SYNTHESIS AND CHARACTERIZATION OF POLY(3,4-ETHYLENEDIOXYTHIOPHENE)-POLY(STYRENESULFONATE) COATED POLYLACTIDE/POLY(3-HYDROXYBUTYRATE-CO-3-HYDROXYVALERATE) ELECTROSPUN MEMBRANES

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This thesis is dedicated to

Dad, Chang Ah Sang,
Mum, Yong Yuet Lian,
Sister, Janice Chang,
Love, Sharon Eng,
Project supervisor, Dr. Naznin
& all my colleagues and friends.

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ABSTRACT

Biomaterials based scaffolds or membranes fabricated from electrospinning with suitable properties are highly desired in tissue engineering. Blending of natural polymer with synthetic polymer allows the modulation of properties to produce membranes for tissue engineering. Recently, conductive polymers have gained great attention in research due to their conductive properties, which can stimulate tissue regeneration. In this study, composite membrane was fabricated by blending a synthetic polymer, polylactic acid (PLA) and a natural polymer, poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV) using electrospinning technique. PLA/PHBV electrospun membranes were dipped into PEDOT:PSS solution to prepare conductive membranes. It was observed that electrospinning of 20 % (w/v) PLA/PHBV with the weight ratio of 50:50 in chloroform solvent produced the most uniform fibers with no beads. The coated and uncoated membranes were evaluated using several techniques, including scanning electron microscopy (SEM), field emission scanning electron microscopy (FESEM), water contact angle (WCA), attenuated total reflectance (ATR), and atomic force microscopy (AFM). The measured electrical conductivity of the 30 % PEDOT:PSS coated PLA/PHBV was 1.45 μS/m. Also, the surface roughness and wettability of the PEDOT:PSS coated PLA/PHBV membranes were greater than the uncoated membranes. Based on the results of the cells viability of human skin fibroblast (HSF) using 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) assay, cell attachment and cell proliferation, the conductive PEDOT:PSS-coated PLA/PHBV membranes were found to be more favorable for tissue engineering application than the uncoated membranes. Antibacterial evaluation also showed that tetracycline hydrochloride (TCH)-coated membrane possess antibacterial properties. In conclusion, conductive PEDOT:PSS coated membrane that has the potential to be used in tissue engineering application was successfully fabricated and characterized.

ABSTRAK

Bahan bio berasaskan perancah atau membran dihasilkan daripada teknik *electrospinning* dengan sifat-sifat yang sesuai adalah sangat dikehendaki dalam bidang kejuruteraan tisu. Penyebatian polimer semula jadi dengan polimer sintetik membolehkan modulasi sifat-sifatnya untuk menghasilkan membran dalam kejuruteraan tisu. Baru-baru ini, polimer konduktif telah mendapat perhatian yang khusus dalam penyelidikan disebabkan sifat konduktif mereka, yang boleh merangsang pertumbuhan semula tisu. Dalam kajian ini, penghasilan membran komposit adalah dengan menggabungkan polimer sintetik, *polylactic acid* (PLA) dan polimer semula jadi, *poly(3-hydroxybutyrate-co-3-hydroxyvalerate)* (PHBV) menggunakan teknik *electrospinning*. Membran PLA/PHBV dicelup ke dalam larutan *poly(3,4-ethylenedioxythiophene)-poly(styrenesulfonate)* (PEDOT:PSS) untuk menghasilkan membrane konduktif. *Electrospinning* 20 % (w/v) PLA/PHBV dalam nisbah 50:50 menghasilkan serat yang lebih seimbang dan tidak bermanik. Membran bersalut dan membran tidak bersalut tersebut dinilai dengan menggunakan beberapa teknik termasuk mikroskopi pengimbas elektron (SEM), mikroskopi pengimbas elektron pancaran medan (FESEM), sudut kontak air (WCA), pengecilan jumplah pantulan (ATR), dan mikrosopi daya atom (AFM). Kekonduksian elektrik yang diukur untuk 30% PEDOT:PSS bersalut PLA/PHBV ialah 1.45 µS/m. Selain itu, kekasaran permukaan dan kebolehbasahan membran PLA/PHBV bersalut PEDOT:PSS adalah lebih tinggi daripada membran tidak bersalut. Keputusan daripada kebolehhidupan sel HSF menggunakan cerakin MTT, lekatan sel dan proliferasi sel menunjukkan bahawa membran PLA/PHBV bersalut PEDOT:PSS adalah lebih sesuai untuk aplikasi kejuruteraan tisu berbanding membran tidak bersalut. Penilaian antibakteria juga menunjukkan bahawa membran bersalut tetrasiklin hidroklorida (TCH) memiliki sifat-sifat anti-bakteria. Kesimpulannya, membran bersalut PEDOT:PSS yang berpotensi untuk digunakan dalam aplikasi kejuruteraan tisu telah berjaya difabrikasi dan dikarakterisasi.

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LIST OF ABBREVIATIONS

AFM	-	Atomic force microscopy
ANOVA	-	Analysis of variance
ATR	-	Attenuated total reflectance
calcein-AM	-	Calcein acetoxymethyl ester
CHA	-	carbonated hydroxyapatite
CMFDA	-	chloromethylfluorescein diacetate
CNT	-	carbon nanotubes
DMEM	-	Dulbecco's Modified Eagle Medium
DMF	-	dimethylformamide
DMSO	-	dimethyl sulfoxide
DNA	-	deoxyribonucleic acid
DSSC	-	dye-sensitized solar cells
ECM	-	extracellular matrix
EDOT	-	ethylenedioxythiphene
EDX	-	Energy dispersive X-ray spectroscopy
EG	-	ethylene glycol
EthD-1	-	Ethidium Homodimer-1
FBS	-	fetal bovine serum
FDA	-	fluorescein diacetate
FESEM	-	Field emission scanning electron microscopy
FPMS	-	flexible pressure mapping system
FTIR	-	Fourier transform infrared spectroscopy
HA	-	Hydroxyapatite
hMSC	-	human mesenchymal stem cells
HSF	-	human skin fibroblast
HV	-	hydroxyvalerate

I	-	iodine
ITO	-	indium tin oxide
L929	-	murine fibroblast cells
LA	-	lactide or lactic acid
MTS	-	3-(4,5-dimethylthiazol-2-yl)-5-(3-carboxymethoxyphenyl)-2-(4-sulfophenyl)-2H-tetrazolium
MTT	-	methylthiazoletetrazolium
NGF	-	neuron growth factor
NSC	-	neural stem cells
ORR	-	oxygen reduction reaction
PAN	-	polyacrylonitrile
PANi	-	polyaniline
PBS	-	phosphate buffer saline
PCL	-	poly(caprolactone)
PDLLA	-	poly(D,L-lactide)
PEDOT	-	Poly(3,4-ethylenedioxythiophene)
PEDOT:PSS	-	Poly(3,4-ethylenedioxythiophene)-poly(styrenesulfonate)
PEG	-	polyethylene glycol
PEO	-	poly(ethylene oxide)
PGA	-	polyglycolic acid
PHA	-	Poly(hydroxyalkanoate)
PHB	-	Poly(3-hydroxybutyrate)
PHBV	-	Poly(hydroxybutyrate-co-valerate)
PLA	-	Poly(lactic acid) or poly(lactide)
PLA or PLLA	-	Poly(L-lactic acid)
PLGA	-	Poly(lactic-co-glycolic acid)
PNB	-	pernigraniline base
POC	-	point-of-care
Ppy	-	polypyrrole
PS	-	polystyrene
PSC	-	polymer solar cells
PSS	-	poly(4-styrenesulfonate)

PTh	-	polythiophene
PVA	-	polyvinyl alcohol
PVF2-TrFE	-	poly(vinylidene fluoride-trifluoroethylene)
RGO	-	reduced graphene oxide
RNA	-	Ribonucleic acid
SC	-	spinal cord
SEM	-	Scanning electron microscopy
SPS	-	sodium polystyrene sulfonate
TCH	-	tetracycline hydrochloride
TCP	-	tricalcium phostphates
UV	-	ultraviolet

LIST OF SYMBOLS

cm	-	centimetre
cP	-	centipoise
g	-	gram
Gpa	-	GigaPascal
Hz	-	Hertz
kV	-	kiloVolt
kΩ	-	kiloOhm
ml	-	millilitre
mm	-	millimetre
Mpa	-	MegaPascal
nm	-	nanometre
v/v	-	volume per total volume
w/v	-	weight per volume
w/w	-	weight per weight
wt%	-	weight percent
°C	-	Degree Celcius
µL	-	microlitre
µm	-	micrometre
µS	-	microSiemens

CHAPTER 1

INTRODUCTION

1.1 Research Background

Tissue engineering has emerged as an alternative method to the conventional methods, which include autografts, allografts, and xenografts, to restore and repair tissue functions. It involves the use of biomaterials as scaffold, cells, and bioactive agents to regenerate and restore damaged tissues.

Various techniques can be used to fabricate biodegradable membranes or scaffolds. These include phase separation (Tu *et al.*, 2003b), self-assembly (Lopes and Jaeger, 2001), freeze drying (Sultana, 2014), and electrospinning (Sill and von Recum, 2008). Recently, electrospinning has been widely researched to produce fibrous scaffolds for tissue engineering purposes. Electrospinning can produce micro- and nanometer-sized electrospun fibers with high surface area and high porosity, that can mimic the cellular environment, hence enhancing cell adhesion and attachment (Tong *et al.*, 2010a). Electrospinning process utilizes electric field to create a charged jet of polymer solution (Doshi and Reneker, 1993). When electrical forces in the solution is balanced by surface tension, a Taylor cone will be formed (Taylor, 1969). By increasing the electric field, the electrostatic forces in the solution will become greater than the surface tension , causing the ejection of a charged fiber jet from the apex of the Taylor cone. The charged fiber jet will then accelerate towards the grounded collector (Hassan *et al.*, 2014). The end product will be the micro- or nano-sized electrospun fibers, also known as electrospun membranes which are collected at the collector (aluminium foil).

Over the past few decades, conductive polymers have been used widely in many applications. They are used in drug delivery system, in the construction of bioactuators, as well as in the tissue engineering field (Ravichandran *et al.*, 2010). Conductive polymers can be sysnthesised alone, or combined with other polymers to form composites. Besides that, they also can be electrospun into microfibers and nanofibers (Balint *et al.*, 2014). Up to date, there are more than 25 types of conductive polymers (Balint *et al.*, 2014). Also, conductive polymers can be modified to be biodegradable and biocompatible, and these make them very useful in tissue engineering applications.

Biocompatible conductive polymers have been researched and used in various biomedical applications (Guimard *et al.*, 2007). Recently, poly(3,4-ethylenedioxythiophene) (PEDOT), a biocompatible conductive polymer, is being researched, to be used as nanobiointerfaces for medical applications, including controlled release of neuron growth factor (NGF), nucleic acid detection, and guided cell growth (Luo *et al.*, 2008). Currently, PEDOT is used in various fields, such as biotechnology and biomedicine due to its properties of high electrical conductivity and chemical stability (Ravichandran *et al.*, 2010). In order to obtain a water soluble polyelectrolyte system with good film-forming properties, PEDOT is doped with poly(4-styrenesulfonate) (PSS) (Groenendaal *et al.*, 2000). This copolymer has good stability and a moderate band gap in the doping state (Schweizer, 2005).

PEDOT:PSS had received great attention from researchers owing to its electrochemical, thermal, and oxidative stability. These properties allow PEDOT:PSS to be used in wide applications in areas such as flexible electrodes, nanocomposites, electrochromical displays, transistors (Chen *et al.*, 2002; Heuer *et al.*, 2002; Daoud *et al.*, 2005; Reddy *et al.*, 2010). In addition, due to its good oxidative stability, there has been an increased interest in PEDOT for biomedical applications (Owens and

Malliaras, 2010). Positive results had shown that conductive polymer scaffolds made from PEDOT:PSS are structurally suitable for bone tissue engineering (Shahini *et al.*, 2014).

In this study, a novel conductive membrane was fabricated using PEDOT:PSS, PLA and PHBV using an established electrospinning protocol. PLA is a Food and Drug Administration (FDA) approved biodegradable and biocompatible polymer to be used in biomedical applications. Meanwhile, PHBV is biocompatible with blood and tissue (Duan *et al.*, 2010). In addition, PEDOT:PSS can enhance cellular response (Shahini et al., 2014). In this research, the fabrication of PLA/PHBV membrane at different blend ratios was reported. The composition of 50:50 PLA/PHBV was found to be suitable to fabricate beadles and uniform fibers. Next, to render the membrane conductive, it was coated with PEDOT:PSS. The conductive membrane was then characterized using Scanning electron microscopy (SEM), Field emission scanning electron microscopy (FESEM), Energy dispersive X-ray spectroscopy (EDX), Attenuated total reflectance (ATR), contact angle measurements, porosity measurements, Atomic force microscopy (AFM), and electrical resistance and conductivity measurements. The fabricated membranes were also tested for *in vitro* cell cytotoxicity, cell adhesion, and cell proliferation using human skin fibroblast (HSF) cells. Also, tetracycline hydrochloride (TCH) was incorporated to the membranes and tested against *Staphylococcus aureus* (*S. aureus)*(Gram-positive bacteria) and *Escherichia coli* (*E. coli)* (Gram-negative bacteria).

1.2 Problem Statement

By using different combinations of biomaterials, cells, and bioactive agents, tissue engineering aims to heal or regenerate injured tissue. Therefore, in this field, it is important to produce a biodegradable scaffold that serves as a temporary and artificial extracellular matrix (ECM) for the growing cell. Also, scaffold serves as a reservoir to deliver bioactive agents to promote regeneration of the injured tissues

(Goh *et al.*, 2013). PHBV is hydrophobic and has a very slow degradation rate, which limit their practical applications. Meanwhile, PLA is a biodegradable and biocompatible polymer and has been approved by the US Food and Drug Administration (FDA) for human use (Marin *et al.*, 2013). By blending PHBV with PLA, its degradation properties will be improved. Studies had shown that the blending of PHBV and PLA improved the biocompatibility and wettability of the electrospun polymer scaffolds compared to the electrospun PLA fibre (Feng *et al.*, 2011).

On the other hand, the conductive nature of the conducting polymer will allow the cells or tissues cultured upon them to be stimulated (Balint *et al.*, 2014). PEDOT:PSS is hydrophilic and possess conductivity properties. Hence, in this research, the conducting polymer, PEDOT:PSS was coated into the PLA/PHBV electrospun membranes to further enhance the surface properties, including conductivity and wettability, of the membranes to be used in tissue engineering applications.

For skin tissue engineering application, scaffolds with antibacterial properties are important to prevent inflammation and infection of wound. Therefore, in this study, the fabricated membranes were loaded with antibacterial agent, TCH which are essential to inhibit bacteria growth on wound prior to skin regeneration.

1.3 Objectives

i. To fabricate PLA, PHBV and PLA/PHBV membranes using electrospinning technique and, to fabricate conductive membrane by coating PEDOT:PSS on PLA/PHBV membrane.
ii. To characterize the morphology, chemical, and conductivity properties of the electrospun membranes and PEDOT:PSS coated membrane.

iii. To evaluate potential use of PLA/PHBV and PEDOT:PSS coated PLA/PHBV membranes in tissue engineering via *in vitro* biological assessment using HSF cells.

iv. To coat tetracycline hydrochloride (TCH) drug into the fabricated membranes and investigate their antibacterial properties.

1.4 Scope

In this research, PLA, PHBV and PLA/PHBV electrospun membranes were fabricated using electrospinning technique by varying electrospinning parameters (voltage, distance between needle-tip to collector, flow rate). Also, PEDOT:PSS was coated into the optimized PLA/PHBV electrospun membranes. Characterization of both PLA/PHBV and PEDOT:PSS coated PLA/PHBV electrospun membranes were carried out using several techniques. The characterization include fiber morphology (SEM and FESEM), wettability (water contact angle), water uptake, density and porosity measurement, chemical bonding analysis (ATR), surface roughness (AFM), and conductivity test. *In vitro* cell cytotoxicity, cell adhesion and cell proliferation were also studied using human skin fibroblast (HSF). Tetracycline hydrochloride drug was incorporated into PLA/PHBV and PEDOT:PSS coated PLA/PHBV electrospun membranes by dipping method and were tested for antibacterial properties against *S. aureus* (Gram-positive bacteria) and *E. coli* (Gram-negative bacteria).

1.5 Significance of Research

In this study, PEDOT:PSS coated PLA/PHBV membranes were fabricated for tissue engineering applicatio. As far as we are concerned, no other research group had fabricated PEDOT:PSS coated electrospun membrane using the similar approach. PEDOT:PSS is hydrophilic and conductive, allowing the coated membranes to be more favorable for cellular adhesion and proliferation. The *in vitro* biological evaluation results of this study demonstrated an increase in human skin fibroblast (HSF) cell adhesion and proliferation on PEDOT:PSS coated membrane compared to the non-coated membrane, providing insight of using different cells and carrying out *in vivo* evaluation in future studies.

REFERENCES

Agarwal, S., Wendorff, J. H. and Greiner, A. (2008). Use of electrospinning technique for biomedical applications. *Polymer*. 49(26),5603-5621.

Al-Shammari, B., Al-Fariss, T., Al-Sewailm, F. and Elleithy, R. (2011). The effect of polymer concentration and temperature on the rheological behavior of metallocene linear low density polyethylene (mLLDPE) solutions. *Journal of King Saud University - Engineering Sciences*. 23(1),9-14.

Annis, D., Bornat, A., Edwards, R., Higham, A., Loveday, B. and Wilson, J. (1978). An elastomeric vascular prosthesis. *ASAIO Journal*. 24(1),209-214.

Ashizawa, S., Horikawa, R. and Okuzaki, H. (2005). Effects of solvent on carrier transport in poly(3,4-ethylenedioxythiophene)/poly(4-styrenesulfonate). *Synthetic Metals*. 153(1–3),5-8.

Asplund, M., Thaning, E., Lundberg, J., Sandberg-Nordqvist, A., Kostyszyn, B. and von Holst, H. (2009). Toxicity evaluation of PEDOT/biomolecular composites intended for neural communication electrodes. *Biomedical Materials*. 4(4),045009.

Ateh, D., Navsaria, H. and Vadgama, P. (2006). Polypyrrole-based conducting polymers and interactions with biological tissues. *Journal of the royal society interface*. 3(11),741-752.

Avella, M., Martuscelli, E. and Raimo, M. (2000). Review Properties of blends and composites based on poly (3-hydroxy) butyrate (PHB) and poly (3-hydroxybutyrate-hydroxyvalerate)(PHBV) copolymers. *Journal of Materials Science*. 35(3),523-545.

Aznar-Cervantes, S., Roca, M. I., Martinez, J. G., Meseguer-Olmo, L., Cenis, J. L., Moraleda, J. M. and Otero, T. F. (2012). Fabrication of conductive electrospun silk fibroin scaffolds by coating with polypyrrole for biomedical applications. *Bioelectrochemistry*. 85(0),36-43.

Baek, K., Hwang, I., Roy, I., Shetty, D. and Kim, K. (2015). Self-Assembly of Nanostructured Materials through Irreversible Covalent Bond Formation. *Accounts of chemical research*.

Balint, R., Cassidy, N. J. and Cartmell, S. H. (2014). Conductive polymers: Towards a smart biomaterial for tissue engineering. *Acta Biomaterialia*. 10(6),2341-2353.

Baumgarten, P. K. (1971). Electrostatic spinning of acrylic microfibers. *Journal of Colloid and Interface Science*. 36(1),71-79.

Benhabbour, S. R., Sheardown, H. and Adronov, A. (2008). Cell adhesion and proliferation on hydrophilic dendritically modified surfaces. *Biomaterials*. 29(31),4177-4186.

Berger, J., Reist, M., Mayer, J. M., Felt, O., Peppas, N. A. and Gurny, R. (2004). Structure and interactions in covalently and ionically crosslinked chitosan hydrogels for biomedical applications. *European Journal of Pharmaceutics and Biopharmaceutics*. 57(1),19-34.

Bettinger, C. J., Bruggeman, J. P., Misra, A., Borenstein, J. T. and Langer, R. (2009). Biocompatibility of biodegradable semiconducting melanin films for nerve tissue engineering. *Biomaterials*. 30(17),3050-3057.

Bhakta, S., Pattanayak, D. K., Takadama, H., Kokubo, T., Miller, C. A., Mirsaneh, M., Reaney, I. M., Brook, I., van Noort, R. and Hatton, P. V. (2010). Prediction of osteoconductive activity of modified potassium fluorrichterite glass-ceramics by immersion in simulated body fluid. *Journal of Materials Science: Materials in Medicine*. 21(11),2979-2988.

Bhardwaj, N. and Kundu, S. C. (2010). Electrospinning: A fascinating fiber fabrication technique. *Biotechnology Advances*. 28(3),325-347.

Bianco, A., Calderone, M. and Cacciotti, I. (2013). Electrospun PHBV/PEO co-solution blends: Microstructure, thermal and mechanical properties. *Materials Science and Engineering: C*. 33(3),1067-1077.

Bingger, P., Zens, M. and Woias, P. (2012). Highly flexible capacitive strain gauge for continuous long-term blood pressure monitoring. *Biomedical microdevices*. 14(3),573-581.

Blackwood, K. A., McKean, R., Canton, I., Freeman, C. O., Franklin, K. L., Cole, D., Brook, I., Farthing, P., Rimmer, S. and Haycock, J. W. (2008). Development of biodegradable electrospun scaffolds for dermal replacement. *Biomaterials*. 29(21),3091-3104.

Boateng, J. S., Matthews, K. H., Stevens, H. N. and Eccleston, G. M. (2008). Wound healing dressings and drug delivery systems: a review. *Journal of pharmaceutical sciences*. 97(8),2892-2923.

Bölgen, N., Vargel, I., Korkusuz, P., Menceloğlu, Y. Z. and Pişkin, E. (2007). In vivo performance of antibiotic embedded electrospun PCL membranes for prevention of abdominal adhesions. *Journal of Biomedical Materials Research Part B: Applied Biomaterials*. 81(2),530-543.

Borhani, S., Etemad, S. G. and Ravandi, S. A. H. (2011). Dynamic heat and moisture transfer in bulky PAN nanofiber mats. *Heat and mass transfer*. 47(7),807-811.

Böttcher-Haberzeth, S., Biedermann, T. and Reichmann, E. (2010). Tissue engineering of skin. *Burns*. 36(4),450-460.

Bousalem, S., Mangeney, C., Chehimi, M. M., Basinska, T., Miksa, B. and Slomkowski, S. (2004). Synthesis, characterization and potential biomedical applications of N-succinimidyl ester functionalized, polypyrrole-coated polystyrene latex particles. *Colloid and Polymer Science*. 282(12),1301-1307.

Caeiro, J., González, P., Guede, D., de Base Tecnológica, T.-E. and Ourense-España, S. (2013). Biomechanics and bone (& II): Trials in different hierarchical levels of bone and alternative tools for the determination of bone strength. *Rev Osteoporos Metab Miner*. 5(2),99-108.

Casper, C. L., Stephens, J. S., Tassi, N. G., Chase, D. B. and Rabolt, J. F. (2004). Controlling surface morphology of electrospun polystyrene fibers: effect of humidity and molecular weight in the electrospinning process. *Macromolecules*. 37(2),573-578.

Ceruso, M., Taddei, F., Bigazzi, P. and Manfrini, M. (2008). Vascularised fibula graft inlaid in a massive bone allograft: considerations on the bio-mechanical behaviour of the combined graft in segmental bone reconstructions after sarcoma resection. *Injury*. 39(3),68-74.

Chan, B. P. and Leong, K. W. (2008). Scaffolding in tissue engineering: general approaches and tissue-specific considerations. *European Spine Journal*. 17(4),467-479.

Chandrasekaran, A. R., Venugopal, J., Sundarrajan, S. and Ramakrishna, S. (2011). Fabrication of a nanofibrous scaffold with improved bioactivity for culture of human dermal fibroblasts for skin regeneration. *Biomedical Materials*. 6(1),015001.

Chang, H.-I. and Wang, Y. (2011). *Cell responses to surface and architecture of tissue engineering scaffolds*INTECH Open Access Publisher.

Chen, G.-Q. and Wu, Q. (2005). The application of polyhydroxyalkanoates as tissue engineering materials. *Biomaterials*. 26(33),6565-6578.

Chen, H., Huang, J., Yu, J., Liu, S. and Gu, P. (2011). Electrospun chitosan-graft-poly (ε-caprolactone)/poly (ε-caprolactone) cationic nanofibrous mats as potential scaffolds for skin tissue engineering. *International journal of biological macromolecules*. 48(1),13-19.

Chen, H., Truckenmuller, R., Blitterswijk, v. C., Moroni, L., Gaharwar, A., Sant, S., Hancock, M. and Hacking, A. (2013). Fabrication of nanofibrous scaffolds for tissue engineering applications. *Nanomaterials in tissue engineering: Fabrication and applications*,158-182.

Chen, M., Nilsson, D., Kugler, T., Berggren, M. and Remonen, T. (2002). Electric current rectification by an all-organic electrochemical device. *Applied Physics Letters*. 81(11),2011-2013.

Chen, Q.-Z., Harding, S. E., Ali, N. N., Lyon, A. R. and Boccaccini, A. R. (2008). Biomaterials in cardiac tissue engineering: Ten years of research survey. *Materials Science and Engineering: R: Reports*. 59(1–6),1-37.

Chen, S. J., Wang, D. Y., Yuan, C. W., Wang, X. D., Zhang, P. Y. and Gu, X. S. (2000). Template synthesis of the polypyrrole tube and its bridging in vivo sciatic nerve regeneration. *Journal of Materials Science Letters*. 19(23),2157-2159.

Cheng, M.-L., Sun, Y.-M., Chen, H. and Jean, Y. C. (2009). Change of structure and free volume properties of semi-crystalline poly(3-hydroxybutyrate-co-3-hydroxyvalerate) during thermal treatments by positron annihilation lifetime. *Polymer*. 50(8),1957-1964.

Chew, S. Y., Wen, J., Yim, E. K. and Leong, K. W. (2005). Sustained release of proteins from electrospun biodegradable fibers. *Biomacromolecules*. 6(4),2017-2024.

Choi, E. J., Son, B., Hwang, T. S. and Hwang, E.-H. (2011). Increase of degradation and water uptake rate using electrospun star-shaped poly (D, L-lactide) nanofiber. *Journal of Industrial and Engineering Chemistry*. 17(4),691-695.

Chong, E., Phan, T., Lim, I., Zhang, Y., Bay, B., Ramakrishna, S. and Lim, C. (2007). Evaluation of electrospun PCL/gelatin nanofibrous scaffold for wound healing and layered dermal reconstitution. *Acta biomaterialia*. 3(3),321-330.

Chong, L. H., Hassan, M. I. and Sultana, N. (2015). Electrospun Polycaprolactone (PCL) and PCL/nano-hydroxyapatite (PCL/nHA)-based nanofibers for bone tissue engineering application. *Control Conference (ASCC), 2015 10th Asian*. 31May - 3June. Kota Kinabalu, 1-4.

Chronakis, I. S., Grapenson, S. and Jakob, A. (2006). Conductive polypyrrole nanofibers via electrospinning: Electrical and morphological properties. *Polymer*. 47(5),1597-1603.

Chung, T.-W., Liu, D.-Z., Wang, S.-Y. and Wang, S.-S. (2003). Enhancement of the growth of human endothelial cells by surface roughness at nanometer scale. *Biomaterials*. 24(25),4655-4661.

Couves, L. D. and Porter, S. J. (1989). Polypyrrole as a potentiometric glucose sensor. *Synthetic Metals*. 28(1–2),761-768.

Cruz, S., Viana, J., Dias, D. H. and Rocha, L. (2014). Pressure sensing platform for health monitoring. *Medical Measurements and Applications (MeMeA), 2014 IEEE International Symposium on*. 11-12 June. Lisboa, 1-5.

Cui, W., Li, X., Zhou, S. and Weng, J. (2007). Investigation on process parameters of electrospinning system through orthogonal experimental design. *Journal of applied polymer science*. 103(5),3105-3112.

Daoud, W. A., Xin, J. H. and Szeto, Y. S. (2005). Polyethylenedioxythiophene coatings for humidity, temperature and strain sensing polyamide fibers. *Sensors and Actuators B: Chemical*. 109(2),329-333.

Dawson, J. I. and Oreffo, R. O. C. (2008). Bridging the regeneration gap: Stem cells, biomaterials and clinical translation in bone tissue engineering. *Archives of Biochemistry and Biophysics*. 473(2),124-131.

De Vrieze, S., Van Camp, T., Nelvig, A., Hagström, B., Westbroek, P. and De Clerck, K. (2009). The effect of temperature and humidity on electrospinning. *Journal of materials science*. 44(5),1357-1362.

Deitzel, J., Kleinmeyer, J., Harris, D. and Tan, N. B. (2001). The effect of processing variables on the morphology of electrospun nanofibers and textiles. *Polymer*. 42(1),261-272.

den Boer, F. C., Wippermann, B. W., Blokhuis, T. J., Patka, P., Bakker, F. C. and Haarman, H. J. T. M. (2003). Healing of segmental bone defects with granular porous hydroxyapatite augmented with recombinant human osteogenic protein-I or autologous bone marrow. *Journal of orthopaedic research*. 21(3),521-528.

Desai, K., Kit, K., Li, J. and Zivanovic, S. (2008). Morphological and surface properties of electrospun chitosan nanofibers. *Biomacromolecules*. 9(3),1000-1006.

Dhandayuthapani, B., Yoshida, Y., Maekawa, T. and Kumar, D. S. (2011). Polymeric scaffolds in tissue engineering application: a review. *International Journal of Polymer Science*. 2011.

Díaz-de León, M. J. (2001). Electrospinning nanofibers of polyaniline and polyaniline/(polystyrene and polyethylene oxide) blends. *Proceeding of The National Conference on Undergraduate Research (NCUR), University of Kentucky*. 15-17 March. Lexington, 15-17.

Diefenbeck, M., Mückley, T. and Hofmann, G. O. (2006). Prophylaxis and treatment of implant-related infections by local application of antibiotics. *Injury*. 37(2, Supplement),S95-S104.

Doshi, J. and Reneker, D. H. (1993). Electrospinning process and applications of electrospun fibers. *Industry Applications Society Annual Meeting, 1993., Conference Record of the 1993 IEEE*. 2-8 Oct. Toronto, 1698-1703.

Draghi, L., Resta, S., Pirozzolo, M. and Tanzi, M. (2005). Microspheres leaching for scaffold porosity control. *Journal of materials science: materials in medicine*. 16(12),1093-1097.

Duan, B., Wang, M., Zhou, W. Y., Cheung, W. L., Li, Z. Y. and Lu, W. W. (2010). Three-dimensional nanocomposite scaffolds fabricated via selective laser sintering for bone tissue engineering. *Acta Biomaterialia*. 6(12),4495-4505.

Feng, S., Shen, X., Fu, Z. and Shao, M. (2011). Preparation and Characterization of Gelatin–Poly(L-lactic) Acid/Poly(hydroxybutyrate-co-hydroxyvalerate) Composite Nanofibrous Scaffolds. *Journal of Macromolecular Science, Part B*. 50(9),1705-1713.

Fonder, M. A., Lazarus, G. S., Cowan, D. A., Aronson-Cook, B., Kohli, A. R. and Mamelak, A. J. (2008). Treating the chronic wound: A practical approach to the care of nonhealing wounds and wound care dressings. *Journal of the American Academy of Dermatology*. 58(2),185-206.

Fonner, J. M., Forciniti, L., Nguyen, H., Byrne, J. D., Kou, Y.-F., Syeda-Nawaz, J. and Schmidt, C. E. (2008). Biocompatibility implications of polypyrrole synthesis techniques. *Biomedical Materials*. 3(3),034124.

Formhals, A. (1934). Process and apparatus for preparing artificial threads. US 1975504.

Formhals, A. (1939). Process and apparatus for spinning. US 2169962.

Formhals, A. (1940). Artificial thread and method of producing same. US 2187306.

Garner, B., Georgevich, A., Hodgson, A. J., Liu, L. and Wallace, G. G. (1999). Polypyrrole–heparin composites as stimulus-responsive substrates for endothelial cell growth. *Journal of Biomedical Materials Research*. 44(2),121-129.

Gauglitz, G. G. and Schauber, J. (2013). *Skin: architecture and Function*. In. *Dermal Replacements in General, Burn, and Plastic Surgery*. (1-11). Springer.

George, P. M., Saigal, R., Lawlor, M. W., Moore, M. J., LaVan, D. A., Marini, R. P., Selig, M., Makhni, M., Burdick, J. A., Langer, R. and Kohane, D. S. (2009). Three-dimensional conductive constructs for nerve regeneration. *Journal of Biomedical Materials Research Part A*. 91A(2),519-527.

Gérard, T. and Budtova, T. (2011). PLA-PHA blends: morphology, thermal and mechanical properties. *International Conference on Biodegradable and Biobased Polymers-BIOPOL 2011*.

Ghasemi-Mobarakeh, L., Prabhakaran, M. P., Morshed, M., Nasr-Esfahani, M.-H. and Ramakrishna, S. (2008). Electrospun poly(ε-caprolactone)/gelatin nanofibrous scaffolds for nerve tissue engineering. *Biomaterials*. 29(34),4532-4539.

Ghasemi-Mobarakeh, L., Prabhakaran, M. P., Morshed, M., Nasr-Esfahani, M. H., Baharvand, H., Kiani, S., Al-Deyab, S. S. and Ramakrishna, S. (2011). Application of conductive polymers, scaffolds and electrical stimulation for nerve tissue engineering. *Journal of tissue engineering and regenerative medicine*. 5(4),e17-e35.

Gilliland, E., Nathwani, N., Dore, C. and Lewis, J. (1988). Bacterial colonisation of leg ulcers and its effect on the success rate of skin grafting. *Annals of the Royal College of Surgeons of England*. 70(2),105.

Goh, Y. F., Shakir, I. and Hussain, R. (2013). Electrospun fibers for tissue engineering, drug delivery, and wound dressing. *Journal of Materials Science*. 48(8),3027-3054.

Gomes, M. E. and Reis, R. L. (2004). Tissue engineering: key elements and some trends. *Macromolecular bioscience*. 4(8),737-742.

Griffith, L. G. (2002). Emerging design principles in biomaterials and scaffolds for tissue engineering. *Annals of the New York Academy of Sciences*. 961(1),83-95.

Groenendaal, L., Jonas, F., Freitag, D., Pielartzik, H. and Reynolds, J. R. (2000). Poly(3,4-ethylenedioxythiophene) and Its Derivatives: Past, Present, and Future. *Advanced Materials*. 12(7),481-494.

Guan, G., Yang, Z., Qiu, L., Sun, X., Zhang, Z., Ren, J. and Peng, H. (2013). Oriented PEDOT: PSS on aligned carbon nanotubes for efficient dye-sensitized solar cells. *Journal of Materials Chemistry A*. 1(42),13268-13273.

Guan, J., Fujimoto, K. L., Sacks, M. S. and Wagner, W. R. (2005). Preparation and characterization of highly porous, biodegradable polyurethane scaffolds for soft tissue applications. *Biomaterials*. 26(18),3961-3971.

Gui-Bo, Y., You-Zhu, Z., Shu-Dong, W., De-Bing, S., Zhi-Hui, D. and Wei-Guo, F. (2010). Study of the electrospun PLA/silk fibroin-gelatin composite nanofibrous scaffold for tissue engineering. *Journal of Biomedical Materials Research Part A*. 93(1),158-163.

Guimard, N. K., Gomez, N. and Schmidt, C. E. (2007). Conducting polymers in biomedical engineering. *Progress in Polymer Science*. 32(8–9),876-921.

Gunn, J. and Zhang, M. (2010). Polyblend nanofibers for biomedical applications: perspectives and challenges. *Trends in Biotechnology*. 28(4),189-197.

Guo, Z., Jiang, C., Teng, C., Ren, G., Zhu, Y. and Jiang, L. (2014). Sulfur, Trace Nitrogen and Iron Codoped Hierarchically Porous Carbon Foams as Synergistic Catalysts for Oxygen Reduction Reaction. *ACS applied materials & interfaces*. 6(23),21454-21460.

Guo, Z., Qiao, Y., Liu, H., Ding, C., Zhu, Y., Wan, M. and Jiang, L. (2012). Self-assembled hierarchical micro/nano-structured PEDOT as an efficient oxygen reduction catalyst over a wide pH range. *Journal of Materials Chemistry*. 22(33),17153-17158.

Haroosh, H. J., Dong, Y. and Lau, K.-T. (2014). Tetracycline hydrochloride (TCH)-loaded drug carrier based on PLA: PCL nanofibre mats: experimental characterisation and release kinetics modelling. *Journal of Materials Science*. 49(18),6270-6281.

Hassan, M. I., Sun, T. and Sultana, N. (2014). Fabrication of Nanohydroxyapatite/Poly(caprolactone) Composite Microfibers Using Electrospinning Technique for Tissue Engineering Applications. *Journal of Nanomaterials*. 2014,7.

Heuer, H. W., Wehrmann, R. and Kirchmeyer, S. (2002). Electrochromic Window Based on Conducting Poly(3,4-ethylenedioxythiophene)–Poly(styrene sulfonate). *Advanced Functional Materials*. 12(2),89-94.

Homayoni, H., Ravandi, S. A. H. and Valizadeh, M. (2009). Influence of the molecular weight of chitosan on the spinnability of chitosan/poly (vinyl alcohol) blend nanofibers. *Journal of applied polymer science*. 113(4),2507-2513.

Hong, K. H., Woo, S. H. and Kang, T. J. (2012). In vitro degradation and drug-release behavior of electrospun, fibrous webs of poly(lactic-co-glycolic acid). *Journal of Applied Polymer Science*. 124(1),209-214.

Hong, Y., Fujimoto, K., Hashizume, R., Guan, J., Stankus, J. J., Tobita, K. and Wagner, W. R. (2008). Generating elastic, biodegradable polyurethane/poly (lactide-co-glycolide) fibrous sheets with controlled antibiotic release via two-stream electrospinning. *Biomacromolecules*. 9(4),1200-1207.

Hou, Z. Y., Li, C. X., Ma, P. A., Cheng, Z. Y., Li, X. J., Zhang, X., Dai, Y. L., Yang, D. M., Lian, H. Z. and Lin, J. (2012). Up-Conversion Luminescent and Porous NaYF4:Yb3+, Er3+@SiO2 Nanocomposite Fibers for Anti-Cancer Drug Delivery and Cell Imaging. *Advanced Functional Materials*. 22(13),2713-2722.

Hsu, Y. Y., Gresser, J. D., Trantolo, D. J., Lyons, C. M., Gangadharam, P. R. and Wise, D. L. (1997). Effect of polymer foam morphology and density on kinetics of in vitro controlled release of isoniazid from compressed foam matrices. *Journal of biomedical materials research*. 35(1),107-116.

Huang, Y., Ren, J., Chen, C., Ren, T. and Zhou, X. (2007). Preparation and properties of poly (lactide-co-glycolide)(PLGA)/nano-hydroxyapatite (NHA) scaffolds by thermally induced phase separation and rabbit MSCs culture on scaffolds. *Journal of biomaterials applications*.

Humpolicek, P., Kasparkova, V., Saha, P. and Stejskal, J. (2012). Biocompatibility of polyaniline. *Synthetic Metals*. 162(7–8),722-727.

Hutmacher, D. W. (2000). Scaffolds in tissue engineering bone and cartilage. *Biomaterials*. 21(24),2529-2543.

Jiang, T., Nukavarapu, S. P., Deng, M., Jabbarzadeh, E., Kofron, M. D., Doty, S. B., Abdel-Fattah, W. I. and Laurencin, C. T. (2010). Chitosan–poly (lactide-co-glycolide) microsphere-based scaffolds for bone tissue engineering: In vitro degradation and in vivo bone regeneration studies. *Acta Biomaterialia*. 6(9),3457-3470.

Jin, H.-J., Chen, J., Karageorgiou, V., Altman, G. H. and Kaplan, D. L. (2004). Human bone marrow stromal cell responses on electrospun silk fibroin mats. *Biomaterials*. 25(6),1039-1047.

Joseph, L. L. (2009). *Characterization and Modification of Porosity in Electrospun Polymeric Materials for Tissue Engineering Applications*. Doctor of Philosophy, Massachusetts Institute Of Technology.

Kara, M. O. P. and Frey, M. W. (2014). Effects of solvents on the morphology and conductivity of poly(3,4-ethylenedioxythiophene):Poly(styrenesulfonate) nanofibers. *Journal of Applied Polymer Science*. 131(11),n/a-n/a.

Karagkiozaki, V., Karagiannidis, P. G., Gioti, M., Kavatzikidou, P., Georgiou, D., Georgaraki, E. and Logothetidis, S. (2013). Bioelectronics meets nanomedicine for cardiovascular implants: PEDOT-based nanocoatings for tissue regeneration. *Biochimica et Biophysica Acta (BBA) - General Subjects*. 1830(9),4294-4304.

Karp, J. M. and Langer, R. (2007). Development and therapeutic applications of advanced biomaterials. *Current Opinion in Biotechnology*. 18(5),454-459.

Katti, D. S., Robinson, K. W., Ko, F. K. and Laurencin, C. T. (2004). Bioresorbable nanofiber-based systems for wound healing and drug delivery: Optimization of fabrication parameters. *Journal of Biomedical Materials Research Part B-Applied Biomaterials*. 70B(2),286-296.

Kelm, J. M., Lorber, V., Snedeker, J. G., Schmidt, D., Broggini-Tenzer, A., Weisstanner, M., Odermatt, B., Mol, A., Zünd, G. and Hoerstrup, S. P. (2010). A novel concept for scaffold-free vessel tissue engineering: Self-assembly of microtissue building blocks. *Journal of Biotechnology*. 148(1),46-55.

Kenawy, E.-R., Bowlin, G. L., Mansfield, K., Layman, J., Simpson, D. G., Sanders, E. H. and Wnek, G. E. (2002). Release of tetracycline hydrochloride from electrospun poly (ethylene-co-vinylacetate), poly (lactic acid), and a blend. *Journal of controlled release*. 81(1),57-64.

Kim, B.-S. and Mooney, D. J. (1998). Development of biocompatible synthetic extracellular matrices for tissue engineering. *Trends in Biotechnology*. 16(5),224-230.

Kim, C. H., Khil, M. S., Kim, H. Y., Lee, H. U. and Jahng, K. Y. (2006). An improved hydrophilicity via electrospinning for enhanced cell attachment and proliferation. *Journal of Biomedical Materials Research Part B: Applied Biomaterials*. 78(2),283-290.

Kim, D. H., Richardson-Burns, S. M., Hendricks, J. L., Sequera, C. and Martin, D. C. (2007). Effect of immobilized nerve growth factor on conductive polymers: electrical properties and cellular response. *Advanced Functional Materials*. 17(1),79-86.

Kim, H.-S., Hobbs, H. L., Wang, L., Rutten, M. J. and Wamser, C. C. (2009). Biocompatible composites of polyaniline nanofibers and collagen. *Synthetic Metals*. 159(13),1313-1318.

Kimtan, T., Thupmongkol, J., Williams, J. C. and Thongpang, S. (2014). Printable and transparent micro-electrocorticography (μECoG) for optogenetic applications. *Engineering in Medicine and Biology Society (EMBC), 2014 36th Annual International Conference of the IEEE*. 482-485.

Koh, H. S., Yong, T., Chan, C. K. and Ramakrishna, S. (2008). Enhancement of neurite outgrowth using nano-structured scaffolds coupled with laminin. *Biomaterials*. 29(26),3574-3582.

Köse, G. T., Kenar, H., Hasırcı, N. and Hasırcı, V. (2003). Macroporous poly(3-hydroxybutyrate-co-3-hydroxyvalerate) matrices for bone tissue engineering. *Biomaterials*. 24(11),1949-1958.

Kumar, S., Kumar, S., Srivastava, S., Yadav, B. K., Lee, S. H., Sharma, J. G., Doval, D. C. and Malhotra, B. D. (2015). Reduced graphene oxide modified smart conducting paper for Cancer biosensor. *Biosensors and Bioelectronics*.
Lang, U., Naujoks, N. and Dual, J. (2009). Mechanical characterization of PEDOT: PSS thin films. *Synthetic Metals*. 159(5),473-479.

Langer, R. and Tirrell, D. A. (2004). Designing materials for biology and medicine. *Nature*. 428(6982),487-492.

Langer, R. and Vacanti, J. P. (1993). Tissue engineering. *Science*. 260(5110),920-926.

Lee, J.-W., Serna, F., Nickels, J. and Schmidt, C. E. (2006). Carboxylic acid-functionalized conductive polypyrrole as a bioactive platform for cell adhesion. *Biomacromolecules*. 7(6),1692-1695.

Leong, M. F., Chan, W. Y., Chian, K. S., Rasheed, M. Z. and Anderson, J. M. (2010). Fabrication and in vitro and in vivo cell infiltration study of a bilayered cryogenic electrospun poly (D, L-lactide) scaffold. *Journal of Biomedical Materials Research Part A*. 94(4),1141-1149.

Li, M., Guo, Y., Wei, Y., MacDiarmid, A. G. and Lelkes, P. I. (2006). Electrospinning polyaniline-contained gelatin nanofibers for tissue engineering applications. *Biomaterials*. 27(13),2705-2715.

Li, W. J., Laurencin, C. T., Caterson, E. J., Tuan, R. S. and Ko, F. K. (2002). Electrospun nanofibrous structure: a novel scaffold for tissue engineering. *Journal of biomedical materials research*. 60(4),613-621.

Li, X., Liu, K. L., Wang, M., Wong, S. Y., Tjiu, W. C., He, C. B., Goh, S. H. and Li, J. (2009). Improving hydrophilicity, mechanical properties and biocompatibility of poly[(R)-3-hydroxybutyrate-co-(R)-3-hydroxyvalerate] through blending with poly[(R)-3-hydroxybutyrate]-alt-poly(ethylene oxide). *Acta Biomaterialia*. 5(6),2002-2012.

Li, Y., Neoh, K. G. and Kang, E.-T. (2004). Plasma protein adsorption and thrombus formation on surface functionalized polypyrrole with and without electrical stimulation. *Journal of Colloid and Interface Science*. 275(2),488-495.

Li, Y., Wang, Y., Wu, D., Zhang, K. and Hu, Q. (2010). A facile approach to construct three-dimensional oriented chitosan scaffolds with in-situ precipitation method. *Carbohydrate Polymers*. 80(2),408-412.

Liang, D., Hsiao, B. S. and Chu, B. (2007). Functional electrospun nanofibrous scaffolds for biomedical applications. *Advanced Drug Delivery Reviews*. 59(14),1392-1412.

Lieberman, J. R. and Friedlaender, G. E. (2005). *Bone regeneration and repair*. In. *Chapter 4, Biology of bone graft*. (57). Springer.

Liu, X., Gilmore, K. J., Moulton, S. E. and Wallace, G. G. (2009). Electrical stimulation promotes nerve cell differentiation on polypyrrole/poly (2-methoxy-5 aniline sulfonic acid) composites. *Journal of neural engineering*. 6(6),065002.

Lopes, W. A. and Jaeger, H. M. (2001). Hierarchical self-assembly of metal nanostructures on diblock copolymer scaffolds. *Nature*. 414(6865),735-738.

Lu, H. H., Cooper Jr, J. A., Manuel, S., Freeman, J. W., Attawia, M. A., Ko, F. K. and Laurencin, C. T. (2005). Anterior cruciate ligament regeneration using braided biodegradable scaffolds: in vitro optimization studies. *Biomaterials*. 26(23),4805-4816.

Ludwig, K. A., Uram, J. D., Yang, J., Martin, D. C. and Kipke, D. R. (2006). Chronic neural recordings using silicon microelectrode arrays electrochemically deposited with a poly (3, 4-ethylenedioxythiophene)(PEDOT) film. *Journal of neural engineering*. 3(1),59.

Luo, C., Nangrejo, M. and Edirisinghe, M. (2010). A novel method of selecting solvents for polymer electrospinning. *Polymer*. 51(7),1654-1662.

Luo, S.-C., Mohamed Ali, E., Tansil, N. C., Yu, H.-h., Gao, S., Kantchev, E. A. B. and Ying, J. Y. (2008). Poly(3,4-ethylenedioxythiophene) (PEDOT) Nanobiointerfaces: Thin, Ultrasmooth, and Functionalized PEDOT Films with in Vitro and in Vivo Biocompatibility. *Langmuir*. 24(15),8071-8077.

Ma, P. X. (2004). Scaffolds for tissue fabrication. *Materials Today*. 7(5),30-40.

Ma, P. X. and Zhang, R. (1999). Synthetic nano-scale fibrous extracellular matrix. *J Biomed Mater Res*. 46(1),60-72.

Ma, Z., Kotaki, M., Yong, T., He, W. and Ramakrishna, S. (2005). Surface engineering of electrospun polyethylene terephthalate (PET) nanofibers towards development of a new material for blood vessel engineering. *Biomaterials*. 26(15),2527-2536.

Ma, Z., Mao, Z. and Gao, C. (2007). Surface modification and property analysis of biomedical polymers used for tissue engineering. *Colloids and Surfaces B: Biointerfaces*. 60(2),137-157.

Maharana, T., Mohanty, B. and Negi, Y. S. (2009). Melt–solid polycondensation of lactic acid and its biodegradability. *Progress in Polymer Science*. 34(1),99-124.

Mai, T. T. T., Nguyen, T. T. T., Le, Q. D., Nguyen, T. N., Ba, T. C., Nguyen, H. B., Phan, T. B. H., Tran, D. L., Nguyen, X. P. and Park, J. S. (2012). A novel nanofiber Cur-loaded polylactic acid constructed by electrospinning. *Adv. Nat. Sci: Nanosci. Nanotechnol.* 3(025014).

Mansur, A. A. P. and Mansur, H. S. (2010). Preparation, characterization and cytocompatibility of bioactive coatings on porous calcium-silicate-hydrate scaffolds. *Materials Science and Engineering: C*. 30(2),288-294.

Marin, E., Briceño, M. I. and Caballero-George, C. (2013). Critical evaluation of biodegradable polymers used in nanodrugs. *International journal of nanomedicine*. 8,3071.

Martínez, O., Bravo, A. G. and Pinto, N. J. (2009). Fabrication of Poly(vinylidene fluoride−trifluoroethylene)/Poly(3,4-ethylenedioxythiophene)−Polystyrene Sulfonate Composite Nanofibers via Electrospinning. *Macromolecules*. 42(20),7924-7929.

Martins, A., Reis, R. and Neves, N. (2008). Electrospinning: processing technique for tissue engineering scaffolding. *International Materials Reviews*. 53(5),257-274.

Martins, A. M., Alves, C. M., Kasper, F. K., Mikos, A. G. and Reis, R. L. (2010). Responsive and in situ-forming chitosan scaffolds for bone tissue engineering applications: an overview of the last decade. *Journal of Materials Chemistry*. 20(9),1638-1645.

McGrath, J., Eady, R. and Pope, F. (2010). Anatomy and organization of human skin. *Rook's textbook of dermatology*. 1,3.1-3.15.

Megelski, S., Stephens, J. S., Chase, D. B. and Rabolt, J. F. (2002). Micro-and nanostructured surface morphology on electrospun polymer fibers. *Macromolecules*. 35(22),8456-8466.

Meng, S., Rouabhia, M., Shi, G. and Zhang, Z. (2008a). Heparin dopant increases the electrical stability, cell adhesion, and growth of conducting polypyrrole/poly (L, L-lactide) composites. *Journal of Biomedical Materials Research Part A*. 87(2),332-344.

Meng, W., Xing, Z. C., Jung, K. H., Kim, S. Y., Yuan, J., Kang, I. K., Yoon, S. C. and Shin, H. I. (2008b). Synthesis of gelatin-containing PHBV nanofiber mats for biomedical application. *Journal of Materials Science-Materials in Medicine*. 19(8),2799-2807.

Menke, N. B., Ward, K. R., Witten, T. M., Bonchev, D. G. and Diegelmann, R. F. (2007). Impaired wound healing. *Clinics in dermatology*. 25(1),19-25.

Metcalfe, A. D. and Ferguson, M. W. (2007). Tissue engineering of replacement skin: the crossroads of biomaterials, wound healing, embryonic development, stem cells and regeneration. *Journal of the Royal Society Interface*. 4(14),413-437.

Middleton, J. C. and Tipton, A. J. (2000). Synthetic biodegradable polymers as orthopedic devices. *Biomaterials*. 21(23),2335-2346.

Miller, L. L. and Zhou, X. Q. (1987). Poly(N-methylpyrrolylium) poly(styrenesulfonate) - a conductive, electrically switchable cation exchanger that cathodically binds and anodically releases dopamine. *Macromolecules*. 20(7),1594-1597.

Mouriño, V. and Boccaccini, A. R. (2010). Bone tissue engineering therapeutics: controlled drug delivery in three-dimensional scaffolds. *Journal of the Royal Society Interface*. 7(43),209-227.

Murphy, C. M., O'Brien, F. J., Little, D. G. and Schindeler, A. (2013). Cell-scaffold interactions in the bone tissue engineering triad.

Murugan, R., Liao, S., Ramakrishna, S., Molnar, P., Huang, Z., Kotaki, M., Rao, K. P. and Hickman, J. J. (2010). Skeletal Regenerative Nanobiomaterials. *Materials Science Foundations (monograph series)*. 62,1-34.

Muschler, G. F., Nakamoto, C. and Griffith, L. G. (2004). Engineering principles of clinical cell-based tissue engineering. *The Journal of Bone & Joint Surgery*. 86(7),1541-1558.

Nair, L. S. and Laurencin, C. T. (2007). Biodegradable polymers as biomaterials. *Progress in Polymer Science*. 32(8–9),762-798.

Naznin, S. and Min, W. (2012). PHBV/PLLA-based composite scaffolds fabricated using an emulsion freezing/freeze-drying technique for bone tissue engineering: surface modification and in vitro biological evaluation. *Biofabrication*. 4(1),015003.

Ndreu, A., Nikkola, L., Ylikauppila, H., Ashammakhi, N. and Hasirci, V. (2008). Electrospun biodegradable nanofibrous mats for tissue engineering. *Nanomedicine*. 3(1),45-60.

Nie, H. and Wang, C.-H. (2007). Fabrication and characterization of PLGA/HAp composite scaffolds for delivery of BMP-2 plasmid DNA. *Journal of controlled release*. 120(1),111-121.

Nisbet, D., Yu, L., Zahir, T., Forsythe, J. and Shoichet, M. (2008). Characterization of neural stem cells on electrospun poly (ε-caprolactone) submicron scaffolds: evaluating their potential in neural tissue engineering. *Journal of Biomaterials Science, Polymer Edition*. 19(5),623-634.

O'Brien, F. J. (2011). Biomaterials & scaffolds for tissue engineering. *Materials Today*. 14(3),88-95.

Olayo, R., Ríos, C., Salgado-Ceballos, H., Cruz, G., Morales, J., Olayo, M., Alcaraz-Zubeldia, M., Alvarez, A., Mondragon, R., Morales, A. and Diaz-Ruiz, A. (2008). Tissue spinal cord response in rats after implants of polypyrrole and polyethylene glycol obtained by plasma. *Journal of Materials Science: Materials in Medicine*. 19(2),817-826.

Ouyang, J., Chu, C. W., Chen, F. C., Xu, Q. and Yang, Y. (2005). High-Conductivity Poly (3, 4-ethylenedioxythiophene): Poly (styrene sulfonate) Film and Its Application in Polymer Optoelectronic Devices. *Advanced Functional Materials*. 15(2),203-208.

Owens, R. M. and Malliaras, G. G. (2010). Organic Electronics at the Interface with Biology. *MRS Bulletin*. 35(06),449-456.

Panapoy, M., Saengsil, M. and Ksapabutr, B. (2008). Electrical Conductivity of Poly (3, 4-ethylenedioxythiophene)-Poly (styrenesulfonate) Coatings on Polyacrylonitrile Nanofibers for Sensor Applications. *Advanced Materials Research*. 55,257-260.

Park, S., Kim, G., Jeon, Y. C., Koh, Y. and Kim, W. (2009). 3D polycaprolactone scaffolds with controlled pore structure using a rapid prototyping system. *Journal of Materials Science: Materials in Medicine*. 20(1),229-234.

Paşcu, E. I., Stokes, J. and McGuinness, G. B. (2013). Electrospun composites of PHBV, silk fibroin and nano-hydroxyapatite for bone tissue engineering. *Materials Science and Engineering: C*. 33(8),4905-4916.

Pattamaprom, C., Hongrojjanawiwat, W., Koombhongse, P., Supaphol, P., Jarusuwannapoo, T. and Rangkupan, R. (2006). The influence of solvent properties and functionality on the electrospinnability of polystyrene nanofibers. *Macromolecular materials and engineering*. 291(7),840-847.

Pham, Q. P., Sharma, U. and Mikos, A. G. (2006). Electrospinning of polymeric nanofibers for tissue engineering applications: a review. *Tissue engineering*. 12(5),1197-1211.

Plunkett, N. and O'Brien, F. J. (2011). Bioreactors in tissue engineering. *Technology and Health Care*. 19(1),55-69.

Poole, C. A., Brookes, N. H. and Clover, G. M. (2003). Confocal imaging of the human keratocyte network using the vital dye 5-chloromethylfluorescein diacetate. *Clinical & experimental ophthalmology*. 31(2),147-154.

Powell, H. M., Supp, D. M. and Boyce, S. T. (2008). Influence of electrospun collagen on wound contraction of engineered skin substitutes. *Biomaterials*. 29(7),834-843.

Prabhakaran, M. P., Vatankhah, E. and Ramakrishna, S. (2013). Electrospun aligned PHBV/collagen nanofibers as substrates for nerve tissue engineering. *Biotechnology and Bioengineering*. 110(10),2775-2784.

Prabhakaran, M. P., Venugopal, J. and Ramakrishna, S. (2009). Electrospun nanostructured scaffolds for bone tissue engineering. *Acta Biomaterialia*. 5(8),2884-2893.

Pukstad, B. S., Ryan, L., Flo, T. H., Stenvik, J., Moseley, R., Harding, K., Thomas, D. W. and Espevik, T. (2010). Non-healing is associated with persistent stimulation of the innate immune response in chronic venous leg ulcers. *Journal of dermatological science*. 59(2),115-122.

Qi, R., Guo, R., Zheng, F., Liu, H., Yu, J. and Shi, X. (2013). Controlled release and antibacterial activity of antibiotic-loaded electrospun halloysite/poly (lactic-co-glycolic acid) composite nanofibers. *Colloids and Surfaces B: Biointerfaces*. 110,148-155.

Ramakrishna, S., Fujihara, K., Teo, W.-E., Lim, T.-C. and Ma, Z. (2005). *An introduction to electrospinning and nanofibers*World Scientific.

Ravichandran, R., Sundarrajan, S., Venugopal, J. R., Mukherjee, S. and Ramakrishna, S. (2010). Applications of conducting polymers and their issues in biomedical engineering. *J. R. Soc. Interface*. 7,559-579.

Rayleigh, L. (1882). XX. On the equilibrium of liquid conducting masses charged with electricity. *Philosophical Magazine Series 5*. 14(87),184-186.

Reddy, K. R., Jeong, H. M., Lee, Y. and Raghu, A. V. (2010). Synthesis of MWCNTs-core/thiophene polymer-sheath composite nanocables by a cationic surfactant-assisted chemical oxidative polymerization and their structural properties. *Journal of Polymer Science Part A: Polymer Chemistry*. 48(7),1477-1484.

Reichert, J. C. and Hutmacher, D. W. (2011). *Bone tissue engineering*. In. *Tissue Engineering*. (431-456). Springer.

Rosso, F., Marino, G., Giordano, A., Barbarisi, M., Parmeggiani, D. and Barbarisi, A. (2005). Smart materials as scaffolds for tissue engineering. *Journal of cellular physiology*. 203(3),465-470.

Ruszczak, Z. and Friess, W. (2003). Collagen as a carrier for on-site delivery of antibacterial drugs. *Advanced Drug Delivery Reviews*. 55(12),1679-1698.

Sadik, O. A. and Wallace, G. G. (1993). Pulse damperometric detection of proteins using antibody containing conducting polymers. *Analytica Chimica Acta*. 279(2),209-212.

Salerno, A., Oliviero, M., Di Maio, E., Iannace, S. and Netti, P. (2009). Design of porous polymeric scaffolds by gas foaming of heterogeneous blends. *Journal of Materials Science: Materials in Medicine*. 20(10),2043-2051.

Schmidt, C. E., Shastri, V. R., Vacanti, J. P. and Langer, R. (1997). Stimulation of neurite outgrowth using an electrically conducting polymer. *Proceedings of the National Academy of Sciences*. 94(17),8948-8953.

Schumacher, M., Uhl, F., Detsch, R., Deisinger, U. and Ziegler, G. (2010). Static and dynamic cultivation of bone marrow stromal cells on biphasic calcium phosphate scaffolds derived from an indirect rapid prototyping technique. *Journal of Materials Science: Materials in Medicine*. 21(11),3039-3048.

Schweizer, T. M. (2005). *Electrical characterization and investigation of the piezoresistive effect of PEDOT: PSS thin films*, Georgia Institute of Technology.

Seal, B., Otero, T. and Panitch, A. (2001). Polymeric biomaterials for tissue and organ regeneration. *Materials Science and Engineering: R: Reports*. 34(4),147-230.

Sencadas, V., Ribeiro, C., Nunes-Pereira, J., Correia, V. and Lanceros-Méndez, S. (2012). Fiber average size and distribution dependence on the electrospinning parameters of poly (vinylidene fluoride–trifluoroethylene) membranes for biomedical applications. *Applied Physics A*. 109(3),685-691.

Shahini, A., Yazdimamaghani, M., Walker, K. J., Eastman, M. A., Hatami-Marbini, H., Smith, B. J., Ricci, J. L., Madihally, S. V., Vashaee, D. and Tayebi, L. (2014). 3D conductive nanocomposite scaffold for bone tissue engineering. *International Journal of Nanomedicine*. 9,167-181.

Sharma, B. and Elisseeff, J. H. (2004). Engineering structurally organized cartilage and bone tissues. *Annals of biomedical engineering*. 32(1),148-159.

Shevchenko, R. V., James, S. L. and James, S. E. (2010). A review of tissue-engineered skin bioconstructs available for skin reconstruction. *Journal of the Royal Society Interface*. 7(43),229-258.

Shi, G., Rouabhia, M., Wang, Z., Dao, L. H. and Zhang, Z. (2004). A novel electrically conductive and biodegradable composite made of polypyrrole nanoparticles and polylactide. *Biomaterials*. 25(13),2477-2488.

Shishatskaya, E. and Volova, T. (2004). A comparative investigation of biodegradable polyhydroxyalkanoate films as matrices for in vitro cell cultures. *Journal of Materials Science: Materials in Medicine*. 15(8),915-923.

Sill, T. J. and von Recum, H. A. (2008). Electrospinning: Applications in drug delivery and tissue engineering. *Biomaterials*. 29(13),1989-2006.

Sin, D., Miao, X., Liu, G., Wei, F., Chadwick, G., Yan, C. and Friis, T. (2010). Polyurethane (PU) scaffolds prepared by solvent casting/particulate leaching (SCPL) combined with centrifugation. *Materials Science and Engineering: C*. 30(1),78-85.

Smith, L. A., Liu, X. and Ma, P. X. (2008). Tissue engineering with nano-fibrous scaffolds. *Soft Matter*. 4(11),2144-2149.

Stevens, M. M. (2008). Biomaterials for bone tissue engineering. *Materials Today*. 11(5),18-25.

Stockert, J. C., Blázquez-Castro, A., Cañete, M., Horobin, R. W. and Villanueva, Á. (2012). MTT assay for cell viability: Intracellular localization of the formazan product is in lipid droplets. *Acta Histochemica*. 114(8),785-796.

Suh, S. W., Shin, J. Y., Kim, J., Kim, J., Beak, C. H., Kim, D.-I., Kim, H., Jeon, S. S. and Choo, I.-W. (2002). Effect of different particles on cell proliferation in polymer scaffolds using a solvent-casting and particulate leaching technique. *ASAIO journal*. 48(5),460-464.

Sultana, N. (2014). Natural-Synthetic Polymer Blend Composite Scaffold for Bone Tissue Engineering: Study of In Vitro Degradation and Protein Adsorption. *Applied Mechanics and Materials*. 42-46.

Sultana, N. and Khan, T. H. (2012). In vitro degradation of PHBV scaffolds and nHA/PHBV composite scaffolds containing hydroxyapatite nanoparticles for bone tissue engineering. *Journal of Nanomaterials*. 2012,1.

Sun, K., Zhang, S., Li, P., Xia, Y., Zhang, X., Du, D., Isikgor, F. H. and Ouyang, J. (2015). Review on application of PEDOTs and PEDOT: PSS in energy conversion and storage devices. *Journal of Materials Science: Materials in Electronics*,1-25.

Sun, T., Khan, T. H. and Sultana, N. (2014). Fabrication and in vitro evaluation of nanosized hydroxyapatite/chitosan-based tissue engineering scaffolds. *Journal of Nanomaterials*. 2014,11.

Tan, S. H., Inai, R., Kotaki, M. and Ramakrishna, S. (2005). Systematic parameter study for ultra-fine fiber fabrication via electrospinning process. *Polymer*. 46(16),6128-6134.

Taylor, G. (1969). Electrical Driven Jets. *Proceeding of the Royal Societies of London, Series A, Mathematical and Physical Sciences* 313(1515),453-475.

Tezcaner, A., Bugra, K. and Hasırcı, V. (2003). Retinal pigment epithelium cell culture on surface modified poly(hydroxybutyrate-co-hydroxyvalerate) thin films. *Biomaterials*. 24(25),4573-4583.

Thapa, A., Webster, T. J. and Haberstroh, K. M. (2003). Polymers with nano-dimensional surface features enhance bladder smooth muscle cell adhesion. *Journal of Biomedical Materials Research Part A*. 67(4),1374-1383.

Theron, S. A., Zussman, E. and Yarin, A. L. (2004). Experimental investigation of the governing parameters in the electrospinning of polymer solutions. *Polymer*. 45(6),2017-2030.

Tong, H.-W. and Wang, M. (2011). Electrospinning of Poly(Hydroxybutyrate-co-hydroxyvalerate) Fibrous Scaffolds for Tissue Engineering Applications: Effects of Electrospinning Parameters and Solution Properties. *Journal of Macromolecular Science, Part B*. 50(8),1535-1558.

Tong, H.-W., Wang, M., Li, Z.-Y. and Lu, W. W. (2010a). Electrospinning, characterization and in vitro biological evaluation of nanocomposite fibers containing carbonated hydroxyapatite nanoparticles. *Biomed. Mater.* 5.

Tong, H.-W., Wang, M., Li, Z.-Y. and Lu, W. W. (2010b). Electrospinning, characterization and in vitro biological evaluation of nanocomposite fibers containing carbonated hydroxyapatite nanoparticles. *Biomedical Materials*. 5(5),054111.

Tripatanasuwan, S., Zhong, Z. and Reneker, D. H. (2007). Effect of evaporation and solidification of the charged jet in electrospinning of poly(ethylene oxide) aqueous solution. *Polymer*. 48(19),5742-5746.

Tu, C., Cai, Q., Yang, J., Wan, Y., Bei, J. and Wang, S. (2003a). The fabrication and characterization of poly (lactic acid) scaffolds for tissue engineering by improved solid-liquid phase separation. *Polymers for Advanced Technologies*. 14(8),565-573.

Tu, C., Cai, Q., Yang, J., Wan, Y., Bei, J. and Wang, S. (2003b). The fabrication and characterization of poly (lactic acid) scaffolds for tissue engineering by improved solid–liquid phase separation. *Polymers for Advanced Technologies*. 14(8),565-573.

Uyar, T. and Besenbacher, F. (2008). Electrospinning of uniform polystyrene fibers: The effect of solvent conductivity. *Polymer*. 49(24),5336-5343.

Vasita, R. and Katti, D. S. (2006). Nanofibers and their applications in tissue engineering. *International Journal of nanomedicine*. 1(1),15.

Vats, A., Tolley, N., Polak, J. and Gough, J. (2003). Scaffolds and biomaterials for tissue engineering: a review of clinical applications. *Clinical Otolaryngology & Allied Sciences*. 28(3),165-172.

Veleirinho, B., Coelho, D. S., Dias, P. F., Maraschin, M., Ribeiro-do-Valle, R. M. and Lopes-da-Silva, J. A. (2012). Nanofibrous poly(3-hydroxybutyrate-co-3-hydroxyvalerate)/chitosan scaffolds for skin regeneration. *International Journal of Biological Macromolecules*. 51(4),343-350.

Vroman, I. and Tighzert, L. (2009). Biodegradable polymers. *Materials*. 2(2),307-344.

Wagner, A., Poursorkhabi, V., Mohanty, A. K. and Misra, M. (2014). Analysis of Porous Electrospun Fibers from Poly(l-lactic acid)/Poly(3-hydroxybutyrate-co-3-hydroxyvalerate) Blends. *ACS Sustainable Chemistry & Engineering*. 2(8),1976-1982.

Waller, J. M. and Maibach, H. I. (2006). Age and skin structure and function, a quantitative approach (II): protein, glycosaminoglycan, water, and lipid content and structure. *Skin Research and Technology*. 12(3),145-154.

Wang, C., Cheng, Y.-W., Hsu, C.-H., Chien, H.-S. and Tsou, S.-Y. (2011). How to manipulate the electrospinning jet with controlled properties to obtain uniform fibers with the smallest diameter?—a brief discussion of solution electrospinning process. *Journal of Polymer Research*. 18(1),111-123.

Wang, C., Chien, H.-S., Hsu, C.-H., Wang, Y.-C., Wang, C.-T. and Lu, H.-A. (2007). Electrospinning of polyacrylonitrile solutions at elevated temperatures. *Macromolecules*. 40(22),7973-7983.

Wang, S. D., Zhang, Y. Z., Wang, H. W., Yin, G. B. and Dong, Z. H. (2009). Fabrication and Properties of the Electrospun Polylactide/Silk Fibroin-Gelatin Composite Tubular Scaffold. *Biomacromolecules*. 10(8),2240-2244.

Wang, X., Gu, X., Yuan, C., Chen, S., Zhang, P., Zhang, T., Yao, J., Chen, F. and Chen, G. (2004). Evaluation of biocompatibility of polypyrrole in vitro and in vivo. *Journal of Biomedical Materials Research Part A*. 68A(3),411-422.

Wannatong, L., Sirivat, A. and Supaphol, P. (2004). Effects of solvents on electrospun polymeric fibers: preliminary study on polystyrene. *Polymer International*. 53(11),1851-1859.

Whitesides, G. M. and Grzybowski, B. (2002). Self-assembly at all scales. *Science*. 295(5564),2418-2421.

Wong, D. J. and Chang, H. Y. (2009). Skin tissue engineering.

Xie, J. and Wang, C.-H. (2006). Electrospun micro-and nanofibers for sustained delivery of paclitaxel to treat C6 glioma in vitro. *Pharmaceutical research*. 23(8),1817-1826.

Xu, C. Y., Yang, F., Wang, S. and Ramakrishna, S. (2004). In vitro study of human vascular endothelial cell function on materials with various surface roughness. *Journal of Biomedical Materials Research Part A*. 71A(1),154-161.

Yan, N., Zhang, X., Cai, Q., Yang, X., Zhou, X., Wang, B. and Deng, X. (2012). The effects of lactidyl/glycolidyl ratio and molecular weight of poly (D, L-lactide-co-glycolide) on the tetracycline entrapment and release kinetics of drug-loaded nanofibers. *Journal of Biomaterials Science, Polymer Edition*. 23(8),1005-1019.

Yang, F., Murugan, R., Wang, S. and Ramakrishna, S. (2005). Electrospinning of nano/micro scale poly (L-lactic acid) aligned fibers and their potential in neural tissue engineering. *Biomaterials*. 26(15),2603-2610.

Yang, F., Xu, C. Y., Kotaki, M., Wang, S. and Ramakrishna, S. (2004). Characterization of neural stem cells on electrospun poly(L-lactic acid) nanofibrous scaffold. *Journal of Biomaterials Science, Polymer Edition*. 15(12),1483-1497.

Yang, J., Zhu, R., Hong, Z., He, Y., Kumar, A., Li, Y. and Yang, Y. (2011). A Robust Inter-Connecting Layer for Achieving High Performance Tandem Polymer Solar Cells. *Advanced Materials*. 23(30),3465-3470.

Yin, H.-E., Wu, C.-H., Kuo, K.-S., Chiu, W.-Y. and Tai, H.-J. (2012). Innovative elastic and flexible conductive PEDOT: PSS composite films prepared by introducing soft latexes. *Journal of materials chemistry*. 22(9),3800-3810.

Yuan, Y. and Lee, T. R. (2013). *Contact angle and wetting properties*. In. *Surface science techniques*. (3-34). Springer.

Yue, G., Wu, J., Xiao, Y., Lin, J., Huang, M., Lan, Z. and Fan, L. (2013). Functionalized graphene/poly(3,4-ethylenedioxythiophene):polystyrenesulfonate as counter electrode catalyst for dye-sensitized solar cells. *Energy*. 54,315-321.

Zaborowska, M., Bodin, A., Bäckdahl, H., Popp, J., Goldstein, A. and Gatenholm, P. (2010). Microporous bacterial cellulose as a potential scaffold for bone regeneration. *Acta Biomaterialia*. 6(7),2540-2547.

Zahedi, P., Karami, Z., Rezaeian, I., Jafari, S. H., Mahdaviani, P., Abdolghaffari, A. H. and Abdollahi, M. (2012). Preparation and performance evaluation of tetracycline hydrochloride loaded wound dressing mats based on electrospun nanofibrous poly (lactic acid)/poly (ϵ-caprolactone) blends. *Journal of Applied Polymer Science*. 124(5),4174-4183.

Zeng, J., Haoqing, H., Schaper, A., Wendorff, J. H. and Greiner, A. (2003a). Poly-L-lactide nanofibers by electrospinning–Influence of solution viscosity and electrical conductivity on fiber diameter and fiber morphology. *e-Polymers*. 3(1),102-110.

Zeng, J., Xu, X., Chen, X., Liang, Q., Bian, X., Yang, L. and Jing, X. (2003b). Biodegradable electrospun fibers for drug delivery. *Journal of Controlled Release*. 92(3),227-231.

Zhang, C., Yuan, X., Wu, L., Han, Y. and Sheng, J. (2005). Study on morphology of electrospun poly(vinyl alcohol) mats. *European Polymer Journal*. 41(3),423-432.

Zhang, F., Johansson, M., Andersson, M. R., Hummelen, J. C. and Inganäs, O. (2002). Polymer photovoltaic cells with conducting polymer anodes. *Advanced Materials*. 14(9),662-665.

Zhang, L., Deng, X., Zhao, S. and Huang, Z. (1997). Biodegradable polymer blends of poly (3-hydroxybutyrate) and starch acetate.

Zhang, L. G., Khademhosseini, A. and Webster, T. (2014). *Tissue and Organ Regeneration: Advances in Micro-and Nanotechnology*CRC Press.

Zhang, Q.-S., Yan, Y.-H., Li, S.-P. and Feng, T. (2009). Synthesis of a novel biodegradable and electroactive polyphosphazene for biomedical application. *Biomedical Materials*. 4(3),035008.

Zhang, X., Baughman, C. B. and Kaplan, D. L. (2008). In vitro evaluation of electrospun silk fibroin scaffolds for vascular cell growth. *Biomaterials*. 29(14),2217-2227.

Zhang, Z., Hu, J. and Ma, P. X. (2012). Nanofiber-based delivery of bioactive agents and stem cells to bone sites. *Advanced Drug Delivery Reviews*. 64(12),1129-1141.

Zhao, H. and Wallace, G. G. (1998). Polypyrrole/poly(2-methoxyaniline-5-sulfonic acid) polymer composite. *Polymer Gels and Networks*. 6(3–4),233-245.

Zheng, J., He, A., Li, J., Xu, J. and Han, C. C. (2006). Studies on the controlled morphology and wettability of polystyrene surfaces by electrospinning or electrospraying. *Polymer*. 47(20),7095-7102.

Zhou, D., Cui, X. T., Hines, A. and Greenberg, R. (2010). *Conducting Polymers in Neural Stimulation Applications*. In Zhou, D. and Greenbaum, E. *Implantable Neural Prostheses 2*. (217-252). Springer New York.

Zhou, J., Anjum, D. H., Chen, L., Xu, X., Ventura, I. A., Jiang, L. and Lubineau, G. (2014). The temperature-dependent microstructure of PEDOT/PSS films: insights from morphological, mechanical and electrical analyses. *Journal of Materials Chemistry C*. 2(46),9903-9910.

Zilberman, M., Nelson, K. D. and Eberhart, R. C. (2005). Mechanical properties and in vitro degradation of bioresorbable fibers and expandable fiber-based stents. *Journal of Biomedical Materials Research Part B: Applied Biomaterials*. 74(2),792-799.

Zong, X. H., Li, S., Chen, E., Garlick, B., Kim, K. S., Fang, D. F., Chiu, J., Zimmerman, T., Brathwaite, C., Hsiao, B. S. and Chu, B. (2004). Prevention of postsurgery-induced abdominal adhesions by electrospun bioabsorbable nanofibrous poly(lactide-co-glycolide)-based membranes. *Annals of Surgery*. 240(5),910-915.