GRAFTED HYDROGEL WITH SWITCHABLE SURFACE WETTABILITY BASED ON TEMPERATURE RESPONSIVE POLY(*N*-ISOPROPYLACRYLAMIDE) FOR OIL/WATER SEPARATION

SITI SAMAHANI BINTI HAJI SURADI

A thesis is submitted in fulfilment of the
requirements for the award of the degree of
Doctor of Philosophy (*Polymer Engineering*)

School of Chemical and Energy Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

JULY 2019

DEDICATION

THANK YOU ALLAH

The Almighty, The Guidance, The Most Gracious and The Most Merciful

Love special dedicate to…
Special inspiring of my late father: Tn. Hj. Suradi B. Hj Sarimon
Most encouraging of my lovely mother: Pn. Hjh. Khasah Bt. Hj Amin;
my remarkable family members
All my fellow friends,
Those who has always support me endlessly
Million Thanks to all of you….

ACKNOWLEDGEMENT

Alhamdulillah, all praise belongs to Allah, the most gracious, the merciful and beneficent. With His power, guidance and only by this assistance, this study has reached its end. My gratitude specially dedicated to my supervisors, Dr Nadia Adrus and Associate Professor Dr Shahrir Hashim upon their sincere, consistent encouragement, advices and supervision throughout ensuring the success of this study. I'm also would like to thank the Malaysian Ministry of Education for providing financial support during my doctorate study.

I'm also would like to take this opportunity to thank all technical staff of School of Chemical and Energy Engineering, School of Science and School of Biosciences and Medical Engineering especially Pn Zainab, En Zainorabidin, En Izad Amir, Pn Juhana, Pn Zahida upon your kindly helping hand and technical assistances since starting this project, your effort is greatly appreciated in completion of research.

A heartfelt thanks to my supportive family; my utmost thought for my beloved mother, Hjh Khasah Hj Amin, and also my family members who have been firing up my spirit and always support in many ways, thank you brothers and sisters; Azmi, Hamsiah, Salwana, Zainal, Huda, Zariza, Izirwan Suhaila, Syahridha, Nurfauzan, Najah and Supri for continuous support and encouragement during my study. All of you are always there at the time of my needs either physically, mentally or financially supports. Never to be left my faith pray for my late father, Allahyarham Hj Suradi Hj Hussein, may peace upon His blessing. Everything memories together and advices during his life will be always kept tightly in my heart.

Last but not least, my great appreciation to all my friends whom are involved directly or indirectly in ensuring the smoothness of this research either through your ideas, advices, support, energy or time consuming. Nice to have co-operation and working with all of you. May all of you always under Allah protection. I'm still alive because of Allah, the protector and the guardian of faith. Syukran, for everything even the trials make me closer to You Allah, with so much loves and affections from peoples at surrounding. *The Author- Siti Samahani Suradi*

ABSTRACT

The ever-increasing oily wastewater from industry and frequently oil spill accidents have fueled the demands for special wettable materials that can effectively separate oil-water mixtures. Therefore, this study emphasized on the development of temperature responsive poly(*N*-isopropylacrylamide) (PNIPAAm) hydrogel grafted onto the polyethylene terephthalate (PET) nonwoven textile (PNIPAAm-*g*-PET) via ultraviolet light emitting diodes (UV LED) photopolymerization system. In the first part, the effect of surface functionalizations and grafting onto unmodified PET (UPET) and functionalized PET textiles via carboxylation (CPET) or hydrolysis (HPET) were explored. The investigations were conducted by using Fourier transform infrared spectroscopy, field emission scanning electron microscopy, atomic force microscopy and surface wettability. These analyses have shown that the HPET surface exhibited high accessibility of the –OH groups, more porous and rougher compared to the CPET and UPET surfaces, which yielded to be more efficient for grafting. Due to these reasons, PNIPAAm-*g*-HPET textile possesses better wettability, anti-oil staining property and reversible switchability functions from hydrophilic/oleophobic to hydrophobic/oleophilic. In addition, the functionalized PNIPAAm-*g*-HPET textile exhibited considerable permeability (1600 L/m^2.hr.bar) and good selectivity (~95%), and therefore, was selected for the next study. In the second part of this study, the PNIPAAm-*g*-HPET textiles were optimally synthesized via response surface method (RSM) approach. Good models with R-squared values between 0.94 to 0.99 in the RSM analysis revealed that the optimal conditions were achieved as follows: the immersion of activated HPET textiles for 7 minutes in the pre-gel solution containing 20 wt% *N*-isopropylacrylamide monomer and 5.53 wt% *N,N'*-methylenebisacrylamide crosslinker (PN20C5.53.E7) and 20 minutes exposure to UV light irradiation. The responses obtained from this study for the degree of grafting, oil/water permeability and oil rejection were best predicted at 31.3%, 1559 L/m^2.hr.bar and 96.23%, respectively. With respect to the actual oil/water separation performances, the permeation of the PNIPAAm-*g*-HPET-PN20C5.53E7 textile was reduced by 8-folds but remarkably improved the oil rejection (~97%). In addition, the PNIPAAm-*g*-HPET consistently maintained satisfactory results by achieving considerable flux recovery ratio values, ~80% by solely gravity-driven even after 7 cycles of measurements. Besides, this grafted PET textiles also exhibited unique self-cleaning property as oil can be repelled instantaneously (~30 seconds) from the textile surface. Lastly, the synthesized PN20C5.53E7 textile was further subjected to separation experiments by using cooking oil, crude oil and oily machinery waste. The overall oil rejection results of the PN20C5.53E7 textiles were >90% when temperature at below LCST and rapidly decreases to <60% when temperature rises above the LCST. Importantly, the PNIPAAm-*g*-HPET textile has possessed higher surface hydrophilicity, stability and recyclability. As a conclusion, the innovation of PNIPAAm-*g*-HPET nonwoven textile has a bright prospect for oil and water separation, owing to its switchability mechanism triggered by temperature change.

ABSTRAK

Peningkatan sisa buangan air berminyak dari industri dan kekerapan kemalangan tumpahan minyak mendorong permintaan yang tinggi dalam penghasilan bahan bersifat kebolehbasahan yang dapat memisahkan campuran air dan minyak dengan berkesan. Oleh itu, kajian ini telah memberi penekanan kepada pembangunan hidrogel poli(*N*-isopropilakrilamida) (PNIPAAm) responsif suhu yang dicangkukkan pada tekstil bukan tenunan polietilena tereptalat (PET) (PNIPAAm-*g*-PET) melalui sistem fotopempolimeran cahaya ultraviolet pancaran diod (UV LED). Pada peringkat pertama, kesan pengubahsuaian permukaan dan cangkukkan pada tekstil PET yang tidak diubahsuai dan yang telah difungsikan melalui karboksilasi (CPET) atau hidrolisis (HPET) telah diterokai. Pencirian telah dijalankan dengan menggunakan spektroskopi transformasi inframerah Fourier, mikroskop elektron imbasan pancaran medan, mikroskopi daya atom dan kebolehbasahan permukaan. Hasil kajian menunjukkan bahawa permukaan HPET mempamerkan lebih banyak kumpulan –OH, permukaan yang lebih berliang dan kasar berbanding dengan permukaan CPET dan UPET, yang mana ianya dapat menghasilkan cangkukan yang lebih berkesan. Oleh itu, tekstil PNIPAAm-*g*-HPET memiliki kebolehbasahan yang baik, sifat anti-lekatan minyak dan fungsi kebolehtukaran berbalik dari hidrofilik/oleofilik kepada hidrofobik/oleofobik. Selain itu, tekstil PNIPAAm-*g*-HPET yang difungsikan mempamerkan kebolehtelapan berpatutan (1600 L/m^2.hr.bar) dan pemilihan yang baik (~95%), oleh itu, dipilih untuk kajian seterusnya. Dalam peringkat kedua kajian ini, tekstil PNIPAAm-*g*-HPET telah disintesis secara optimum melalui pendekatan kaedah sambutan permukaan (RSM). Model-model yang baik dengan nilai R-kuadrat antara 0.94 hingga 0.99 dalam analisis RSM menunjukkan keadaan optimum dicapai seperti berikut: rendaman tekstil HPET yang diaktifkan selama 7 minit di dalam larutan pra-gel yang mengandungi monomer *N*-isopropilakrilamida, 20 wt% dan *N,N'*-metilenabisakrilamida pemaut-silang, 5.53 wt% (PN20C5.53.E7) dan pendedahan selama 20 minit pada sinaran UV. Keputusan dari kajian ini dalam darjah cangkukan, kebolehtelapan minyak/air dan penolakan minyak dapat dijangkakan baik masing-masing pada 31.32%, 1559 L/m^2.hr.bar dan 96.23%. Berdasarkan tahap pisahan minyak/air yang sebenar, kebolehtelapan tekstil PNIPAAm-*g*-HPET-PN20C5.53E7 berkurangan sebanyak 8 kali ganda, namun menunjukkan kecekapan pemisahan minyak yang sangat baik (~97%). Di samping itu, tekstil PNIPAAm-*g*-HPET mengekalkan hasil yang memuaskan dengan mencapai nilai perolehan fluks yang tinggi, >80% walaupun selepas 7 kitaran ujikaji pada tekanan graviti. Selain itu, tekstil PET yang dicangkukkan ini juga mempamerkan sifat pembersihan diri yang unik kerana minyak boleh disingkirkan dengan mudah (~30 saat) dari permukaan tekstil. Akhir sekali, tekstil PN20C5.53E7 yang disintesis telah melalui eksperimen pemisahan menggunakan minyak masak, minyak mentah dan sisa minyak jentera yang dikumpul. Hasil penolakan minyak keseluruhan tekstil PN20C5.53E7 adalah >90% apabila suhu dibawah tahap LCST dan nilai merosot menjadi <60% apabila suhu meningkat di atas LCST. Yang penting, tekstil PNIPAAm-*g*-HPET mempunyai sifat permukaan hidrofilik yang lebih tinggi, stabil dan boleh dikitar semula. Sebagai kesimpulan, inovasi teksil bukan tenunan PNIPAAm-*g*-HPET mempunyai prospek yang cerah untuk digunakan dalam pemisahan minyak dan air disebabkan oleh mekanisma kebolehtukaran yang tercetus akibat perubahan suhu.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AA	-	Acrylic Acid
AAm	-	Acrylamide
CH_3COOH	-	Acetic Acid
AFM	-	Atomic Force Microscopy
ANOVA	-	Analysis of Variance
ATRP	-	Atom Transfer Radical Polymerization
APTES	-	3-Aminopropyltriethoxysilane
BP	-	Benzophenone
CA	-	Contact Angle
CB	-	Carbon Black
CCD	-	Central Composite Design
CCRD	-	Central Composite Rotatable Design
CI	-	Confident Limit
CNF	-	Carbon Nanofiber
CRP	-	Carbon Nanotube
CPET	-	Carboxylated Polyethylene Terephthalate
DG	-	Degree of Grafting
$C_2H_4CO_2$	-	Ethanol
Fe_3O_4	-	Ferum (III) Oxide
FESEM	-	Field Emission Scanning Electron Microscope
FRP	-	Free Radical Polymerization
FRR	-	Degree of Flux Recovery
FTIR	-	Fourier Tranform Infrared Spectroscopy
GNPs	-	Graphene Nanoplatelets

HGMNC	-	Hydrogel Magnetic Nanocomposite
HPET	-	Hydrolyzed Polyethylene Terephthalate
HR	-	Relative Humidity
HCl	-	Hydrochloric Acid
KPS	-	Potassium Peroxodisulfate
$KMnO_4$	-	Potassium Permanganate
LCST	-	Lower Critical Solution Temperature
LED	-	Light Emitting Diodes
LPSA	-	Laser Particle Size Analyzer
MBAA	-	*N*,*N*-methylenebisacrylamide
MLS	-	Method of The Least Square
OCA	-	Oil Contact Angle
NaOH	-	Natrium Hydroxide
NaN_3	-	Natrium Azide
NHMAA	-	*N*-Hydroxymethyl Acrylamide
NIPAAm	-	*N*-Isopropylacrylamide
PAAm	-	Polyacrylamide
PNIPAAm	-	Poly(*N*-Isopropylacrylamide)
PHFBMA	-	Poly(hexafluorobutyl methacrylate)
PDMS	-	Polydimethysiloxane
PVDF	-	Polyvinylidene Diflouride
PEG	-	Polyethylene Glycol
PEGD	-	Polyethylene Glycol Diacrylate
PEGM	-	Polyethylene Glycol Methacrylate
PEO	-	Polyethylene Oxide
PES	-	Polyethersulfone
PET	-	Polyethylene Terephthalate

PHEMA	-	Polyhydroxyethyl Methacrylate
PLA	-	Polylactic Acid
PMMA	-	Polymethylmethacrylate
PDMAEMA	-	Poly(dimethylamino) Ethyl Methacrylate
PP	-	Polypropylene
PS	-	Polystyrene
PSF	-	Polysulfone
PVPy	-	Poly(*N*-vinylpyrrlidone)
RAFT	-	Reversible Addition Fragmentation Chain Tranfer Polymerization
RSM	-	Response Surface Methodology
SAA	-	Surface Active Agent
SAMs	-	Self-Assembled Monolayers
SE	-	Standard Error of the Fit
SFE	-	Surface Free Energy
SIP	-	Surface Initiated Polymerization
TEMED	-	*N*,*N*'- Tetramethylethylenediamine
TRH	-	Temperature Responsive Hydrogel
UCST	-	Upper Critical Solution Temperature
UF	-	Ultrafiltration
UV	-	Ultraviolet
WCA	-	Water Contact Angle
ZnO	-	Zinc Oxide

LIST OF SYMBOLS

A	-	Effective Surface Area
$\boldsymbol{\gamma_s}$	-	Surface Free Energy
γ_s^p	-	Polar Component of Surface Tension
γ_s^d	-	Dispersion Component of Surface Tension
θ	-	Degree
λ	-	Wavelength
μm	-	Micrometer
mW/cm^2	-	Intensity of UV Irradiation
C_f	-	Feed Concentration
C_p	-	Permeate Concentration
d	-	Diameter
J_W	-	Water Permeability
kW	-	Kilowatt
kPa	-	Kilopascal
mL	-	Milliliter
mM	-	miliMolar
MPa	-	Megapascal
nm	-	Nanometer
N	-	Normality
N	-	Switching Coefficient
R^2	-	Regression Coefficient
R(%)	-	Rejection Coefficient
R_{ms}	-	Root Mean Square Average Roughness
W_f	-	Weight of PET sample After Modification

W_i	-	Initial Weight of PET sample
L/m^2.hr.bar	-	Permeability

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

Hydrogels are constructed of three dimensional hydrophilic polymeric networks which exhibit excellent water absorbing and retaining capacity. Hydrogels can maintain the dimensional stability in aqueous media due to their crosslinking structure which can be considered as soft and rubbery materials. Predominantly, hydrogels are classified into two categories; conventional and stimuli responsive for which polyacrylamide (PAAm) and poly(*N*-isopropylacrylamide) (PNIPAAm) hydrogels, respectively are the typical examples (Ayub et al, 2017; Samchenko et al, 2011).

Conventional hydrogels exhibit swelling behavior due to their hydrophilic nature. Furthermore, conventional hydrogels also possess antifouling properties towards oil, protein, cell/bacteria or microorganisms (Chen et al, 2015a; Chen et al, 2016; Zhao et al, 2013a) as they can build compact hydration layer on the surface through hydrogen bonding or ionic bonding. Smart or stimuli responsive hydrogels exhibit similarities with conventional hydrogels except that they exhibit sudden volume change in response to the external stimuli of the environment. Hydrogels containing such 'sensor' properties can undergo reversible volume phase transition upon changes in the environmental condition. There are many physical and chemical stimuli which has been applied to induce various responses of the smart hydrogels such as temperature (Sun et al, 2018b; Zhang et al, 2018), pH (Wei et al, 2018), ionic strength of medium (Zhao et al, 2014b), lights (ter Schiphorst et al, 2016), magnetic or electric field (Reddy et al, 2011) and many more. This unique feature of hydrogels has been frequently applied in many fields that involving environmental engineering (Ou et al, 2016; Wei et al, 2018), biomedical technologies (Liu et al, 2018a), tissue

engineering (Wu et al, 2018) and others (Liu et al, 2016b; Xue et al, 2013b; Xue et al, 2014).

The demand for the innovation of smart hydrogels is particularly devoted to the temperature responsive hydrogels (TRH) such as PNIPAAm hydrogel. This is owing to its unique temperature responsive swelling, antifouling and wettability (Adrus and Ulbricht, 2013; Büning et al, 2018; Klouda et al, 2011; Wang et al, 2015b). The PNIPAAm hydrogel exhibits a sharp phase transition at 32ºC which is termed as the lower critical solution temperature (LCST). Below the LCST, PNIPAAm hydrogel is extremely water swollen and highly hydrated. But above its LCST, PNIPAAm hydrogel undergoes a reversible phase transition from swollen to shrunken dehydrated state (Adrus and Ulbricht, 2012a; Samchenko et al, 2011). Other researchers interpreted PNIPAAm as a crosslinked thermo-responsive hydrogels which can be switched from the hydrophilic (swollen state) to hydrophobic (de-swollen state) when heated above the LCST (Ganesh et al, 2015; Li et al, 2016).

In the past decades, many researchers have dedicated their research towards the surface modification of hydrophobic substrates in order to control their properties such as hydrophobicity, adhesion or wettability (Shi et al, 2018; Zhao et al, 2014a). For instance, hydrogels grafting on the solid polymer substrate was proposed as one of the alternative methods to improve the antifouling properties of various substrates (Kato et al, 2003; Zhao et al, 2013b). The preparation hydrogels grafting via photografting technique on polymer substrate depends on decisive factors such as photoinitiator, crosslinker and conditions of photopolymerization. Photopolymerization process can be conducted by using several ultraviolet (UV) light sources: mercury (Sokker et al, 2011) or light emitting diodes (LED) (Ayub et al, 2017).

The surface modification of hydrophobic polyethylene terephthalate (PET) textile with hydrophilic substances such as hydrogels has improved properties such as wettability, softness, absorbency and antifouling resistance (Chenxi et al, 2014; Goddard and Hotchkiss, 2007; Guo et al, 2019). Chen et al (2002b) discovered that PNIPAAm hydrogel grafted with polypropylene (PP) nonwoven and PET films

exhibited better wettability. The PET textile is considered a good substrate for hydrogels grafting as it is low cost, flexible, thin and lightweight as well as having anti-wrinkle properties (Hadjizadeh et al, 2010; Makoto et al, 2013; Štular et al, 2018). The PET substrate is also widely used in many applications such as scaffolds in tissue engineering fields (Liang et al, 2018), filter materials (Makoto et al, 2013; Zhao et al, 2018) and drainage membrane (Nguyen-Tri et al, 2014).

The TRH grafting on a surface textile substrate has been developed as a tool in smart responsive material. This smart TRH grafting has the ability to tune wettability induced by temperature change (Ganesh et al, 2015; Tripathi et al, 2014; Zhang et al, 2018). Besides, TRH grafting on textile substrate enhanced hydrophilic surface that could lead to better antifouling properties. In addition, it has a switchable wettability function and great antifouling surface resistance towards oil (Chen et al, 2016; Deng et al, 2009; Xiang et al, 2018). Hence, this unique feature of TRH grafting has gained attention to be considered as a new alternative tool for oil/ water separation.

Currently, PNIPAAm hydrogel grafting for oil/water separation using photopolymerization is still limited. Plus, the studies on the interplay between the PNIPAAm hydrogels and the PET textile via chemical functionalization are need to be considered due to hydrophilic/hydrophobic incompatibility. Surface functionalization via carboxylation or hydrolysis have been proven to impart more hydrophilicity and specific functionalities on the PET surface (Geismann and Ulbricht, 2005; Ng et al, 2009). So far, most of the studies used the physical coating approach to attach hydrogel onto a substrate (Li et al, 2015; Wen et al, 2013). With respect to the stability of the hydrogel, the chemical grafting method was more suitable for modifying the surface chemistry of textile and the surface functionalization of textile has effectively enhanced the grafting with this smart PNIPAAm hydrogel.

Subsequently, the selected PNIPAAm-*g*-PET textile was further investigated at decisive parameters in order to obtain the optimal conditions in synthesis of the modified PNIPAAm-g-PET with significant performances in oil/water separation. The surface wettability of the PNIPAAm-*g*-PET can be switchable from hydrophilic/oleophobic to hydrophobic/oleophilic induced by temperature change.

Moreover, the synthesis of modified PNIPAAm-*g*-PET textile has provided the PET textile to be more hydrophilic and anti-oil fouling resistant, which making it easily recyclable and recoverable. Apparently, the study on the modification of PNIPAAm hydrogel onto PET textile for oil/water separation has not been reported yet. Therefore, the outcome of this study could be brought benefit and novelty to the society. This smart PNIPAAm grafted PET textile would have a vivid potential in the future as a novel separation material.

1.2 Problem Statement

An increase of oily wastewater from industrial activities and frequent oil spilled have brought extensive damage to the environment and energy wastage. In order to comply with the environmental regulations, many approaches have been introduced to develop new separation materials that could enhance the oil/water separation performances.

Existing hydrophobic/oleophilic materials for oil/water separation such as carbon absorber and aerogels still inherent some drawbacks such as deficient sorption capacity, low stability and flexibility as well as poor separation efficiency (Baig et al, 2018; Du et al, 2019; Wang and Wang, 2019). These *'oil-removing'* type of materials are easily fouled by oil or grease which lead to pore clogging due to their intrinsic oleophilicity. Hence, these problems have caused serious flux reduction and poor selectivity. These materials also show deficient recoverability which ultimately caused the secondary pollution.

Most recently, the research of hydrogels has gained attention as the *'water-removing'* type of materials which exhibit opposite wettability to oil. The hydrophilicity of hydrogels induced the formation of the hydration layer on the surface that can repel oils. Hydrogels also possess antifouling surface resistance towards protein, cell/bacteria or microorganism. However, bulk hydrogels have limitations in term of slow response in swelling rate and damage after exposure to frequent loading-unloading cycle as there are mechanically unstable. Hence, hydrogels coated onto the

substrate either films, membranes or textiles can be a solution to overcome these problems (Cao et al, 2014; Ou et al, 2016; Zhang et al, 2018).

Nevertheless, the physical coating of hydrogel has a limitation for practical applications due to its poor interfacial surface properties. For instance, the modification of stainless steel meshes via physical coating resulted in coating delamination from the substrate surface (Weifeng et al, 2014). Additionally, stainless steel meshes are difficult to be chemically modified due to the lack of reactive functional groups on their surface. In this regard, the grafting method is more suitable for modifying the surface chemistry of polymer substrates such as textile in order to improve the compatibility with hydrogel. Polyethylene terephthalate (PET) textile is one of the most commonly used substrates (Chen et al, 2002b). Yet, it has a limitation with regards to its surface properties. This is due to the intrinsically hydrophobic surface of PET textile nonwoven. Hence, several techniques have been applied, including surface functionalization via carboxylation and hydrolysis which can improve the hydrophilicity of PET and then, impart the effectiveness in grafting with hydrogel (Ng et al, 2009).

The PNIPAAm grafting onto the PET nonwoven textile has not been reported yet. In addition, the TRH PNIPAAm has an ability to tune the surface from hydrophilic-oleophobic to hydrophobic-oleophilic (Cao et al, 2014; Jindan et al, 2016). Thus, the aims of this research are to synthesize the smart TRH-PNIPAAm grafting with PET nonwoven textile substrate via UV LED photografting approach. Moreover, this research has attempted the optimization procedure in synthesizing PNIPAAm grafted PET that could achieved the optimal performances in the oil/water separation. Hence, this smart PNIPAAm hydrogel grafted PET textile can be used as a water-removing tool for oil/ water separation with more economic and environmentally friendly as well as possessing longer lifespan.

1.3 Objectives

Based on the aforementioned problem statements, this research is focused on the TRH PNIPAAm grafted onto PET nonwoven (PNIPAAm-*g*-PET) textile. The PNIPAAm-*g*-UPET textile is a benchmark for preparation and characterization. The objectives of this research are:

1. To evaluate the effect of surface modification on the PET textile via carboxylation and hydrolysis functionalizations in term of chemical structure, morphology, topography, surface wettability and permeability.

2. To prepare and characterize the unmodified and modified PNIPAAm-*g*-PET textiles in terms of degree of grafting (DG), surface functional groups, morphology, topography, surface wettability, permeability and oil-staining property.

3. To determine the optimum parameters for the preparation of the modified PNIPAAm-*g*-PET textiles that resulting in the highest of DG, oil/water permeability and oil rejection by using response surface methodology (RSM).

4. To evaluate the performances of modified PNIPAAm-*g*-PET in terms of permeability, selectivity, switchability and recyclability towards various oils sources (cooking oil, crude oil and machinery waste oil) at different temperatures.

1.4 Scope of the Research

The scopes of this research study are divided into three stages in order to meet the objectives. The first part consists of the preparation of the functionalized PET nonwoven textiles via carboxylation and hydrolysis functionalizations. After that, the PNIPAAm hydrogel were grafted onto the unmodified and functionalized PET

nonwoven textiles under UV LED irradiation for 20 minutes. The effect of the photografting of PNIPAAm hydrogel onto the PET was further analyzed based on the DG.

The evaluations of the ungrafted and grafted textiles samples in term of basic characterizations were carried out with respect to the Fourier transform infrared spectroscopy (FTIR), field emission scanning microscopic (FESEM), atomic force microscopy (AFM) and contact angle measurements (CA). Besides that, the functional characterizations of the PET textiles including permeabilities and anti-oil staining property have also been tested. Later, the selected functionalized PNIPAAm-*g*-PET was determined based on the basic and functional characterizations

By selecting the suitable functionalization conditions of PET textile, the optimization procedure in synthesizing the grafted PNIPAAm-*g*-PET was determined. Three independent variables were selected for the optimization study; concentration of monomer (10–20 wt%), concentration of crosslinker (2-8 wt%) and equilibration time of PET textiles in pre-gel NIPAAm solution (5–25 minutes) using the designated of experimental (DoE) of response surface methodology (RSM). An appropriate tuning on the synthesis parameters of PNIPAAm-*g*-PET has to be realized in order to achieve significant performances for oil/water separations include the DG, permeability and total oil rejection. Each individual and interactive relationships amongst variables and responses that give the optimal results in the oil/water separation were evaluated in details

The scope of study also verifies the feasibility of the modified PNIPAAm-*g*-PET textile for oil/water separation through different tests; permeability, selectivity and recyclability. The switchability of the modified PNIPAAm-*g*-PET textile was studied by evaluating the permeability, oil rejection, optical images of oils particles and oils particles distribution for various of oils resources: cooking oil, crude oil and waste machinery oil at different temperatures.

1.5 Significant of the study

1. The initial part of this study was an attempt to make the PET surface more hydrophilic and compatible with hydrogel for further grafting. This enhancement of hydrophilic/oleophobic surfaces of PET textiles can be achieved by using functionalizations via carboxylation and hydrolysis.

2. Next, the development of the quadratic regression model was used to determine the suitable formulation for the preparation of TRH PNIPAAm-*g*-PET textiles that give optimal performance for oil/water separation. Up to now, there is no relevant study reported on the correlation between the oil/water separation and preparation parameters of PNIPAAm-*g*-PET textiles.

3. Efforts were made to investigate switchability function of the grafted PET textiles triggered by temperatures. It could be expected that outcomes from this study would be beneficial for the development of adjustable PNIPAAm-*g*-PET textile with an improvement towards oil-fouling resistance. The materials produced from this study are easily recyclable with excellent switchable from wetting to anti-wetting surfaces or vice versa.

REFERENCES

Abdurrahmanoglu, S., Can, V., and Okay, O. (2009) 'Design of High-Toughness Polyacrylamide Hydrogels by Hydrophobic Modification', *Polymer,* 50(23), 5449-5455. doi: http://dx.doi.org/10.1016/j.polymer.2009.09.042

Adrus, N. (2012) *Stimuli-Responsive Hydrogels and Hydrogel Pore-Filled Composite Membranes.* PhD thesis, Universität Duisburg-Essen. Germany.

Adrus, N., and Ulbricht, M. (2012a) 'Molecularly Imprinted Stimuli-Responsive Hydrogels for Protein Recognition', *Polymer,* 53(20), 4359-4366. doi: 10.1016/j.polymer.2012.07.062

Adrus, N., and Ulbricht, M. (2012b) 'Novel hydrogel pore-filled composite membranes with tunable and temperature-responsive size-selectivity', *Journal of Materials Chemistry,* 22(7), 3088-3098. doi: 10.1039/C2JM15022K

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. doi: 10.1016/j.reactfunctpolym.2012.08.015

Ahmed, F. E., Lalia, B. S., Hilal, N., and Hashaikeh, R. (2014) 'Underwater Superoleophobic Cellulose/Electrospun PVDF–HFP Membranes for Efficient Oil/Water Separation', *Desalination,* 344, 48-54. doi: 10.1016/j.desal.2014.03.010

Al Meslmani, B., Mahmoud, G., Strehlow, B., Mohr, E., Leichtweiß, T., and Bakowsky, U. (2014) 'Development of thrombus-resistant and cell compatible crimped polyethylene terephthalate cardiovascular grafts using surface co-immobilized heparin and collagen', *Materials Science and Engineering: C,* 43, 538-546. doi: http://dx.doi.org/10.1016/j.msec.2014.07.059

Alexander, A., Ajazuddin, Khan, J., Saraf, S., and Saraf, S. (2014) 'Polyethylene Glycol (PEG)–Poly(*N*-isopropylacrylamide) (PNIPAAm) based Thermosensitive Injectable Hydrogels for Biomedical Applications', *European Journal of Pharmaceutics and Biopharmaceutics,* (0), In Press. doi: http://dx.doi.org/10.1016/j.ejpb.2014.07.005

Aliff Radzuan, M. R., Abia-Biteo Belope, M. A., and Thorpe, R. B. (2016) 'Removal of fine oil droplets from oil-in-water mixtures by dissolved air flotation', *Chemical Engineering Research and Design,* 115, 19-33. doi: https://doi.org/10.1016/j.cherd.2016.09.013

Almeida, J. F., Ferreira, P., Lopes, A., and Gil, M. H. (2011) 'Photocrosslinkable Biodegradable Responsive Hydrogels as Drug Delivery Systems', *International Journal of Biological Macromolecules,* 49(5), 948-954. doi: 10.1016/j.ijbiomac.2011.08.010

Arzani, M., Mahdavi, H. R., Bakhtiari, O., and Mohammadi, T. (2016) 'Preparation of mullite ceramic microfilter membranes using Response surface methodology based on central composite design', *Ceramics International,* 42(7), 8155-8164. doi: https://doi.org/10.1016/j.ceramint.2016.02.022

Asthana, A., Maitra, T., Büchel, R., Tiwari, M. K., and Poulikakos, D. (2015) 'Multifunctional Superhydrophobic Polymer/Carbon Nanocomposites: Graphene, Carbon Nanotubes, or Carbon Black?', *ACS Applied Materials & Interfaces*, In Press. doi: 10.1021/am501649w

Aurand, E. R., Lampe, K. J., and Bjugstad, K. B. (2012) 'Defining and Designing Polymers and Hydrogels for Neural Tissue Engineering', *Neuroscience Research* 72(3), 199-213. doi: 10.1016/j.neures.2011.12.005

Awang, N., Jaafar, J., Ismail, A. F., Othman, M. H. D., Rahman, M. A., Yusof, N., Aziz, F., Salleh, W. N. W., Suradi, S. S., Ilbeygi, H., Wan Mohd Noral Azman, W. N. E., and Arthanareeswaran, G. (2017) 'Development of dense void-free electrospun SPEEK-Cloisite15A membrane for direct methanol fuel cell application: Optimization using response surface methodology', *International Journal of Hydrogen Energy,* 42(42), 26496-26510. doi: 10.1016/j.ijhydene.2017.07.077

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,* 41(13), 5613-5619. doi: 10.1039/C7NJ00176B

Babaki, M., Yousefi, M., Habibi, Z., and Mohammadi, M. (2017) 'Process optimization for biodiesel production from waste cooking oil using multi-enzyme systems through response surface methodology', *Renewable Energy,* 105, 465-472. doi: https://doi.org/10.1016/j.renene.2016.12.086

Baig, N., Alghunaimi, F. I., and Saleh, T. A. (2018) 'Hydrophobic and oleophilic carbon nanofiber impregnated styrofoam for oil and water separation: A green technology', *Chemical Engineering Journal*. doi: https://doi.org/10.1016/j.cej.2018.10.042

Bao, L., Fan, H., Chen, Y., Yan, J., Yang, T., and Guo, Y. (2016) 'Effect of surface free energy and wettability on the adhesion property of waterborne polyurethane adhesive', *RSC Advances,* 6(101), 99346-99352. doi: 10.1039/C6RA15899D

Bashar, M. M., Zhu, H., Yamamoto, S., and Mitsuishi, M. (2017) 'Superhydrophobic surfaces with fluorinated cellulose nanofiber assemblies for oil–water separation', *RSC Advances,* 7(59), 37168-37174. doi: 10.1039/c7ra06316d

Bernstein, R., Antón, E., and Ulbricht, M. (2013) 'Tuning the Nanofiltration Performance of Thin Film Strong Polyelectrolyte Hydrogel Composite Membranes by Photo-Grafting Conditions', *Journal of Membrane Science,* 427, 129-138. doi: 10.1016/j.memsci.2012.09.034

Bertrand, T., Peixinho, J., Mukhopadhyay, S., and MacMinn, C. (2016) *Dynamics of Swelling and Drying in a Spherical Gel* (Vol. 6).

Bezerra, M. A., Santelli, R. E., Oliveira, E. P., Villar, L. S., and Escaleira, L. A. (2008) 'Response surface methodology (RSM) as a tool for optimization in analytical chemistry', *Talanta,* 76(5), 965-977. doi: http://dx.doi.org/10.1016/j.talanta.2008.05.019

Büning, D., Ennen-Roth, F., Walter, S. V., Hennecke, T., and Ulbricht, M. (2018) 'Potassium-sensitive poly(N-isopropylacrylamide)-based hydrogels for sensor applications', *Polymer Chemistry,* 9(26), 3600-3614. doi: 10.1039/C8PY00490K

Burdzik, A., Stähler, M., Carmo, M., and Stolten, D. (2018) 'Impact of reference values used for surface free energy determination: An uncertainty analysis', *International Journal of Adhesion and Adhesives,* 82, 1-7. doi: https://doi.org/10.1016/j.ijadhadh.2017.12.002

Buwalda, S. J., Boere, K. W. M., Dijkstra, P. J., Feijen, J., Vermonden, T., and Hennink, W. E. (2014) 'Hydrogels in a Historical Perspective: from Simple Networks to Smart Materials', *Journal of Controlled Release,* 190(0), 254-273. doi: http://dx.doi.org/10.1016/j.jconrel.2014.03.052

Cai, J., Zhou, S., Zhao, Y., Xue, A., Zhang, Y., Li, M., and Xing, W. (2016) 'Enhanced hydrophilicity of a thermo-responsive PVDF/palygorskite-g-PNIPAAM hybrid ultrafiltration membrane via surface segregation induced by temperature', *RSC Advances,* 6(67), 62186-62192. doi: 10.1039/C6RA12807F

Cao, B., Tang, Q., Li, L., Humble, J., Wu, H., Liu, L., and Cheng, G. (2013) 'Switchable Antimicrobial and Antifouling Hydrogels with Enhanced Mechanical Properties', *Advanced Healthcare Materials,* 2(8), 1096-1102. doi: 10.1002/adhm.201200359

Cao, Y., Liu, N., Fu, C., Li, K., Tao, L., Feng, L., and Wei, Y. (2014) 'Thermo and pH Dual-Responsive Materials for Controllable Oil/Water Separation', *ACS Applied Materials & Interfaces,* 6(3), 2026-2030. doi: 10.1021/am405089m

Chen, D.-Q., Wang, Y.-Z., Hu, X.-P., Wang, D.-Y., Qu, M.-H., and Yang, B. (2005) 'Flame-retardant and anti-dripping effects of a novel char-forming flame retardant for the treatment of poly(ethylene terephthalate) fabrics', *Polymer Degradation and Stability,* 88(2), 349-356. doi: https://doi.org/10.1016/j.polymdegradstab.2004.11.010

Chen, H., Chen, Q., Hu, R., Wang, H., Newby, B.-m. Z., Chang, Y., and Zheng, J. (2015a) 'Mechanically strong hybrid double network hydrogels with antifouling properties', *Journal of Materials Chemistry B,* 3(27), 5426-5435. doi: 10.1039/c5tb00681c

Chen, H., Zhao, C., Zhang, M., Chen, Q., Ma, J., and Zheng, J. (2016) 'Molecular Understanding and Structural-Based Design of Polyacrylamides and Polyacrylates as Antifouling Materials', *Langmuir,* 32(14), 3315-3330. doi: 10.1021/acs.langmuir.6b00386

Chen, J.-P., Kuo, C.-Y., and Lee, W.-L. (2012) 'Thermo-Responsive Wound Dressings by Grafting Chitosan And Poly(N-Isopropylacrylamide) to Plasma-Induced Graft Polymerization Modified Non-Woven Fabrics', *Applied Surface Science,* 262, 95-101. doi: 10.1016/j.apsusc.2012.02.106

Chen, K.-S., Tsai, J.-C., Chou, C.-W., Yang, M.-R., and Yang, J.-M. (2002a) 'Effects of additives on the photo-induced grafting polymerization of N-isopropylacrylamide gel onto PET film and PP nonwoven fabric surface', *Materials Science and Engineering: C,* 20(1–2), 203-208. doi: http://dx.doi.org/10.1016/S0928-4931(02)00034-6

Chen, K. S., Tsai, J. C., Chou, C. W., Yang, M. R., and Yang, J. M. (2002b) 'Effects of Additives on the Photo-Induced Grafting Polymerization of *N*-isopropylacrylamide Gel onto PET Film and PP Nonwoven Fabric Surface', *Materials Science and Engineering C,* 20, 203-208.

Chen, P.-C., and Xu, Z.-K. (2013) 'Mineral-Coated Polymer Membranes with Superhydrophilicity and Underwater Superoleophobicity for Effective Oil/Water Separation', *Scientific Reports,* 3, 2776. doi: 10.1038/srep02776

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. doi: http://dx.doi.org/10.1016/j.polymer.2010.08.022

Chen, W., He, H., Zhu, H., Cheng, M., Li, Y., and Wang, S. (2018) 'Thermo-Responsive Cellulose-Based Material with Switchable Wettability for Controllable Oil/Water Separation', *Polymers,* 10(6), 592.

Chen, Y., Lin, X., Liu, N., Cao, Y., Lu, F., Xu, L., and Feng, L. (2015b) 'Magnetically Recoverable Efficient Demulsifier for Water-in-Oil Emulsions', *ChemPhysChem,* 16(3), 595-600. doi: 10.1002/cphc.201402761

Cheng, Y., Xu, P., Zeng, W., Ling, C., Zhao, S., Liao, K., Sun, Y., and Zhou, A. (2017) 'Highly hydrophobic and ultralight graphene aerogel as high efficiency oil absorbent material', *Journal of Environmental Chemical Engineering,* 5(2), 1957-1963. doi: 10.1016/j.jece.2017.04.005

Chenxi, N., Sarvesh, L., Shivkumar, G., and Song, L. (2014) 'Effect of Hydrogel Grafting, Water and Surfactant Wetting on the Adherence of PET Wound Dressings', *Burns,* 40(6), 1164-1171. doi: http://dx.doi.org/10.1016/j.burns.2013.12.024

Chetty, A. (2012) 'A Versatile Characterization of Poly(*N*-Isopropylacrylamide-co-*N,N'*-Methylene-Bis-Acrylamide) Hydrogels for Composition, Mechanical Strength, and Rheology', *Express Polymer Letters,* 7(1), 95-105. doi: 10.3144/expresspolymlett.2013.9

Chu, Z., Feng, Y., and Seeger, S. (2015) 'Oil/Water Separation with Selective Superantiwetting/Superwetting Surface Materials', *Angewandte Chemie International Edition,* 54(8), 2328-2338. doi: 10.1002/anie.201405785

Cong, H., Li, L., and Zheng, S. (2013) 'Poly(*N*-isopropylacrylamide)-block-poly(vinyl pyrrolidone) Block Copolymer Networks: Synthesis and Rapid

Thermoresponse of Hydrogels', *Polymer,* 54(4), 1370-1380. doi: http://dx.doi.org/10.1016/j.polymer.2012.12.069

Curti, P. S., Moura, M. R. d., Veiga, W., Radovanovic, E., Rubira, A. F., and Muniz, E. C. (2005) 'Characterization of PNIPAAm Photografted on PET and PS Surfaces', *Applied Surface Science,* 245(1–4), 223-233. doi: http://dx.doi.org/10.1016/j.apsusc.2004.10.019

Czajka, R. (2005) 'Development of Medical Textile Market', *FIBERS & TEXTILES in Eastern Europe,* 13(49), 13-15.

Dai, J., Tian, Q., Sun, Q., Wei, W., Zhuang, J., Liu, M., Cao, Z., Xie, W., and Fan, M. (2019) 'TiO2-alginate composite aerogels as novel oil/water separation and wastewater remediation filters', *Composites Part B: Engineering,* 160, 480-487. doi: 10.1016/j.compositesb.2018.12.097

Dai, J., Zhang, R., Ge, W., Xie, A., Chang, Z., Tian, S., Zhou, Z., and Yan, Y. (2018) '3D macroscopic superhydrophobic magnetic porous carbon aerogel converted from biorenewable popcorn for selective oil-water separation', *Materials & Design,* 139, 122-131. doi: https://doi.org/10.1016/j.matdes.2017.11.001

Dave, J., Kumar, R., and Srivastava, H. C. (1987) 'Studies on modification of polyester fabrics I: Alkaline hydrolysis', *Journal of Applied Polymer Science,* 33(2), 455-477. doi: 10.1002/app.1987.070330215

Deligkaris, K., Tadele, T. S., Olthuis, W., and van den Berg, A. (2010) 'Hydrogel-based Devices for Biomedical Applications', *Sensors and Actuators B: Chemical,* 147(2), 765-774. doi: http://dx.doi.org/10.1016/j.snb.2010.03.083

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. doi: http://dx.doi.org/10.1016/j.progpolymsci.2008.06.002

Dong, B., Jiang, H., Manolache, S., Wong, A. C. L., and Denes, F. S. (2007) 'Plasma-Mediated Grafting of Poly(ethylene glycol) on Polyamide and Polyester Surfaces and Evaluation of Antifouling Ability of Modified Substrates', *Langmuir,* 23(13), 7306-7313. doi: 10.1021/la0633280

Du, L., Quan, X., Fan, X., Chen, S., and Yu, H. (2019) 'Electro-responsive carbon membranes with reversible superhydrophobicity/superhydrophilicity switch for efficient oil/water separation', *Separation and Purification Technology,* 210, 891-899. doi: 10.1016/j.seppur.2018.05.032

Du, X., Huang, X., Li, X., Meng, X., Yao, L., He, J., Huang, H., and Zhang, X. (2015) 'Wettability behavior of special microscale ZnO nail-coated mesh films for oil–water separation', *Journal of Colloid and Interface Science,* 458, 79-86. doi: http://dx.doi.org/10.1016/j.jcis.2015.07.040

Dunstan, T. S., Fletcher, P. D. I., and Mashinchi, S. (2012) 'High Internal Phase Emulsions: Catastrophic Phase Inversion, Stability, and Triggered Destabilization', *Langmuir,* 28, 339-349. doi: 10.1021/la204104m

Ebara, M., kotsuhibashi, Y., Narain, R., Idota, N., Hoffman, J. M., Kim, Y.-J., Uto, K., and Aoyagi, T. (2014). Smart Hydrogels *Smart Biomaterials* (Vol. 373, pp. 9-65). Springer Japan: National Institute for Materials Science, Japan.

Fradet, A., and Tessier, M. (2003). Polyesters *Synthetic Methods in Step-Growth Polymers* (pp. 17-134). New Jersey, United State of America: John Wiley & Sons, Inc.

Frost, S., and Ulbricht, M. (2013) 'Thermoresponsive ultrafiltration membranes for the switchable permeation and fractionation of nanoparticles', *Journal of Membrane Science,* 448(0), 1-11. doi: http://dx.doi.org/10.1016/j.memsci.2013.07.036

Ganesh, V. A., Ranganath, A. S., Sridhar, R., Raut, H. K., Jayaraman, S., Sahay, R., Ramakrishna, S., and Baji, A. (2015) 'Cellulose Acetate–Poly(N-isopropylacrylamide)-Based Functional Surfaces with Temperature-Triggered Switchable Wettability', *Macromolecular Rapid Communications,* 36(14), 1368-1373. doi: 10.1002/marc.201500037

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. doi: 10.1002/macp.200400374

Geismann, C., Yaroshchuk, A., and Ulbricht, M. (2007) 'Permeability and Electrokinetic Characterization of Poly(ethylene terephthalate) Capillary Pore Membranes with Grafted Temperature-Responsive Polymers', *Langmuir,* 23, 76-83.

Glampedaki, P., and Dutschk, V. (2015). Superabsorbent Finishes for Textiles *Functional Finishes for Textiles* (pp. 283-302): Elsevier Ltd.

Goddard, J. M., and Hotchkiss, J. H. (2007) 'Polymer Surface Modification for the Attachment of Bioactive Compounds', *Progress Polymer Science* 32, 698-725. doi: 10.1016/j.progpolymsci.2007.04.002

Golshaei, P., and Güven, O. (2017) 'Chemical modification of PET surface and subsequent graft copolymerization with poly(N-isopropylacrylamide)', *Reactive and Functional Polymers,* 118, 26-34. doi: http://dx.doi.org/10.1016/j.reactfunctpolym.2017.06.015

Gu, J., Xiao, P., Huang, Y., Zhang, J., and Chen, T. (2015) 'Controlled Functionalization of Carbon Nanotubes as Superhydrophobic Material for Adjustable Oil/Water Separation', *Journal of Materials Chemistry A,* 3(8), 4124-4128. doi: 10.1039/C4TA07173E

Guilherme, M. R., da Silva, R., Rubira, A. F., Geuskens, G., and Muniz, E. C. (2004) 'Thermo-sensitive Hydrogels Membranes from PAAM Networks and Entangled PNIPAAM: Effect of Temperature, Cross-Linking and PNIPAAM Contents on the Water Uptake and Permeability', *Reactive and Functional Polymers,* 61(2), 233-243. doi: 10.1016/j.reactfunctpolym.2004.06.004

Guo, F., and Guo, Z. (2016) 'Inspired smart materials with external stimuli responsive wettability: a review', *RSC Advances,* 6(43), 36623-36641. doi: 10.1039/C6RA04079A

Guo, F., Jiao, K., Bai, Y., Guo, J., Chen, Q., Yang, R., and Zhang, X. (2019) 'Novel transcatheter aortic heart valves exhibiting excellent hemodynamic performance and low-fouling property', *Journal of Materials Science & Technology,* 35(1), 207-215. doi: https://doi.org/10.1016/j.jmst.2018.09.026

Guo, H., and Ulbricht, M. (2011) 'Preparation of Thermo-Responsive Polypropylene Membranes via Surface Entrapment of Poly(*N*-Isopropylacrylamide)-Containing Macromolecules', *Journal of Membrane Science,* 372(1-2), 331-339. doi: 10.1016/j.memsci.2011.02.018

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. doi: doi:10.1002/adfm.200900622

Hadjizadeh, A., Ajji, A., and Bureau, M. N. (2010) 'Preparation and Characterization of NaOH Treated Micro-Fibrous Polyethylene Terephthalate Nonwovens for Biomedical Application', *Mechanical Behavior of Biomedical Materials,* 3(8), 574-583. doi: 10.1016/j.jmbbm.2010.07.002

Han, J., Wang, K., Yang, D., and Nie, J. (2009) 'Photopolymerization of methacrylated chitosan/PNIPAAm hybrid dual-sensitive hydrogels as carrier for drug delivery', *International Journal of Biological Macromolecules,* 44(3), 229-235. doi: 10.1016/j.ijbiomac.2008.12.009

He, L., Dumée, L. F., Feng, C., Velleman, L., Reis, R., She, F., Gao, W., and Kong, L. (2015) 'Promoted water transport across graphene oxide–poly(amide) thin film composite membranes and their antibacterial activity', *Desalination,* 365, 126-135. doi: 10.1016/j.desal.2015.02.032

Hennink, W. E., and van Nostrum, C. F. (2012) 'Novel Crosslinking Methods to Design Hydrogels', *Advanced Drug Delivery Reviews,* 64(0), 223-236. doi: http://dx.doi.org/10.1016/j.addr.2012.09.009

Hesampour, M., Huuhilo, T., Mäkinen, K., Mänttäri, M., and Nyström, M. (2008) 'Grafting of temperature sensitive PNIPAAm on hydrophilised polysulfone UF membranes', *Journal of Membrane Science,* 310(1–2), 85-92. doi: http://dx.doi.org/10.1016/j.memsci.2007.10.038

Hoffman, A. S. (2012) 'Hydrogels for Biomedical Applications', *Advanced Drug Delivery Reviews,* 64, Supplement(0), 18-23. doi: http://dx.doi.org/10.1016/j.addr.2012.09.010

Holz, K., Lietard, J., and Somoza, M. M. (2017) 'High-Power 365 nm UV LED Mercury Arc Lamp Replacement for Photochemistry and Chemical Photolithography', *ACS Sustainable Chemistry and Engineering,* 5(1), 828-834. doi: 10.1021/acssuschemeng.6b02175

Hsieh, Y. L., Miller, A., and Thompson, J. (1996) 'Wetting, Pore Structure, and Liquid Retention of Hydrolyzed Polyester Fabrics', *Textile Research Journal,* 66(1), 1-10. doi: 10.1177/004051759606600101

Hu, Y.-T., Ting, Y., Hu, J.-Y., and Hsieh, S.-C. (2017) 'Techniques and methods to study functional characteristics of emulsion systems', *Journal of Food and Drug Analysis,* 25(1), 16-26. doi: https://doi.org/10.1016/j.jfda.2016.10.021

Huang, J., Wang, X.-L., Qi, W.-S., and Yu, X.-H. (2002) 'Temperature Sensitivity and Electrokinetic Behavior of A *N*-Isopropylacrylamide Grafted Microporous Polyethylene Membrane', *Desalination,* 146, 345-351.

Islam, M. R., Lu, Z., Li, X., Sarker, A. K., Hu, L., Choi, P., Li, X., Hakobyan, N., and Serpe, M. J. (2013) 'Responsive Polymers for Analytical Applications: A Review', *Analytica Chimica Acta,* 789, 17-32. doi: 10.1016/j.aca.2013.05.009

Jiang, C., Wang, Q., and Wang, T. (2012) 'Thermoresponsive PNIPAAm-Modified Cotton Fabric Surfaces that Switch Between Superhydrophilicity and Superhydrophobicity', *Applied Surface Science,* 258(11), 4888-4892. doi: 10.1016/j.apsusc.2012.01.107

Jindan, W., Yuelin, J., Ju, H., Sufang, Z., Guoqiang, C., and Jiping, W. (2016) 'Thermo-responsive poly(N-isopropylacrylamide) grafted polyester textiles with switchable surface wettability', *Textile Research Journal,* 86(7), 677-684. doi: 10.1177/0040517515599748

Jing, B., Wang, H., Lin, K.-Y., McGinn, P. J., Na, C., and Zhu, Y. (2013) 'A Facile Method to Functionalize Engineering Solid Membrane Supports for Rapid and Efficient Oil–Water Separation', *Polymer,* 54(21), 5771-5778. doi: 10.1016/j.polymer.2013.08.030

Jinlian, H., Harper, M., Guoqiang, L., and Samuel, I. I. (2012) 'A review of stimuli-responsive polymers for smart textile applications', *Smart Materials and Structures,* 21(5), 053001.

Jung, Y. C., and Bhushan, B. (2009) 'Wetting Behavior of Water and Oil Droplets in Three-Phase Interfaces for Hydrophobicity/philicity and Oleophobicity/philicity', *Langmuir,* 25(24), 14165-14173. doi: 10.1021/la901906h

Kalia, S., Thakur, K., Celli, A., Kiechel, M. A., and Schauer, C. L. (2013) 'Surface Modification of Plant Fibers using Environment Friendly Methods for Their Application in Polymer Composites, Textile Industry and Antimicrobial Activities: Review', *Journal of Environmental Chemical Engineering,* 1, 97–112. doi: 10.1016/j.jece.2013.04.009

Kalshetti, P. P., Rajendra, V. B., N.Dixit, D., and Parekh, P. P. (2012) 'Hydrogels as A Drug Delivery System and Applications: A Review', *International Journal of Pharmacy and Pharmaceutical Sciences,* 4(1), 1-7.

Kara, S., and Pekcan, Ö. (2003) 'Phase Transitions of *N*-isopropylacrylamide Gels Prepared with Various Crosslinker Contents', *Materials Chemistry and Physics,* 80(2), 555-559. doi: http://dx.doi.org/10.1016/S0254-0584(03)00111-1

Karaca Balta, D., Karahan, Ö., Avci, D., and Arsu, N. (2015) 'Synthesis, Photophysical and Photochemical Studies of Benzophenone based Novel Monomeric and

Polymeric Photoinitiators', *Progress in Organic Coatings,* 78(0), 200-207. doi: http://dx.doi.org/10.1016/j.porgcoat.2014.09.003

Kato, K., Uchida, E., Kang, E.-T., Uyama, Y., and Ikada, Y. (2003) 'Polymer Surface with Graft Chains', *Progress in Polymer Science,* 28(2), 209-259. doi: http://dx.doi.org/10.1016/S0079-6700(02)00032-1

Khuri, A. I., and Cornell, J. A. (2018) *Response Surfaces: Designs and Analyses: Second Edition*: CRC Press.

Kizilay, M. Y., and Okay, O. (2004) 'Effect of Swelling on Spatial Inhomogeneity In Poly(acrylamide) Gels Formed at Various Monomer Concentrations', *Polymer,* 45(8), 2567-2576. doi: http://dx.doi.org/10.1016/j.polymer.2004.01.074

Klouda, L., Perkins, K. R., Watson, B. M., Hacker, M. C., Bryant, S. J., Raphael, R. M., Kasper, F. K., and Mikos, A. G. (2011) 'Thermoresponsive, In Situ Cross-Linkable Hydrogels based on N-Isopropylacrylamide: Fabrication, Characterization and Mesenchymal Stem Cell Encapsulation', *Acta Biomaterials,* 7(4), 1460-1467. doi: 10.1016/j.actbio.2010.12.027

Ko, D. Y., Shinde, U. P., Yeon, B., and Jeong, B. (2013) 'Recent Progress of In Situ Formed Gels for Biomedical Applications', *Progress in Polymer Science,* 38(3-4), 672-701. doi: 10.1016/j.progpolymsci.2012.08.002

Kobayashi, M., Terayama, Y., Yamaguchi, H., Terada, M., Murakami, D., Ishihara, K., and Takahara, A. (2012) 'Wettability and Antifouling Behavior on the Surfaces of Superhydrophilic Polymer Brushes', *Langmuir,* 28(18), 7212-7222. doi: 10.1021/la301033h

Kongyin, Z., Beibei, L., Wenkui, C., Lingzhi, F., Tian, C., and Junfu, W. (2014) 'Preparation and Adsorption of Bovine Serum Albumin-Imprinted Polyacrylamide Hydrogel Membrane Grafted on Non-Woven Polypropylene', *Talanta,* 121(0), 256-262. doi: http://dx.doi.org/10.1016/j.talanta.2014.01.010

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. doi: 10.1016/j.progpolymsci.2007.05.003

Kwok, A. Y., Prime, E. L., Qiao, G. G., and Solomon, D. H. (2003) 'Synthetic hydrogels 2. Polymerization induced phase separation in acrylamide systems', *Polymer,* 44(24), 7335-7344. doi: http://dx.doi.org/10.1016/j.polymer.2003.09.026

La, Y.-H., McCloskey, B. D., Sooriyakumaran, R., Vora, A., Freeman, B., Nassar, M., Hedrick, J., Nelson, A., and Allen, R. (2011) 'Bifunctional Hydrogel Coatings for Water Purification Membranes: Improved Fouling Resistance and Antimicrobial Activity', *Journal of Membrane Science,* 372(1-2), 285-291. doi: 10.1016/j.memsci.2011.02.005

Laftah, W. A., and Hashim, S. (2013) 'The influence of plant natural fibers on swelling behavior of polymer hydrogels', *Journal of Composite Materials,* 48(5), 555-569. doi: 10.1177/0021998313476323

Leal-Calderon, F. (2012) 'Emulsified Lipids: Formulation and Control of End-Use Properties', *Dossier Fonctionnalites Des Huiles,* 19(2), 111-119. doi: 10.1051/ocl.2012.0438

Lee, S. C., Kwon, I. K., and Park, K. (2013) 'Hydrogels for Delivery of Bioactive Agents: A Historical Perspective', *Advanced Drug Delivery Reviews,* 65(1), 17-20. doi: http://dx.doi.org/10.1016/j.addr.2012.07.015

Li, B., Liu, X., Zhang, X., and Chai, W. (2015) 'Stainless steel mesh coated with silica for oil–water separation', *European Polymer Journal,* 73, 374-379. doi: http://dx.doi.org/10.1016/j.eurpolymj.2015.10.031

Li, C., Mingjie, L., Ling, L., Tong, Z., Jie, M., Yanlin, S., and Lei, J. (2010) 'Thermal-Responsive Hydrogel Surface: Tunable Wettability and Adhesion to Oil at the Water/Solid Interface', *Soft Matter,* 6(12), 2708. doi: 10.1039/c002543g

Li, D., He, L., Dong, D., Forsyth, M., and Wang, H. (2012) 'Preparation of silicalite-polyamide composite membranes for desalination', *Asia-Pacific Journal of Chemical Engineering,* 7(3), 434-441. doi: 10.1002/apj.588

Li, J.-J., Zhu, L.-T., and Luo, Z.-H. (2016) 'Electrospun fibrous membrane with enhanced swithchable oil/water wettability for oily water separation', *Chemical Engineering Journal,* 287, 474-481. doi: http://dx.doi.org/10.1016/j.cej.2015.11.057

Li, Z.-T., Lin, B., Jiang, L.-W., Lin, E.-C., Chen, J., Zhang, S.-J., Tang, Y.-W., He, F.-A., and Li, D.-H. (2018a) 'Effective preparation of magnetic superhydrophobic Fe3O4/PU sponge for oil-water separation', *Applied Surface Science,* 427, 56-64. doi: 10.1016/j.apsusc.2017.08.183

Li, Z., Shao, L., Hu, W., Zheng, T., Lu, L., Cao, Y., and Chen, Y. (2018b) 'Excellent reusable chitosan/cellulose aerogel as an oil and organic solvent absorbent', *Carbohydrate Polymers,* 191, 183-190. doi: 10.1016/j.carbpol.2018.03.027

Liang, L., Feng, X., Peurrung, L., and Viswanathan, V. (1999) 'Temperature Sensitive Membrane Prepared by UV Photopolymerization of *N*-Isopropylacrymida on A Surface of Porous Hydrophilic Polypropylene Membrane', *Journal of Membrane Science,* 162, 235-246.

Liang, W., Hou, J., Fang, X., Bai, F., Zhu, T., Gao, F., Wei, C., Mo, X., and Lang, M. (2018) 'Synthesis of cellulose diacetate based copolymer electrospun nanofibers for tissues scaffold', *Applied Surface Science,* 443, 374-381. doi: https://doi.org/10.1016/j.apsusc.2018.02.087

Liu, C., Yang, J., Tang, Y., Yin, L., Tang, H., and Li, C. (2015a) 'Versatile Fabrication of The Magnetic Polymer-based Graphene Foam and Applications for Oil–Water Separation', *Colloids and Surfaces A: Physicochemical and Engineering Aspects,* 468(0), 10-16. doi: http://dx.doi.org/10.1016/j.colsurfa.2014.12.005

Liu, F., and Urban, M. W. (2010) 'Recent Advances and Challenges in Designing Stimuli-Responsive Polymers', *Progress in Polymer Science,* 35(1-2), 3-23. doi: 10.1016/j.progpolymsci.2009.10.002

Liu, G., Yuan, Q., Hollett, G., Zhao, W., Kang, Y., and Wu, J. (2018a) 'Cyclodextrin-based host–guest supramolecular hydrogel and its application in biomedical fields', *Polymer Chemistry,* 9(25), 3436-3449. doi: 10.1039/C8PY00730F

Liu, J., Li, P., Chen, L., Feng, Y., He, W., and Lv, X. (2016a) 'Modified superhydrophilic and underwater superoleophobic PVDF membrane with ultralow oil-adhesion for highly efficient oil/water emulsion separation', *Materials Letters,* 185, 169-172. doi: http://dx.doi.org/10.1016/j.matlet.2016.08.124

Liu, J., Li, P., Chen, L., Feng, Y., He, W., Yan, X., and Lü, X. (2016b) 'Superhydrophilic and underwater superoleophobic modified chitosan-coated mesh for oil/water separation', *Surface and Coatings Technology,* 307, Part A, 171-176. doi: http://dx.doi.org/10.1016/j.surfcoat.2016.08.052

Liu, J., Nie, J., Zhao, Y., and He, Y. (2010a) 'Preparation and Properties of Different Photoresponsive Hydrogels Modulated with UV and Visible Light Irradiation', *Journal of Photochemistry and Photobiology A: Chemistry,* 211(1), 20-25. doi: http://dx.doi.org/10.1016/j.jphotochem.2010.01.016

Liu, K., Tian, Y., and Jiang, L. (2013) 'Bio-Inspired Superoleophobic and Smart Materials: Design, Fabrication, and Application', *Progress in Materials Science,* 58(4), 503-564. doi: http://dx.doi.org/10.1016/j.pmatsci.2012.11.001

Liu, R.-L., Li, X.-Q., Liu, H.-Q., Luo, Z.-M., Ma, J., Zhang, Z.-Q., and Fu, Q. (2016c) 'Eco-friendly fabrication of sponge-like magnetically carbonaceous fiber aerogel for high-efficiency oil-water separation', *RSC Advances,* 6(36), 30301-30310. doi: 10.1039/C6RA02794F

Liu, W., Zhang, S., Chen, X., Yu, L., Zhu, X., and Feng, Q. (2010b) 'Thermal Behavior and Fire Performance of Nylon-6,6 Fabric Modified with Acrylamide by Photografting', *Polymer Degradation and Stability,* 95(9), 1842-1848. doi: http://dx.doi.org/10.1016/j.polymdegradstab.2010.04.023

Liu, X., Ye, Q., Song, X., Zhu, Y., Cao, X., Liang, Y., and Zhou, F. (2011) 'Responsive wetting transition on superhydrophobic surfaces with sparsely grafted polymer brushes', *Soft Matter,* 7(2), 515-523. doi: 10.1039/C0SM00682C

Liu, Y., Su, Y., Li, Y., Zhao, X., and Jiang, Z. (2015b) 'Improved antifouling property of PVDF membranes by incorporating an amphiphilic block-like copolymer for oil/water emulsion separation', *RSC Advances,* 5(27), 21349-21359. doi: 10.1039/C4RA16290K

Liu, Y., Tas, S., Zhang, K., de Vos, W. M., Ma, J., and Vancso, G. J. (2018b) 'Thermoresponsive Membranes from Electrospun Mats with Switchable Wettability for Efficient Oil/Water Separations', *Macromolecules,* 51(21), 8435-8442. doi: 10.1021/acs.macromol.8b01853

Luo, Y.-L., Huang, R.-J., Zhang, L.-L., Xu, F., and Chen, Y.-S. (2013) 'Dual-responsive polyacrylate copolymer micelles with PMAA and PNIPAAm graft brushes: Physicochemical properties and prednisone release', *Colloids and Surfaces A: Physicochemical and Engineering Aspects,* 436(0), 1175-1185. doi: http://dx.doi.org/10.1016/j.colsurfa.2013.08.018

Lv, X., Tian, D., Peng, Y., Li, J., and Jiang, G. (2019) 'Superhydrophobic magnetic reduced graphene oxide-decorated foam for efficient and repeatable oil-water separation', *Applied Surface Science,* 466, 937-945. doi: 10.1016/j.apsusc.2018.10.110

Ma, D., Chen, H., Shi, D., Li, Z., and Wang, J. (2009) 'Preparation and Characterization of Thermo-Responsive PDMS Surfaces Grafted with Poly(*N*-isopropylacrylamide) by Benzophenone-Initiated Photopolymerization', *Journal of Colloid and Interface Science,* 332(1), 85-90. doi: 10.1016/j.jcis.2008.12.046

Ma, H., Davis, R. H., and Bowman, C. N. (2000) 'A Novel Sequential Photoinduced Living Graft Polymerization', *Macromolecules,* 33(2), 331-335. doi: 10.1021/ma990821s

Makoto, I., Takanori, M., Yuka, K., Yohei, J., Tsuruo, N., Hironori, O., Tetsuo, H., Takashi, T., and Masatake, H. (2013) 'Air Purification by Gold Catalysts Supported on PET Nonwoven Fabric', *Applied Catalysis B: Environmental,* 134-135, 130-135. doi: 10.1016/j.apcatb.2012.12.018

Marchand-Brynaert, J., Deldime, M., Dupont, I., Dewez, J.-L., and Schneider, Y.-J. (1995) 'Surface Functionalization of Poly(ethylene terephthalate) Film and Membrane by Controlled Wet Chemistry: Chemical Characterization of Carboxylated Surfaces', *Journal of Colloid and Interface Science,* 173(1), 236-244. doi: http://dx.doi.org/10.1006/jcis.1995.1319

Matalanis, A., and McClements, D. J. (2013) 'Hydrogel Microspheres for Encapsulation of Lipophilic Components: Optimization of Fabrication & Performance', *Food Hydrocolloids,* 31(1), 15-25. doi: 10.1016/j.foodhyd.2012.09.012

Mehmood, T., Ahmad, A., Ahmed, A., and Ahmed, Z. (2017) 'Optimization of olive oil based O/W nanoemulsions prepared through ultrasonic homogenization: A response surface methodology approach', *Food Chemistry,* 229, 790-796. doi: https://doi.org/10.1016/j.foodchem.2017.03.023

Meng, H., Yan, T., Yu, J., and Jiao, F. (2018) 'Super-hydrophobic and super-lipophilic functionalized graphene oxide/polyurethane sponge applied for oil/water separation', *Chinese Journal of Chemical Engineering,* 26(5), 957-963. doi: 10.1016/j.cjche.2017.09.004

Ming, T., Gaohong, H., Xiangcun, L., Yuanfa, L., Chunxu, D., and Jinghai, F. (2012) 'Prediction of the effects of preparation conditions on pervaporation performances of polydimethylsiloxane(PDMS)/ceramic composite membranes by backpropagation neural network and genetic algorithm', *Separation and Purification Technology,* 89, 142-146. doi: 10.1016/j.seppur.2012.01.011

Mohamed, N. H., Bahners, T., Wego, A., Gutmann, J. S., and Ulbricht, M. (2012a) 'Surface modification of poly(ethylene terephthalate) fabric via photo-chemical reaction of dimethylaminopropyl methacrylamide', *Applied Surface Science,* 259, 261-269.

Mohamed, N. H., Bahners, T., Wego, A., Gutmann, J. S., and Ulbricht, M. (2012b) 'Surface modification of poly(ethylene terephthalate) fabric via photo-chemical reaction of dimethylaminopropyl methacrylamide', *Applied Surface Science,* 259, 261-269. doi: http://dx.doi.org/10.1016/j.apsusc.2012.07.029

Mondal, S., and 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. doi: http://dx.doi.org/10.1016/j.seppur.2012.02.024

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. doi: http://dx.doi.org/10.1016/j.procbio.2009.04.024

Ngang, H. P., Ahmad, A. L., Low, S. C., and Ooi, B. S. (2017a) 'Adsorption-desorption study of oil emulsion towards thermo-responsive PVDF/SiO2-PNIPAM composite membrane', *Journal of Environmental Chemical Engineering,* 5(5), 4471-4482. doi: https://doi.org/10.1016/j.jece.2017.08.038

Ngang, H. P., Ahmad, A. L., Low, S. C., and Ooi, B. S. (2017b) 'Preparation of thermoresponsive PVDF/SiO2-PNIPAM mixed matrix membrane for saline oil emulsion separation and its cleaning efficiency', *Desalination,* 408, 1-12. doi: https://doi.org/10.1016/j.desal.2017.01.005

Nguyen-Tri, P., El Aidani, R., Leborgne, É., Pham, T., and Vu-Khanh, T. (2014) 'Chemical Ageingaging of A Polyester Nonwoven Membrane used in Aerosol and Drainage Filter', *Polymer Degradation and Stability,* 101(0), 71-80. doi: http://dx.doi.org/10.1016/j.polymdegradstab.2014.01.001

Nguyen, K. T., and West, J. L. (2002) 'Photopolymerizable Hydrogels for Tissue Engineering Applications', *Biomaterials,* 23(22), 4307-4314. doi: http://dx.doi.org/10.1016/S0142-9612(02)00175-8

Nurcan, K., Gokhan, T., Demet, K. B., Meral, A., and Nergis, A. (2009) 'Preparation of hydrogels by photopolymerization of acrylates in the presence of Type I and one-component Type II photoinitiators', *Journal of Photochemistry and Photobiology A: Chemistry* 209, 1-6. doi: 10.1016/j.jphotochem.2009.09.017

Oguz, O. (2009) 'General Properties of Hydrogels', *Hydrogel Sensors and Actuators,Engineering Technology*, 1-14. doi: 10.1007/978-3-540-75645-3_1

Omidian, H., and Park, K. (2012). Hydrogels *Fundamentals and Applications of Controlled Release Drug Delivery* (pp. 75-106). Advances in Delivery Science and Technology.

Ou, R., Wei, J., Jiang, L., Simon, G. P., and Wang, H. (2016) 'Robust Thermoresponsive Polymer Composite Membrane with Switchable Superhydrophilicity and Superhydrophobicity for Efficient Oil–Water Separation', *Environmental Science & Technology,* 50(2), 906-914. doi: 10.1021/acs.est.5b03418

Özçam, A. E., Roskov, K. E., Genzer, J., and Spontak, R. J. (2012) 'Responsive PET Nano/Microfibers via Surface-Initiated Polymerization', *ACS Applied Materials & Interfaces,* 4(1), 59-64. doi: 10.1021/am201559f

Papagora, C., Roukas, T., and Kotzekidou, P. (2013) 'Optimization of extracellular lipase production by Debaryomyces hansenii isolates from dry-salted olives using response surface methodology', *Food and Bioproducts Processing,* 91(4), 413-420. doi: http://dx.doi.org/10.1016/j.fbp.2013.02.008

Peeva, P. D., Million, N., and Ulbricht, M. (2012) 'Factors Affecting the Sieving Behavior of Anti-Fouling Thin-Layer Cross-Linked Hydrogel Polyethersulfone Composite Ultrafiltration Membranes', *Journal of Membrane Science,* 390-391, 99-112. doi: 10.1016/j.memsci.2011.11.025

Peeva, P. D., Pieper, T., and Ulbricht, M. (2010) 'Tuning the ultrafiltration properties of anti-fouling thin-layer hydrogel polyethersulfone composite membranes by suited crosslinker monomers and photo-grafting conditions', *Journal of Membrane Science,* 362(1-2), 560-568. doi: 10.1016/j.memsci.2010.07.016

Pennadam, S. S., Firman, K., Alexander, C., and Górecki, D. C. (2004) 'Protein-polymer nano-machines. Towards synthetic control of biological processes', *Journal of Nanobiotechnology,* 2(1), 8. doi: 10.1186/1477-3155-2-8

Peppas, N. A. (1997) 'Hydrogels and Drug Delivery', *Current Opinion in Colloid & Interface Science,* 2(531-537).

Pi, P., Hou, K., Zhou, C., Wen, X., Xu, S., Cheng, J., and Wang, S. (2016) 'A novel superhydrophilic-underwater superoleophobic Cu2S coated copper mesh for efficient oil-water separation', *Materials Letters,* 182, 68-71. doi: http://dx.doi.org/10.1016/j.matlet.2016.06.087

Puleo, G. L., Zulli, F., Piovanelli, M., Giordano, M., Mazzolai, B., Beccai, L., and Andreozzi, L. (2013) 'Mechanical and Rheological Behavior of PNIPAAm Crosslinked Macrohydrogel', *Reactive and Functional Polymers,* 73(9), 1306-1318. doi: 10.1016/j.reactfunctpolym.2013.07.004

Qin, D., Liu, Z., Liu, Z., Bai, H., and Sun, D. D. (2018) 'Superior Antifouling Capability of Hydrogel Forward Osmosis Membrane for Treating Wastewaters with High Concentration of Organic Foulants', *Environmental Science & Technology,* 52(3), 1421-1428. doi: 10.1021/acs.est.7b04838

Qufu, W., Yingying, W., Qin, Y., and Liangyan, Y. (2016) 'Functionalization of Textile Materials by Plasma Enhanced Modification', *Journal of Industrial Textiles,* 36(4), 301-309. doi: 10.1177/1528083707072375

Rahimpour, A. (2011) 'UV photo-grafting of hydrophilic monomers onto the surface of nano-porous PES membranes for improving surface properties', *Desalination,* 265(1–3), 93-101. doi: http://dx.doi.org/10.1016/j.desal.2010.07.037

Ranganath, A. S., Ganesh, V. A., Sopiha, K., Sahay, R., and Baji, A. (2017) 'Thermoresponsive electrospun membrane with enhanced wettability', *RSC Advances,* 7(32), 19982-19989. doi: 10.1039/C6RA27848E

Rasib, S. Z. M., Ahmad, Z., Khan, A., Akil, H. M., Othman, M. B. H., Hamid, Z. A. A., and Ullah, F. (2018) 'Synthesis and evaluation on pH- and temperature-responsive chitosan-p(MAA-co-NIPAM) hydrogels', *International Journal of Biological Macromolecules,* 108, 367-375. doi: 10.1016/j.ijbiomac.2017.12.021

Ratner, B. D. (1995) 'Surface Modification of Polymers: Chemical, Biological and Surface Analytical Challenges', *Biosensors and Bioelectronics,* 10(9–10), 797-804. doi: http://dx.doi.org/10.1016/0956-5663(95)99218-A

Razali, N. F., Mohammad, A. W., Hilal, N., Leo, C. P., and Alam, J. (2013) 'Optimisation of polyethersulfone/polyaniline blended membranes using response surface methodology approach', *Desalination,* 311, 182-191. doi: http://dx.doi.org/10.1016/j.desal.2012.11.033

Reddy, N. N., Mohan, Y. M., Varaprasad, K., Ravindra, S., Joy, P. A., and Raju, K. M. (2011) 'Magnetic and Electric Responsive Hydrogel-Magnetic Nanocomposites for Drug-Delivery Application', *Journal of Applied Polymer Science,* 122(2), 1364-1375. doi: 10.1002/app.34016

Roux, S., and Demoustier-Champagne, S. (2003) 'Surface-initiated polymerization from poly(ethylene terephthalate)', *Journal of Polymer Science Part a-Polymer Chemistry,* 41(9), 1347-1359. doi: 10.1002/pola.10686

Ruiz, J. C., Alvarez-Lorenzo, C., Taboada, P., Burillo, G., Bucio, E., De Prijck, K., Nelis, H. J., Coenye, T., and Concheiro, A. (2008) 'Polypropylene grafted with smart polymers (PNIPAAm/PAAc) for loading and controlled release of vancomycin', *European Journal of Pharmaceutics & Biopharmaceutics,* 70(2), 467-477. doi: 10.1016/j.ejpb.2008.05.020

Sabbagh, F., Muhamad, I. I., Nazari, Z., Mobini, P., and Taraghdari, S. B. (2018) 'From formulation of acrylamide-based hydrogels to their optimization for drug release using response surface methodology', *Materials Science and Engineering: C,* 92, 20-25. doi: https://doi.org/10.1016/j.msec.2018.06.022

Saïhi, D., El-Achari, A., Ghenaim, A., and Claude, C. (2002) 'Wettability of grafted poly(ethylene terephthalate) fibers', *Polymer Testing,* 21(6), 615-618. doi: https://doi.org/10.1016/S0142-9418(01)00131-3

Salahi, A., Noshadi, I., Badrnezhad, R., Kanjilal, B., and Mohammadi, T. (2013) 'Nano-porous membrane process for oily wastewater treatment: Optimization using response surface methodology', *Journal of Environmental Chemical Engineering,* 1(3), 218-225. doi: http://dx.doi.org/10.1016/j.jece.2013.04.021

Samchenko, Y., Ulberg, Z., and Korotych, O. (2011) 'Multipurpose Smart Hydrogel Systems', *Advances in Colloid and Interface Science,* 168(1-2), 247-262. doi: 10.1016/j.cis.2011.06.005

Schwark, S., and Ulbricht, M. (2012) 'Toward Protein-Selective Membrane Adsorbers: A Novel Surface-Selective Photo-Grafting Method', *European Polymer Journal,* 48(11), 1914-1922. doi: http://dx.doi.org/10.1016/j.eurpolymj.2012.08.003

Shahidi, S., Wiener, J., and Ghoranneviss, M. (2013). Surface Modification Methods for Improving the Dyeability of Textile Fabrics *Eco-Friendly Textile Dyeing and Finishing* (pp. 33-51). INTECH-open science.

Shi, J., Zhang, L., Xiao, P., Huang, Y., Chen, P., Wang, X., Gu, J., Zhang, J., and Chen, T. (2018) 'Biodegradable PLA Nonwoven Fabric with Controllable Wettability for Efficient Water Purification and Photocatalysis Degradation', *ACS Sustainable Chemistry & Engineering,* 6(2), 2445-2452. doi: 10.1021/acssuschemeng.7b03897

Sholtes, K. A., Lowe, K., Walters, G. W., Sobsey, M. D., Linden, K. G., and Casanova, L. M. (2016) 'Comparison of ultraviolet light-emitting diodes and low-pressure mercury-arc lamps for disinfection of water', *Environmental Technology,* 37(17), 2183-2188. doi: 10.1080/09593330.2016.1144798

Singh, B., and Pal, L. (2011) 'Radiation crosslinking polymerization of sterculia polysaccharide–PVA–PVP for making hydrogel wound dressings', *International Journal of Biological Macromolecules,* 48(3), 501-510. doi: http://dx.doi.org/10.1016/j.ijbiomac.2011.01.013

Škvarla, J., Luxbacher, T., Nagy, M., and Sisol, M. (2010) 'Relationship of Surface Hydrophilicity, Charge, and Roughness of PET Foils Stimulated by Incipient Alkaline Hydrolysis', *ACS Applied Materials & Interfaces,* 2(7), 2116-2127. doi: 10.1021/am100368v

Sokker, H. H., M. El-Sawy, N., Hassan, M. A., and E. El-Anadouli, B. (2011) 'Adsorption of crude oil from aqueous solution by hydrogel of chitosan based polyacrylamide prepared by radiation induced graft polymerization', *Journal of Hazardous Materials,* 190, 359–365. doi: 10.1016/j.jhazmat.2011.03.055

Stolz, A., Le Floch, S., Reinert, L., Ramos, S. M. M., Tuaillon-Combes, J., Soneda, Y., Chaudet, P., Baillis, D., Blanchard, N., Duclaux, L., and San-Miguel, A. (2016) 'Melamine-derived carbon sponges for oil-water separation', *Carbon,* 107, 198-208. doi: 10.1016/j.carbon.2016.05.059

Štular, D., Primc, G., Mozetič, M., Jerman, I., Mihelčič, M., Ruiz-Zepeda, F., Tomšič, B., Simončič, B., and Gorjanc, M. (2018) 'Influence of non-thermal plasma treatement on the adsorption of a stimuli-responsive nanogel onto polyethylene terephthalate fabric', *Progress in Organic Coatings,* 120, 198-207. doi: 10.1016/j.porgcoat.2018.03.023

Suh, K. Y., and Jon, S. (2005) 'Control over Wettability of Polyethylene Glycol Surfaces Using Capillary Lithography', *Langmuir,* 21, 6836-6841.

Sun, G., Zhang, X., Bao, Z., Lang, X., Zhou, Z., Li, Y., Feng, C., and Chen, X. (2018a) 'Reinforcement of thermoplastic chitosan hydrogel using chitin whiskers optimized with response surface methodology', *Carbohydrate Polymers,* 189, 280-288. doi: https://doi.org/10.1016/j.carbpol.2018.01.083

Sun, T., Wang, G., Feng, L., Liu, B., Ma, Y., Jiang, L., and Zhu, D. (2004) 'Reversible Switching between Superhydrophilicity and Superhydrophobicity',

Angewandte Chemie International Edition, 43(3), 357-360. doi: 10.1002/anie.200352565

Sun, T. L., Kurokawa, T., Kuroda, S., Ihsan, A. B., Akasaki, T., Sato, K., Haque, M. A., Nakajima, T., and Gong, J. P. (2013) 'Physical Hydrogels Composed of Polyampholytes Demonstrate High Toughness and Viscoelasticity', *Nat Mater,* 12(10), 932-937. doi: 10.1038/nmat3713

http://www.nature.com/nmat/journal/v12/n10/abs/nmat3713.html#supplementary-information

Sun, X., DenHartog, E., Zhang, X., and McCord, M. (2018b) 'Study of poly(N-isopropylacrylamide) grafted cotton fabrics initiated by atmospheric pressure plasma', *Applied Surface Science,* 453, 182-191. doi: https://doi.org/10.1016/j.apsusc.2018.05.056

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

Suzuki, D., and Yamakawa, S. (2012) 'Hydrogel particles as a particulate stabilizer for dispersion polymerization', *Langmuir,* 28(29), 10629-10634. doi: 10.1021/la301127q

Teng, C., Lu, X., Ren, G., Zhu, Y., Wan, M., and Jiang, L. (2014) 'Underwater Self-Cleaning PEDOT-PSS Hydrogel Mesh for Effective Separation of Corrosive and Hot Oil/Water Mixtures', *Advanced Materials Interfaces,* 1(6), 1400099 - n/a. doi: 10.1002/admi.201400099

ter Schiphorst, J., van den Broek, M., de Koning, T., Murphy, J. N., Schenning, A. P. H. J., and Esteves, A. C. C. (2016) 'Dual light and temperature responsive cotton fabric functionalized with a surface-grafted spiropyran-NIPAAm-hydrogel', *Journal of Materials Chemistry A,* 4(22), 8676-8681. doi: 10.1039/C6TA00161K

Tokuyama, H., and Kanehara, A. (2007) 'Novel Synthesis of Macroporous Poly(*N*-isopropylacrylamide) Hydrogels Using Oil-in-Water Emulsions', *Langmuir,* 23, 11246-11251. doi: 10.1021/la701492u

Tokuyama, H., and Yazaki, N. (2010) 'Preparation of Poly(*N*-Isopropylacrylamide) Hydrogel Beads by Circulation Polymerization', *Reactive & Functional Polymers* 70, 967-971. doi: 10.1016/j.reactfunctpolym.2010.10.004

Tripathi, B. P., Dubey, N. C., Simon, F., and Stamm, M. (2014) 'Thermo responsive ultrafiltration membranes of grafted poly(N-isopropyl acrylamide) via polydopamine', *RSC Advances,* 4(64), 34073-34083. doi: 10.1039/C4RA03485F

Tsai, F.-H., Kitamura, Y., and Kokawa, M. (2017) 'Liquid-core alginate hydrogel beads loaded with functional compounds of radish by-products by reverse spherification: Optimization by response surface methodology', *International Journal of Biological Macromolecules,* 96, 600-610. doi: https://doi.org/10.1016/j.ijbiomac.2016.12.056

Tuncaboylu, D. C., Argun, A., Algi, M. P., and Okay, O. (2013) 'Autonomic Self-Healing in Covalently Crosslinked Hydrogels Containing Hydrophobic Domains', *Polymer,* 54(23), 6381-6388. doi: http://dx.doi.org/10.1016/j.polymer.2013.09.051

Ulbricht, M. (2006) 'Advanced Functional Polymer Membranes', *Polymer,* 47(7), 2217-2262. doi: http://dx.doi.org/10.1016/j.polymer.2006.01.084

Ulbricht, M., Matuschewski, H., Oechel, A., and Hicke, H.-G. (1996) 'Photo-induced graft polymerization surface modifications for the preparation of hydrophilic and low-proten-adsorbing ultrafiltration membranes', *Journal of Membrane Science,* 115(1), 31-47. doi: http://dx.doi.org/10.1016/0376-7388(95)00264-2

Varaprasad, K., Nagireddy, N., Ravindra, S., Kanikireddy, V., and Raju, K. (2011) 'Synthesis and Characterizations of Macroporous Poly(acrylamide-2-acrylamido-2-methyl-1-propanesulfonic acid) Hydrogels for In Vitro Drug Release of Ranitidine Hydrochloride', *International Journal of Polymeric Materials,* 60, 490-503. doi: 10.1080/00914037.2010.531816

Veiga, A. S., and Schneider, J. P. (2013) 'Antimicrobial Hydrogels for the Treatment of Infection', *Biopolymers,* 100(6), 637-644. doi: 10.1002/bip.22412

Venault, A., Chiang, C.-H., Chang, H.-Y., Hung, W.-S., and Chang, Y. (2018) 'Graphene oxide/PVDF VIPS membranes for switchable, versatile and gravity-driven separation of oil and water', *Journal of Membrane Science,* 565, 131-144. doi: 10.1016/j.memsci.2018.08.018

Wandera, D., Wickramasinghe, S. R., and Husson, S. M. (2010) 'Stimuli-Responsive Membranes', *Journal of Membrane Science,* 357(1–2), 6-35. doi: http://dx.doi.org/10.1016/j.memsci.2010.03.046

Wang, B., Xu, X. D., Wang, Z. C., Cheng, S. X., Zhang, X. Z., and Zhuo, R. X. (2008) 'Synthesis and Properties of pH and Temperature Sensitive P(NIPAAm-co-DMAEMA) Hydrogels', *Colloids Surf B Biointerfaces,* 64(1), 34-41. doi: 10.1016/j.colsurfb.2008.01.001

Wang, J., Sun, H., Gao, X., and Gao, C. (2014a) 'Enhancing antibiofouling performance of Polysulfone (PSf) membrane by photo-grafting of capsaicin derivative and acrylic acid', *Applied Surface Science,* 317, 210-219. doi: http://dx.doi.org/10.1016/j.apsusc.2014.08.102

Wang, J., and Wang, H. (2018) 'One-step fabrication of coating-free mesh with underwater superoleophobicity for highly efficient oil/water separation', *Surface and Coatings Technology,* 340, 1-7. doi: https://doi.org/10.1016/j.surfcoat.2018.02.036

Wang, J., and Wang, H. (2019) 'Ultra-hydrophobic and mesoporous silica aerogel membranes for efficient separation of surfactant-stabilized water-in-oil emulsion separation', *Separation and Purification Technology,* 212, 597-604. doi: 10.1016/j.seppur.2018.11.078

Wang, S., Liu, C., Zhou, H., Gao, C., and Zhang, W. (2017) 'An efficient route to synthesize thermoresponsive molecular bottlebrushes of poly[o-aminobenzyl alcohol-graft-poly(N-isopropylacrylamide)]', *Polymer Chemistry,* 8(12), 1932-1942. doi: 10.1039/C6PY02188C

Wang, T., Chen, H., Liu, K., Wang, S., Xue, P., Yu, Y., Ge, P., Zhang, J., and Yang, B. (2015a) 'Janus Si micropillar arrays with thermal-responsive anisotropic wettability for manipulation of microfluid motions', *ACS Applied Materials and Interfaces,* 7(1), 376-382. doi: 10.1021/am5063647

Wang, X., Liu, X., and Wang, X. (2014b) 'Hydrogel Diffraction Grating as Sensor: A Tool for Studying Volume Phase Transition of Thermo-Responsive Hydrogel', *Sensors and Actuators B: Chemical,* 204(0), 611-616. doi: http://dx.doi.org/10.1016/j.snb.2014.08.013

Wang, Y., Lai, C., Hu, H., Liu, Y., Fei, B., and Xin, J. H. (2015b) 'Temperature-responsive nanofibers for controllable oil/water separation', *RSC Advances,* 5(63), 51078-51085. doi: 10.1039/C5RA08851H

Wang, Z., Elimelech, M., and Lin, S. (2016) 'Environmental Applications of Interfacial Materials with Special Wettability', *Environmental Science & Technology,* 50(5), 2132-2150. doi: 10.1021/acs.est.5b04351

Wavhal, D. S., and Fisher, E. R. (2003) 'Membrane Surface Modification by Plasma-Induced Polymerization of Acrylamide for Improved Surface Properties and Reduced Protein Fouling', *Langmuir,* 19(1), 79-85. doi: 10.1021/la020653o

Wei, R., Song, W., Yang, F., Zhou, J., Zhang, M., Zhang, X., Zhao, W., and Zhao, C. (2018) 'Bidirectionally pH-Responsive Zwitterionic Polymer Hydrogels with Switchable Selective Adsorption Capacities for Anionic and Cationic Dyes', *Industrial & Engineering Chemistry Research,* 57(24), 8209-8219. doi: 10.1021/acs.iecr.8b01027

Weifeng, Z., Yingze, C., Na, L., Yuning, C., and Lin, F. (2014) 'A Novel Solution-Controlled Hydrogel Coated Mesh for Oil/Water Separation based on Monolayer Electrostatic Self-Assembly', *RSC Advances,* 4(93), 51404-51410. doi: 10.1039/C4RA09140J

Wen, Q., Di, J., Jiang, L., Yu, J., and Xu, R. (2013) 'Zeolite-Coated Mesh Film for Efficient Oil-Water Separation', *Chemical Science,* 4(2), 591-595. doi: 10.1039/C2SC21772D

Wu, G., Li, Y., Han, M., and Liu, X. (2006) 'Novel thermo-sensitive membranes prepared by rapid bulk photo-grafting polymerization of N,N-diethylacrylamide onto the microfiltration membranes Nylon', *Journal of Membrane Science,* 283(1–2), 13-20. doi: http://dx.doi.org/10.1016/j.memsci.2006.05.017

Wu, S.-W., Liu, X., Miller, A. L., Cheng, Y.-S., Yeh, M.-L., and Lu, L. (2018) 'Strengthening injectable thermo-sensitive NIPAAm-g-chitosan hydrogels using chemical cross-linking of disulfide bonds as scaffolds for tissue engineering', *Carbohydrate Polymers,* 192, 308-316. doi: https://doi.org/10.1016/j.carbpol.2018.03.047

Wu, Z.-Y., Li, C., Liang, H.-W., Zhang, Y.-N., Wang, X., Chen, J.-F., and Yu, S.-H. (2014) 'Carbon Nanofiber Aerogels for Emergent Cleanup of Oil Spillage and Chemical Leakage Under Harsh Conditions', *Science Reports,* 4(4079), 1-6. doi: 10.1038/srep04079

www.particlescience.com. (2011). Emulsion Stability and Testing. *Technical Brief, 2*.

Xiang, T., Lu, T., Zhao, W.-F., and Zhao, C.-S. (2018) 'Ionic strength- and thermo-responsive polyethersulfone composite membranes with enhanced antifouling properties', *New Journal of Chemistry,* 42(7), 5323-5333. doi: 10.1039/C8NJ00039E

Xiao, X. C. (2007) 'Effect of the Initiator on Thermosensitive Rate of Poly(*N*-isopropylacrylamide) Hydrogels', *eXPRESS Polymer Letters,* 1(4), 232-235. doi: 10.3144/expresspolymlett.2007.35

Xue, B., Gao, L., Hou, Y., Liu, Z., and Jiang, L. (2013a) 'Temperature Controlled Water/Oil Wettability of a Surface Fabricated by a Block Copolymer: Application as a Dual Water/Oil On–Off Switch', *Advanced Materials,* 25(2), 273-277. doi: 10.1002/adma.201202799

Xue, C.-H., Ji, P.-T., Zhang, P., Li, Y.-R., and Jia, S.-T. (2013b) 'Fabrication of Superhydrophobic and Superoleophilic Textiles for Oil–Water Separation', *Applied Surface Science,* 284, 464-471. doi: 10.1016/j.apsusc.2013.07.120

Xue, L., Lu, X., Wei, H., Long, P., Xu, J., and Zheng, Y. (2014) 'Bio-Inspired Self-Cleaning PAAS Hydrogel Released Coating for Marine Antifouling', *Journal of Colloid and Interface Science,* 421(0), 178-183. doi: http://dx.doi.org/10.1016/j.jcis.2013.12.063

Yang, B., and Yang, W. (2003) 'Thermo-sensitive switching membranes regulated by pore-covering polymer brushes', *Journal of Membrane Science,* 218(1), 247-255. doi: http://dx.doi.org/10.1016/S0376-7388(03)00182-0

Yang, C.-L. (2007) 'Electrochemical coagulation for oily water demulsification', *Separation and Purification Technology,* 54(3), 388-395. doi: http://dx.doi.org/10.1016/j.seppur.2006.10.019

Yang, H.-C., Pi, J.-K., Liao, K.-J., Huang, H., Wu, Q.-Y., Huang, X.-J., and Xu, Z.-K. (2014) 'Silica-Decorated Polypropylene Microfiltration Membranes with a Mussel-Inspired Intermediate Layer for Oil-in-Water Emulsion Separation', *ACS Applied Materials & Interfaces,* 6(15), 12566-12572. doi: 10.1021/am502490j

Yang, H., Zhu, H., Hendrix, M. M. R. M., Lousberg, N. J. H. G. M., de With, G., Esteves, A. C. C., and Xin, J. H. (2013) 'Temperature-Triggered Collection and Release of Water from Fogs by a Sponge-Like Cotton Fabric', *Advanced Materials,* 25(8), 1150-1154. doi: 10.1002/adma.201204278

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. doi: 10.1039/c0jm02234a

Yi, X. S., Shi, W. X., S.L.Yu, Ma, C., Sun, N., Wang, S., Jin, L. M., and Sun, L. P. (2011) 'Optimization of complex conditions by response surface methodology

for APAM–oil/water emulsion removal from aqua solutions using nano-sized TiO2/Al2O3 PVDF ultrafiltration membrane', *Journal of Hazardous Materials,* 193, 37-44. doi: http://dx.doi.org/10.1016/j.jhazmat.2011.06.063

Yilmaz, G., Aydogan, B., Temel, G., Arsu, N., Moszner, N., and Yagci, Y. (2010) 'Thioxanthone−Fluorenes as Visible Light Photoinitiators for Free Radical Polymerization', *Macromolecules,* 43(10), 4520-4526. doi: 10.1021/ma100371y

Yoshihiko, M., Masahiro, K., and Suguru, N. (2014) 'Development and future of ultraviolet light-emitting diodes: UV-LED will replace the UV lamp', *Semiconductor Science and Technology,* 29(8), 084004.

Yu, J.-Z., Zhu, L.-P., Zhu, B.-K., and Xu, Y.-Y. (2011a) 'Poly(*N*-isopropylacrylamide) grafted Poly(Vinylidene Fluoride) Copolymers for Temperature-Sensitive Membranes', *Journal of Membrane Science,* 366(1-2), 176-183. doi: 10.1016/j.memsci.2010.09.055

Yu, L., Hao, G., Zhou, S., and Jiang, W. (2016) 'Durable and modified foam for cleanup of oil contamination and separation of oil-water mixtures', *RSC Advances,* 6(29), 24773-24779. doi: 10.1039/C5RA27370F

Yu, Q., Li, X., Zhang, Y., Yuan, L., Zhao, T., and Chen, H. (2011b) 'The synergistic effects of stimuli-responsive polymers with nano- structured surfaces: wettability and protein adsorption', *RSC Advances,* 1(2), 262-269. doi: 10.1039/C1RA00201E

Zhang, L., Li, H., Lai, X., Su, X., Liang, T., and Zeng, X. (2017) 'Thiolated graphene-based superhydrophobic sponges for oil-water separation', *Chemical Engineering Journal,* 316, 736-743. doi: 10.1016/j.cej.2017.02.030

Zhang, R., Liu, Y., He, M., Su, Y., Zhao, X., Elimelech, M., and Jiang, Z. (2016) 'Antifouling membranes for sustainable water purification: strategies and mechanisms', *Chemical Society Reviews,* 45(21), 5888-5924. doi: 10.1039/C5CS00579E

Zhang, W., Liu, N., Zhang, Q., Qu, R., Liu, Y., Li, X., Wei, Y., Feng, L., and Jiang, L. (2018) 'Thermo-Driven Controllable Emulsion Separation by a Polymer-Decorated Membrane with Switchable Wettability', *Angewandte Chemie International Edition,* 57(20), 5740-5745. doi: doi:10.1002/anie.201801736

Zhao, C., Li, X., Li, L., Cheng, G., Gong, X., and Zheng, J. (2013a) 'Dual Functionality of Antimicrobial and Antifouling of Poly(*N*-

hydroxyethylacrylamide)/Salicylate Hydrogels', *Langmuir,* 29(5), 1517-1524. doi: 10.1021/la304511s

Zhao, C., Lin, Z., Yin, H., Ma, Y., Xu, F., and Yang, W. (2014a) 'PEG Molecular Net-Cloth Grafted on Polymeric Substrates and Its Bio-Merits', *Scientific Reports,* 4(4982), 1-7. doi: 10.1038/srep04982

Zhao, C., Zhao, J., Li, X., Wu, J., Chen, S., Chen, Q., Wang, Q., Gong, X., Li, L., and Zheng, J. (2013b) 'Probing Structure–Antifouling Activity Relationships of Polyacrylamides and Polyacrylates', *Biomaterials,* 34(20), 4714-4724. doi: http://dx.doi.org/10.1016/j.biomaterials.2013.03.028

Zhao, J., Han, P., Quan, Q., Shan, Y., Zhang, T., Wang, J., and Xiao, C. (2018) 'A convenient oil-water separator from polybutylmethacrylate/graphene-deposited polyethylene terephthalate nonwoven fabricated by a facile coating method', *Progress in Organic Coatings,* 115(Supplement C), 181-187. doi: https://doi.org/10.1016/j.porgcoat.2017.11.004

Zhao, Y.-F., Zhu, L.-P., Yi, Z., Zhu, B.-K., and Xu, Y.-Y. (2014b) 'Zwitterionic hydrogel thin films as antifouling surface layers of polyethersulfone ultrafiltration membranes anchored via reactive copolymer additive', *Journal of Membrane Science,* 470, 148-158. doi: http://dx.doi.org/10.1016/j.memsci.2014.07.023

Zhao, Z., Li, Z., Xia, Q., Xi, H., and Lin, Y. (2008) 'Fast synthesis of temperature-sensitive PNIPAAm hydrogels by microwave irradiation', *European Polymer Journal,* 44(4), 1217-1224. doi: 10.1016/j.eurpolymj.2008.01.014

Zheng, Y., Liu, Y., and Wang, A. (2011) 'Fast removal of ammonium ion using a hydrogel optimized with response surface methodology', *Chemical Engineering Journal,* 171(3), 1201-1208. doi: 10.1016/j.cej.2011.05.026

Zhong, Q., Chen, Y. Y., Guan, S. L., Fang, Q. S., Chen, T., Muller-Buschbaum, P., and Wang, J. P. (2015) 'Smart cleaning cotton fabrics cross-linked with thermo-responsive and flexible poly(2-(2-methoxyethoxy)ethoxyethyl methacrylate-co-ethylene glycol methacrylate)', *RSC Advances,* 5(48), 38382-38390. doi: 10.1039/C5RA03256C

Zhong, Y.-N., Li, J.-J., Zhang, Q., Zheng-Luo, and Luo, H. (2014) 'Light-Responsive Smart Surface with Controllable Wettability and Excellent Stability', *Langmuir,* 30(41), 12236-12242. doi: 10.1021/la501907w

Zhou, S., Xue, A., Zhang, Y., Li, M., Wang, J., Zhao, Y., and Xing, W. (2014) 'Fabrication of temperature-responsive ZrO2 tubular membranes, grafted with poly (N-isopropylacrylamide) brush chains, for protein removal and easy cleaning', *Journal of Membrane Science,* 450, 351-361. doi: http://dx.doi.org/10.1016/j.memsci.2013.09.011

Zhou, Y.-N., Li, J.-J., and Luo, Z.-H. (2015) 'PhotoATRP-Based Fluorinated Thermosensitive Block Copolymer for Controllable Water/Oil Separation', *Industrial & Engineering Chemistry Research,* 54(43), 10714-10722. doi: 10.1021/acs.iecr.5b02394

Zhu, H., and Guo, Z. (2016) 'Understanding the Separations of Oil/Water Mixtures from Immiscible to Emulsions on Super-wettable Surfaces', *Journal of Bionic Engineering,* 13(1), 1-29. doi: http://dx.doi.org/10.1016/S1672-6529(14)60156-6

Zhu, Y., Wang, D., Jiang, L., and Jin, J. (2014) 'Recent Progress in Developing Advanced Membranes for Emulsified Oil/Water Separation', *NPG Asia Materials,* 6, e101. doi: 10.1038/am.2014.23