.

Burtovyy, O., Klep, V., Chen, H-C., Hu, R-K., Lin, C-C. and Luzinov, I. (2007). Hydrophobic Modification of Polymer Surfaces via “Grafting to” Approach. *Journal of Macromolecular Science, Part B*, 46(1): 137–154.

Buskens, P., Wouters, M., Rentrop, C. and Vronn, Z. (2013). A Brief Review of Environmentally Benign Antifouling and Foul-release Coatings for Marine Applications. *Journal of Coatings Technology Research*, 10(1): 9–36.

Cao, B., Wu, H. and Tang, Q. (2013). Switchable Antimicrobial and Antifouling Hydrogels with Enhanced Mechanical Properties. *Advanced Healthcare Materials*, 2(8): 1096–1102.

Carole. M.-C. and M, P.B. (2007). In Vitro Water Wettability of Silicone Hydrogel Contact Lenses Determined Using The Sessile Drop And Captive Bubble Techniques. *Journal of Biomedical Materials Research Part A*: 496–502.

Carr, L.R., Zhou, Y., Krause, J.E., Xue, H. and Jiang, H. (2011). Uniform Zwitterionic Polymer Hydrogels With A Nonfouling and Functionalizable Crosslinker Using Photopolymerization. *Biomaterials*, 32(29): 6893–6899.

Cha, E., Kohman, R.E. and Kong, H. (2009). Biodegradable Polymer Crosslinker: Independent Control of Stiffness, Toughness, And Hydrogel Degradation Rate. *Advanced Functional Materials*, 19(19): 3056–3062.

Chakraborty, M., Chowdhury, D. and Chattopadhyay, A. (2003). Spin-Coating of Polystyrene Thin Films as an Advanced Undergraduate Experiment. *Journal of Chemical Education*, 80(7): 806.

Chalker, P.R. (2016). Surface & Coatings Technology Photochemical Atomic Layer Deposition And Etching. *Surface & Coatings Technology*, 291: 258–263.

Chambers, L.D., Stokes, K.R., Walsh, F.C. and Wood, R.J.K. (2006). Modern Approaches to Marine Antifouling Coatings. *Surface and Coatings Technology*, 201(6): 3642–3652.

Chandy, T., Das, G.S., Wilson, R.F. and Rao, G.H.R. (2000). Use of Plasma Glow for Surface-Engineering Biomolecules to Enhance Bloodcompatibility of Dacron and PTFE Vascular Prosthesis. *Biomaterials*, 21(7): 699–712.

Charles, P.T., Stubbs, V.R., Soto, C.M., Martin, B.D., White, J. and Taitt, C.R. (2009). Reduction of Non-Specific Protein Adsorption Using Poly(ethylene) Glycol (PEG) Modified Polyacrylate Hydrogels In Immunoassays for Staphylococcal Enterotoxin B detection. *Sensors*, 9(1): 645–655.

Chen, S., Shi, J., Zhang, M., Chen, Y., Wang, X., Zhang, L., Tian, Z., Yan, Y., Li, Q., Zhong, W., Xing, M., Zhang, L. and Zhang, L. (2016). Mesenchymal Stem Cell-Laden Anti-Inflammatory Hydrogel Enhances Diabetic Wound Healing. *Scientific Reports*, 5(1): 18104.

Chen, S, Li, L., Zhao, C. and Zheng, J. (2010). Surface Hydration: Principles and Applications Toward Low-Fouling/Nonfouling Biomaterials. *Polymer*, 51(23): 5283–5293.

Chirani, N., Yahia, L'H., Gritsch, L., Motta, F. L., Chirani, S. and Faré, S. (2015). History and Applications of Hydrogels. *Journal of Biomedical Sciences*, 4: 1–23.

Chirila, T.V., Chen, Y-C., Griffin, B.J. and Constable, I.J. (1993). Hydrophilic Sponges Based on 2-hydroxyethyl Methacrylate. I. Effect of Monomer Mixture Composition on the Pore Size. *Polymer International*, 32(3): 221–232.

Chu, L.Y., Wang, S. and Chen, W.M. (2005). Surface Modification of Ceramic-Supported Polyethersulfone Membranes by Interfacial Polymerization for Reduced Membrane Fouling. *Macromolecular Chemistry and Physics*, 206(19): 1934–1940.

Chu, P.K., Chen, J.Y., Wang, L.P and Huang, N. (2002). Plasma-surface Modification of Biomaterials. *Materials Science and Engineering: R: Reports*, 36: 143–206.

Cuong, N.K. (2007). Plasma-Induced Graft Polymerization of Acrylic Acid onto Poly (ethylene terephthalate) Films : Hydrophilic Modification 2 . Experimental Procedures: 47–56.

Dalsin, J.L. and Messersmith, P.B. (2005). Bioinspired Antifouling Polymers. *Materials Today*, 8(9): 38–46.

Dautzenberg, H. (2000). Polyelectrolyte Complex Formation: Role of A Double Hydrophilic Polymer. *Macromolecular Chemistry and Physics*: 1765–1773.

Deng, J., Wang, L., Liu, L.and Yang, W. (2009). Developments and New Applications of UV-Induced Surface Graft Polymerizations. *Progress in Polymer Science*, 34(2): 156–193.

Donelli, I., Taddei, P., Smet, P.F., Poelman, D., Nierstrasz, V.A. and Freddi, G. (2009). Enzymatic Surface Modification and Functionalization of PET: A Water Contact Angle, FTIR, and Fluorescence Spectroscopy Study. *Biotechnology and bioengineering*, 103(5): 845–56.

Ekblad, T., Bergstrom, G., Ederth, T., Conlan, S.L., Mutton, R., Clare, A.S., Wand, S., Liu, Y., Zhao, Q., D'Souza, F., Donnelly, G.T., Willemsen, P.R., Pettitt, M.E., Callow, M.E., Callow, J.A. and Liedberg, B. (2008). Poly(ethylene glycol)-Containing Hydrogel Surfaces for Antifouling Applications in Marine and Freshwater Environments. *Biomacromolecules*, 9: 2775–2783.

Feng, L., Zhang, Z., Mai, Z., Ma, Y., Liu, B., Jiang, L. and Zhu, D. (2004). A Super-Hydrophobic and Super-Oleophilic Coating Mesh Film for the Separation of Oil and Water. *Angewandte Chemie - International Edition*, 43(15): 2012–2014.

Geismann, C. and Ulbricht, M. (2005). Photoreactive Functionalization of Poly(ethylene terephthalate) Track-Etched Pore Surfaces with Smart Polymer Systems. *Macromolecular Chemistry and Physics*, 206(2): 268–281.

Guebitz, G.M. and Cavaco-Paulo, A. (2008). Enzymes Go Big: Surface Hydrolysis and Functionalisation of Synthetic Polymers. *Trends in Biotechnology*, 26(1): 32–38.

Goddard, J.M. and Hotchkiss, J.H. (2007). Polymer Surface Modification for the Attachment of Bioactive Compounds. *Progress Polymer Science*, 32: 698–725.

Gunavadhi, M., Maria, L.A.A., Chamundeswari, V.N and Parthasarathy, M. (2012). Nanotube-Grafted Polyacrylamide Hydrogels for Electrophoretic Protein Separation. *Electrophoresis*, 33(8): 1271–1275.

Guney, A., Kara, F., Ozgen, O., Aksoy, E.A., Hasirci, V. and Hasirci, N. (2013). Surface Modification of Polymeric Biomaterials. *Wiley-VGH Verlag GmbH & Co. KGaA*: 89–157.

Guvendiren, M., Yang, S. and Burdick, J.A. (2009). Swelling-Induced Surface Patterns In Hydrogels with Gradient Crosslinking Density. *Advanced Functional Materials*, 19(19): 3038–3045.

Hadjizadeh, A., Ajji, A. and Bureau, M.N. (2010). Preparation and Characterization of NaOH Treated Micro-fibrous Polyethylene Terephthalate Nonwovens for Biomedical Application. *Journal of the mechanical behavior of biomedical materials*, 3(8): 574–83.

Heo, S-B., Jeon, Y-S., Kim, S.I., Kim, S.H. and Kim, J-H. (2014). Bioinspired Adhesive Coating on PET Film for Antifouling Surface Modification. *Macromolecular Research*, 22(2): 203–209.

Hosseinzadeh, H. and Mohammadi, S. (2014). Synthesis of a Novel Hydrogel Nanocomposite Coated on Cotton Fabric for Water-Oil Separation. *Water, Air, & Soil Pollution*, 225(9): 2115.

Huang, S. and Shi, J. (2014). Monolithic Macroporous Carbon Materials as High-Performance and Ultralow-Cost Sorbents for Efficiently Solving Organic Pollution. *Industrial and Engineering Chemistry Research*, 53: 4888–4893.

Huang, X. and Lim, T.T. (2006). Performance and Mechanism of a Hydrophobic-Oleophilic Kapok Filter for Oil/Water Separation. *Desalination*, 190: 295–307.

Imran, A. Bin and Takeoka, Y. (2014). The Development of Novel “Stimuli-Sensitive” Hydrogels for Various Applications. *Nature Communications (electronic version)*: 4–7.

Inagaki, M., Kawahara, A., Nishi, Y. and Iwashita, N. (2002). Heavy Oil Sorption and Recovery by Using Carbon Fiber Felts. *Carbon*, 40: 1487–1492.

Inagaki, N., Narushim, K., Tuchida, N. and Miyazaki, K. (2004). Surface Characterization of Plasma-Modified Poly(ethylene terephthalate) Film Surfaces. *Journal of Polymer Science, Part B: Polymer Physics*, 42(20): 3727–3740.

Ishihara, K. (1998). Reduced Protein Adsorption on Novel Phospholipid Polymers. *Biomaterials Applications*, 13: 111–127.

Iwata, H., Ivanchenko, M.I. & Miyaki, Y. (1994). Preparation of Anti-Oil Stained Membrane by Grafting Polyethylene Glycol Macromer Onto Polysulfone Membrane. *Journal of Applied Polymer Science*, 54(1): 125–128.

Jiang, J., Zhu, L., Zhu, L., Zhang, H., Zhu, B. and Xu, Y. (2013). Antifouling and Antimicrobial Polymer Membranes Based on Bioinspired Polydopamine and Strong Hydrogen-Bonded Poly(N-vinyl pyrrolidone). *ACS Applied Materials & Interfaces*, 5(24): 12895–12904.

Jiao, Y.P. & Cui, F.Z. (2007). Surface Modification of Polyester Biomaterials for Tissue Engineering. *Biomedical Materials*, 2(4): 24–37.

Ju, G., Cheng, M. & Shi, F. (2014). A pH-responsive Smart Surface for The Continuous Separation of Oil/Water/Oil Ternary Mixtures. *NPG Asia Materials*, 6(7): 111.

Ju, H., McCloskey, B.D., Sagle, A.C., Kusuma, V.A. and Freeman, B.D. (2009). Preparation and Characterization of Crosslinked Poly(ethylene glycol) Diacrylate Hydrogels As Fouling-Resistant Membrane Coating Materials. *Journal of Membrane Science*, 330(1-2): 180–188.

Kato, K., Uchida, E., Kang, E.T., Uyama, Y. and Ikada, Y. (2003). Polymer Surface with Graft Chains. *Progress in Polymer Science (Oxford)*, 28(2): 209–259.

Keir, N. & Jones, L. (2013). Wettability and Silicone Hydrogel Lenses: A Review. *Eye & Contact Lens*, 39(1): 100–108.

Kim, M., Schmitt, S.K., Choi, J.W., Krutty, J.D. and Gopalan, P. (2015). From Self-Assembled Monolayers to Coatings: Advances in the synthesis and nanobio applications of polymer brushes. *Polymers*, 7(7): 1346–1378.

Krsko, P. & Libera, M. (2005). Biointeractive Hydrogels. *Materials Today*, 8(12): 36–44.

Kumar, A., Srivastava, A., Galaev, I.Y. and Mattiasson, B. (2007). Smart Polymers: Physical Forms and Bioengineering Applications. *Progress in Polymer Science*, 32(10): 1205–1237.

Lin, D. C., Y.B. and L.N.A. (2004). Mechanical Properties of a Reversible, DNA-Crosslinked Polyacrylamide Hydrogel. *Journal of Biomechanical Engineering*, 126(1): 104–110.

Liu, Y., Su, Y., Li, Y., Zhao, X. and Jiang, Z. (2015). Improved Antifouling property of PVDF Membranes by Incorporating an Amphiphilic Block-Like Copolymer for Oil/Water Emulsion Separation. *RSC Advances*, 5(27): 21349–21359.

Magalhães, A.S.G., Neto, M.P.A., Bezerra, M.N., Ricardo, N. M.P.S. and Feitosa, J.P.A. (2012). Application of FTIR in the Determination of Acrylate Content in Poly(sodium Acrylate-CO-acrylamide) Superabsorbent Hydrogels. *Quimica Nova*, 35(7): 1464–1467.

Mohamed, N.H., Bahners, T., Wego, A., Gutmann, J.S. and Ulbricht, M. (2012). Surface Modification of Poly(ethylene terephthalate) Fabric via Photo-Chemical Reaction of Dimethylaminopropyl Methacrylamide. *Applied Surface Science*, 259: 261–269.

Mondal, S. & Wickramasinghe, S.R. (2012). Photo-Induced Graft Polymerization of N-Isopropyl Acrylamide on Thin Film composite Membrane: Produced Water Treatment and Antifouling Properties. *Separation and Purification Technology*, 90(0): 231–238.

Montazer, M. & Sadighi, A. (2006). Optimization of The Hot Alkali Treatment of Polyester/Cotton Fabric with Sodium Hydrosulfite. *Journal of Applied Polymer Science*, 100(6): 5049–5055.

Murosaki, T., Ahmed, N. and Ping Gong, J. (2011). Antifouling Properties of Hydrogels. *Science and Technology of Advanced Materials*, 12(6): 64706.

Ng, R., Zhang, X., Liu, N. and Yang, S-T. (2009). Modifications of Nonwoven Polyethylene Terephthalate Fibrous Matrices via NaOH Hydrolysis: Effects on Pore Size, Fiber Diameter, Cell Seeding and Proliferation. *Process Biochemistry*, 44(9): 992–998.

Noeske, M., Degenhardt, J., Strudthoff, S. and Lommatzsch, U. (2004). Plasma Jet Treatment of Five Polymers at Atmospheric Pressure: Surface Modifications and the Relevance for Adhesion. *International Journal of Adhesion and Adhesives*, 24(2): 171–177.

Norrman, K., Ghanbari-Siahkali, A. and Larsen, N.B. (2005). 6 Studies of Spin-coated Polymer Films. *Annual Reports Section "C" (Physical Chemistry)*, 101: 174.

Nunes, S.P. and Car, A. (2013). From Charge-mosaic to Micelle Self-assembly: Block Copolymer Membranes in the Last 40 years. *Industrial and Engineering Chemistry Research*, 52: 993–1003.

Nurioglu, A.G., Catarina, A., Esteves, C. and De With, G. (2015). Nontoxic, Nonbiociderelease Antifouling Coatings based on Molecular Structure Design for Marine Applications. *J. Mater. Chem. B*, 3(3): 65476570.

Ono, T., Sugimoto, T., Shinkai, S. and Sada, K. (2007). Lipophilic Polyelectrolyte Gels as Super-Absorbent Polymers for Nonpolar Organic Solvents. *Nature materials*, 6(6): 429–33.

Ozay, O., Ekici, S., Baran, Y., Aktas, N. and Sahiner, N. (2009). Removal of Toxic Metal Ions with Magnetic Hydrogels. *Water research*, 43(17): 4403–11.

Park, I., Efimenko, K., Sjoblom, J. and Genzer, J. (2009). Rapid Removal of Organics and Oil Spills from Waters Using Silicone Rubber "Sponges." *Journal of Dispersion Science and Technology*, 30(July 2015): 318–327.

Park, S. and Kim, S. (2014). Poly (ethylene terephthalate) Recycling for High Value Added Textiles. *Fashion and Textiles*, 1: 1–17.

Peppas, N.A., Hilt, J.Z., Khademhosseini, A. and Langer, R. (2006). Hydrogels in Biology and Medicine: From Molecular Principles to Bionanotechnology. *Advanced Materials*, 18(11): 1345–1360.

Pham., N.P., Burghaetz., J.N. and Sarro, P.M. (2005). Optimization of Spray Coating Photoresist for High Topography Surfaces. *Journal of Micromechanics and Microengineering*, 15: 691–697.

Pintor, A.M.a., Vilar, V.J.J.P., Botelho, C.M.M.S. and Boaventura, R.a.R. (2014). Optimization of A Primary Gravity Separation Treatment for Vegetable Oil Refinery Wastewaters. *Clean Technologies and Environmental Policy*: 1725–1734.

Pojman, J.A., Willis, J., Fortenberry, D., Ilyashenko, V. and Khan, A.M. (1995). Factors Affecting Propagating Fronts of Addition Polymerization: Velocity, Front Curvature, Temperatue Profile, Conversion, and Molecular Weight Distribution. *Journal of Polymer Science Part A: Polymer Chemistry*, 33(4): 643–652.

Praschak, D., Bahners, T. and Schollmeyer, E. (2000). Excimer UV Lamp Irradiation Induced Grafting on Synthetic Polymers. *Applied Physics A: Materials Science and Processing*, 71(5): 577–581.

Qunyi, T. and Ganwei, Z. (2005). Rapid Synthesis of a Superabsorbent from a Saponified Starch and Acrylonitrile/AMPS Graft Copolymers. *Carbohydrate Polymers*, 62(1): 74–79.

Ranby, B. (1999). Surface modication and Lamination of Polymers by Photografting. *Journal Of Adhesion and Adhesives*, 19: 337–343.

Reynolds, J.G., Coronado, P.R. and Hrubesh, L.W. (2001). Hydrophobic Aerogels for Oil-Spill Clean Up, Synthesis and Characterization. *Journal of Non-Crystalline Solids*, 292: 127–137.

Sagle, A.C., Ju, H., Freeman, B.D. and Sharma, M.M. (2009). PEG-based Hydrogel Membrane Coatings. *Polymer*, 50(3): 756–766.

Sagle, A.C. and Freeman, B.D. (2009). PEG Hydrogels as Anti-Fouling Coatings for Reverse Osmosis Membranes. *Chemical Engineering*, Ph. D., p.186.

Sahiner, N., Ozay, O., Inger, E. and Aktas, N. (2011). Superabsorbent Hydrogels for Cobalt Nanoparticle Synthesis and Hydrogen Production from Hydrolysis of Sodium Boron Hydride. *Applied Catalysis B: Environmental*, 102(1-2): 201–206.

Sai, H., Fu, R., Xing, J., Li, Z., Li, F. and Zhang, T. (2015). Surface Modification of Bacterial Cellulose Aerogels' Web-Like Skeleton for Oil/Water Separation. *ACS Applied Materials and Interfaces*, 7(13): 7373–7381.

Sakthi Kumar, D., Fujioka, M., Asano, K., Shoji, A., Jayakrishnan, A. and Yoshida, Y. (2007). Surface Modification of Poly(ethylene terephthalate) by Plasma Polymerization of Poly(ethylene glycol). *Journal of Materials Science: Materials in Medicine*, 18(9): 1831–1835.

Shahkaramipour, N., Ramanan, S. and Lin, H. (2017). Membranes with Surface-Enhanced Antifouling Properties for Water Purification. *Membranes*, 7(1): 1–18.

Silva Nykänen, V.P., Nykänen, A., Puska, M.a., Silva, G.G. and Ruokolainen, J. (2011). Dual-Responsive and Super Absorbing Thermally Cross-Linked Hydrogel based on Methacrylate Substituted Polyphosphazene. *Soft Matter*, 7(9): 4414.

Solomon, B.R., Hyder, M.N. and Varanasi, K.K. (2014). Separating Oil-Water Nanoemulsions using Flux-Enhanced Hierarchical Membranes. *Scientific reports*, 4: 5504.

Stuart, M.A.C., Huck, W.T.S., Genzer, J., Muller, M., Ober, C., Stamm, M., Sukhorukov, G.B., Szleifer, I., Tsukruk, V.V., Urban, M., Winnik, F., Zauscher, S., Luzinov, I. and Minko, S. (2010). Emerging Applications of Stimuli-Responsive Polymer Materials. *Nat Mater*, 9(2): 101–113.

Su, G., Zhou, T., Zhang, Y., Liu, X. and Zhang, A. (2016). Microdynamics Mechanism of D_2O Absorption of the P(2-hydroxyethyl methacrylate)-Based Contact Lens Hydrogel Studied by Two-Dimensional correlation ATR-FTIR spectroscopy. Soft Matter, 12(4): 1145–1157.

Su, G., Zhou, T., Liu, X. and Ma, Y. (2017). Micro-Dynamics Mechanism of the Phase Transition Behavior of Poly(N-isopropylacrylamide-co-2-hydroxyethyl methacrylate) Hydrogels Revealed by Two-Dimensional Correlation Spectroscopy. *Polymer Chemistry*: 1-15.

Susanto, H. and Ulbricht, M. (2008). High-Performance Thin-Layer Hydrogel Composite Membranes for Ultrafiltration of Natural Organic Matter. *Water Research*, 42(10-11): 2827–2835.

Susanto, H. and Ulbricht, M. (2007). Photografted Thin Polymer Hydrogel Layers on PES Ultrafiltration mMembranes: Characterization, Stability, and Influence on Separation Performance. *Langmuir,* 23(14): 7818–7830.

Talaat, H.A., Sorour, M.H., Aboulnour, A.G., Shaalan, H.F., Ahmed, E. M., Awad, A.M. and Ahmed, M.A. (2008). Development of a Multi-Component Fertilizing Hydrogel. *American-Eruasian Journal Agriculture & Environment Science*, 3(5): 764–770.

Tanan, W. and Saengsuwan, S. (2014). Microwave Assisted Synthesis of Poly (acrylamide-co-2-hydroxyethyl methacrylate)/poly(vinyl alcohol) Semi-IPN Hydrogel. *Energy Procedia*, 56(C): 386–393.

Tkavc, T., Petrinič, I., Luxbacher, T., Vesel, A., Ristić, T. and Zemljič, L.F. (2014). Influence of O2 and CO2 Plasma Treatment on the Deposition of Chitosan Onto Polyethylene Terephthalate (PET) Surfaces. *International Journal of Adhesion and Adhesives*, 48: 168–176.

Tuteja, A., Choi, W., Ma, M., Mabry, J.M., Mazzella, S.a., Rutledge, G.C., McKinley, G.H. and Cohen, R.E. (2007). Designing Superoleophobic Surfaces. *Science (New York, N.Y.)*, 318(5856): 1618–22.

Tyagi, P., Kumar, A. & Lahiri;, S.S. (2011). Synthesis and Characterization of Poly(HEMA-MAA) Hydrogel Carrier for Oral Delivery of Insulin. *Journal of Applied Polymer Science*, 122: 2004–2012.

Ulbricht, M. (2006). Advanced Functional Polymer Membranes. *Polymer*, 47(7): 2217–2262.

Valipour M., N., Birjandi, F.C. & Sargolzaei, J. (2014). Super-non-wettable Surfaces: A Review. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, 448(1): 93–106.

Vesel, a & Mozetic, M. (2008). Modification of PET Surface by Nitrogen Plasma Treatment. *Journal of Physics: Conference Series*, 100(1): 12-27.

Vrlinic, T., Vesel, A., Cvelbar, U., Kranjnc, M. and Mozetic, M. (2007). Rapid Surface Functionalization of Poly(ethersulphone) Foils using A Highly Reactive Oxygen-Plasma Treatment. *Surface and Interface Analysis*, 39: 476–481.

Wandera, D., Wickramasinghe, S.R. & Husson, S.M. (2010). Stimuli-Responsive Membranes. *Journal of Membrane Science*, 357(1-2): 6–35.

Wang, W., Gu, Y. & Liu, Y. (2003). Applications of Weak Gel for In-depth Profile Modification and Oil Displacement. *Journal of Canadian Petroleum Technology*, 42(6): 54–61.

Wichterle, O. & Lim, D. (1960). Hydrophilic Gels for Biological Use. *Nature*, 185(4706): 117–118.

Xing, C.-M., Deng, J.-P. & Yang, W.-T. (2002). Surface Photografting Polymerization of Binary Monomers Maleic Anhydride and n-Butyl Vinyl Ether on Polypropylene Film II. Some Mechanistical Aspects. *Polymer Journal*, 34(11): 809–816.

Xue, C.-H., Ji, P-T., Zhang, P., Li, Y-R. and Jia, S-T. (2013). Fabrication of Superhydrophobic and Superoleophilic Textiles for Oil–Water Separation. *Applied Surface Science*, 284: 464–471.

Xue, Z., Wang, S., Lin, L., Chen, L., Liu, M., Feng, L. and Jiang, L. (2011). A Novel Superhydrophilic and Underwater Superoleophobic Hydrogel-Coated Mesh for Oil/Water Separation. *Advanced Materials*, 23(37): 4270–4273.

Xue, Z., Cao, Y., Liu, N., Feng, L. and Jiang, L. (2014). Special Wettable Materials for Oil/Water Separation. *Journal of Materials Chemistry A*, 2: 2445–2460.

Yang, J., Zhu, L., Yan, X., Wei, D., Qin, G., Liu, B., Liu, S. and Chen, Q. (2016). Hybrid Nanocomposite Hydrogels with High Strength and Excellent Self-Recovery Performance. *RSC Adv.*, 6(64): 59131–59140.

Yang, J., Zhang, Z., Xu, X., Zhu, X., Men, X. and Zhou, X. (2012). Superhydrophilic–Superoleophobic Coatings. *Journal of Materials Chemistry*, 22(7): 2834.

Yang, Q., Adrus, N., Tomicki, F. and Ulbricht, M. (2011). Composites of Functional Polymeric Hydrogels and Porous Membranes. *Journal of Materials Chemistry*, 21(9): 2783–2811.

Yang, W.J., Pranantyo, D., Neoh, K.G., Kang, E.T., Toe, S.L.M. and Rittschof, D. (2012). Layer-by-Layer Click Deposition of Functional Polymer Coatings for Combating Marine Biofouling. *Biomacromolecules*, 13(9); 2769–2780.

Yoshida R. and Okano T. (2010). Stimuli-Responsive Hydrogels and Their Application to Functional Material, in R.M. Ottenbrite, K. Park, T. Okano (Eds.) Biomedical Applications of Hydrogel Handbook. *Springer New York:*19–43.

Yuan, T., Meng, J., Hao, T., Wang, Z. and Zhang, Y. (2015). A Scalable Method toward Superhydrophilic and Underwater Superoleophobic PVDF Membranes for Effective Oil/Water Emulsion Separation. *ACS Applied Materials and Interfaces*, 7(27): 14896–14904.

Yuan, T., Meng, J., Hao, T., Zhang, Y. and Xu, M. (2014). Polysulfone Membranes Clicked with Poly (ethylene glycol) of High Density and Uniformity for Oil/Water Emulsion Purification: Effects of Tethered Hydrogel microstructure. *Journal of Membrane Science*, 470: 112–124.

Yun, J., Jin, D., Lee, Y-S. and Kim, H-I. (2010.) Photocatalytic Treatment of Acidic Waste Water by Electrospun Composite Nanofibers of pH-Sensitive Hydrogel and TiO2. *Materials Letters*, 64(22): 2431–2434.

Zhang, X.F., Zhou, K.S., Deng, C.M., Liu, M., Deng, Z.Q., Deng, C.G. and Song, J.B. (2016). Gas-Deposition Mechanisms of 7YSZ Coating based on Plasma Spray-Physical Vapor Deposition. *Journal of the European Ceramic Society*, 36(3): 697–703.

Zhao, J., Ren, W. & Cheng, H.-M. (2012). Graphene sponge for efficient and repeatable adsorption and desorption of water contaminations. *Journal of Materials Chemistry*, 22: 20197.

Zhou, X., Xu, X., Guo, F., Zhu, X., Men, X. and Ge, B. (2013). Robust and Durable Superhydrophobic Cotton Fabrics for Oil/Water Separation. *ACS Applied Materials & Interfaces*, 5(15): 7208–7214.

Zhu, Y., Zhang, F., Wang, D., Pei, X.F., Zhang, W. and Jin, J. (2013). A Novel Zwitterionic Polyelectrolyte Grafted PVDF Membrane for Thoroughly Separating Oil from Water with Ultrahigh Efficiency. *Journal of Materials Chemistry A*, 1: 5758–5765.

Zuwei Ma, Zhengwei Mao & Gao, C. (2007). Review-Surface Modification and Property Analysis of Biomedical Polymers Used for Tissue Engineering. *Colloids and Surfaces B: Biointerfaces*, 60: 137–157.