
# PROBING THE POTENTIAL OF BRANCHED POLYMERS AS BIOMATERIALS

**By**

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'This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.'



Signed:

Date:

This thesis is dedicated to my granny, Mrs Chris Kerr, who asks every day whether I have invented anything yet and is a constant inspiration.

"We Kerr's have never been beat (*beaten*)."

Robert Love Kerr 1923-1984

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# ABSTRACT

Biomedical devices are susceptible to biofilm colonisation; these are bacterial communities which adhere to a surface and secrete extracellular polymers and proteins establishing chronic infections. Biofilms are highly resistant to antibiotic chemotherapy and require implant excision followed by an aggressive course of intravenous antibiotics to be effectively eliminated. This is costly and invasive to the patient. The work presented in this thesis investigates the synthesis of novel branched polymers as coatings for biomedical implants.

Branched acrylate and thiol-ene polymers were chosen for this study as the synthesis is a facile and well established within the literature. All polymers were characterised using multiple techniques to determine their chemical properties and biological response. Acrylate and thiol-ene materials were synthesised using methods adapted from those within the literature however, in order to promote novelty monomer species were chosen which had not been cited in any previous literature. Polymerisation, in each instance, was completed efficiently with minimal work up required, demonstrating the potential high throughput capability of these techniques. Post synthesis, all polymers were analysed to determine their chemical composition, surface properties, crystallinity and bacterial control.

Differential Scanning Calorimetry and Textural Analysis clarified elements of the polymers structure including their crystallinity along with changes which are incurred post submersion in liquid. Chemical composition, including the present functional groups, was determined using Infrared and RAMAN spectroscopy. Bacterial testing was carried out using two organisms which are known to be prolific biofilm producers along with being common pathogenic agents in humans*, Staphylococcus aureus* and *Pseudomonas aeruginosa*. Data from the bacterial studies carried out on the acrylate material indicated that the proliferation of biofilms can be controlled upon the addition of further branching species into the reaction mixture. In comparison, the thiol-ene polymers produced appear to retard the growth of bacteria in all instances with respect to polystyrene, a commercially available and commonplace biomaterial, however no trends were observed indicating the preferred reagent combination. A number of materials synthesised also had the ability to take on large volumes of water in a hydrogel like manner, this was investigated using a number of novel compression and texture analysis techniques to clarify the changes in the

polymer matrix upon immersion in water. From this work it can be concluded that both branched acrylate and thiol-ene polymers are efficient to manufacture and can be prepared using a number of possible monomer units. Response to known biofilm producing bacterial strains can be modified via the reagents and is both simple and effective. These plastics, which are facile to make and modify, have been shown to be a possible candidate for bio-resistant coatings, for commercially available bioimplants or wound dressings.

# ABBREVIATIONS

| | |
|---|---|
| AFM | Atomic force microscopy |
| CAG | Contact Angle Goniometry |
| CV | Crystal Violet |
| DIM | Diiodomethane |
| DMPA | 2,2–dimethoxy 2-phenyl acetophenone |
| DMSO | Dimethylsulfoxide |
| DNA | Deoxyribonucleic acid |
| DSC | Differential scanning calorimetry |
| EG | Ethylene glycol |
| FDA | Food and Drug Administration |
| FTIR | Fourier Transform Infrared spectroscopy |
| FW | Filtered water |
| GFP | Green Fluorescent Protein |
| HIS | Hyperspectral imaging |
| hMSC | Human mesenchymal stem cell |
| LB | Luria Bertani |
| MRSA | Methicillin-resistant *Staphylococcus aureus* |
| NIR | Near infra red |
| PBS | Phosphate buffered saline |
| PCA | Principle component analysis |
| PEG | Poly(ethyleneglycol) |
| pHEMA | Poly(2-hydroxyethyl methacrylate) |
| PLA | Polylactic acid |
| PMA | Polymethacrylate |
| PMMA | Poly(methyl methacrylate) |
| PVA | Poly(vinyl alcohol) |
| SCVP | Self-condensing vinyl polymerisation |
| SE | Surface energy |
| SPM | Scanning Probe Microscope |
| TA | Texture Analysis |
| Tc | Crystallisation temperature |

| | |
|---|---|
| tEGDA | Tetra ethylene glycol diacrylate |
| Tg | Glass transition temperature |
| TGA | Thermogravimetric analysis |
| Tm | Melting temperature |
| TPA | Texture Profile Analysis |
| UV | Ultraviolet |