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Die Optimierung von Poly(Dimethylsiloxan) für biomedizinische Anwendungen durch oberflächeninitiierte Atom-Transferradikal-Polymerisation
Improvement of Poly(dimethyl siloxane) towards biomedical applications by surface initiated Atom Transfer Radical Polymerization

Introduction

Poly(dimethyl siloxane) (PDMS) is an ideal material for manufacturing implantable devices because of its ease of moulding and excellent mechanical properties. The major drawback of such devices however is associated with surface biofilm colonization, as formed by a variety of bacterial and yeast strains [1]. This poses a severe problem as it leads to frequent device failure and also in some cases to thrombus formation and/or fibrosis occurrence [2,3].

Several authors recognize that the health problems associated with the use of medical devices are mainly due to the surface properties of the materials [4,5]. Hydrophobic surfaces readily adsorb serum proteins that mediate subsequent mechanisms leading to infections [6]. Conversely, hydrophilic polymers are known to inhibit protein and microbial adhesion [7]. Some surface and bulk modification techniques have been used to improve the material's biocompatibility and antifouling features, mostly by improving the surface's hydrophilic character. These include devices' coating with polymers, hydrogels, metals, antimicrobial and surface-active agents such as surfactants [4,5,7,9-12].

As a surface-modification technique, the "grafting-from" approach allows significant modification and control of the materials' surface properties. The control of the polymer's molecular weight, composition, end functionalities and grafting densities is well achieved by Atom Transfer Radical Polymerization (ATRP) [11,12]. ATRP is based on the reversible activation/deactivation between alkyl halides (R-X) by means of a metal catalyst / ligant complex (Mtn/2L). This dynamic equilibrium allows the formation of growing radicals (R•) that propagate by monomer addition (M). Control is then achieved by a fast initiation and a slow polymerization rate. Biocompatible, non-toxic and hydrophilic polymers can be used, and ATRP can be done in aqueous medium, which minimizes the use of toxic solvents. Therefore, ATRP opens interesting possibilities regarding the enhancement of the material's surface functionality.

Materials and Methods

In the present study, the modification of bare PDMS (Sylgard® 184) surfaces was conducted by surface-ATRP using PEGMA as a model monomer. The surface morphology was studied by scanning electron microscopy (SEM) and the extent of surface modification, namely the surface elemental composition, was confirmed by X-ray photoelectron spectroscopy (XPS). In parallel, FTIR-ATR was used to characterize the surface groups. Contact angles were also measured to determine the modified surfaces hydrophobicity. Finally, modified PDMS were characterized regarding their inhibition of microbial adhesion.

Results & Discussion

Water contact angles measured on the modified PDMS samples (as obtained at different polymerization intervals) were found to decrease with the polymerization time, and to be significantly lower (19°) than the bare PDMS (113°), thus allowing to conclude that modification occurred. Nevertheless, the adhesion experiments showed an increase in the number of microorganisms adhered to the modified surfaces in comparison to the unmodified one, which was not expected. This fact leads to the suspicion that probably the surface has not been homogeneously modified. SEM, XPS and FTIR-ATR, revealed some surface degradation caused by the polymerization process. The high level of roughness exhibited by the PDMS surface can explain the higher microbial adhesion after polymerization. Following a protocol modification, preliminary results suggest that, though a less hydrophilic surface can be obtained, this surface shows less surface roughness. These promising results indicate that a reproducible method was obtained to surface-modify PDMS, while minimizing the surface degradation and allowing good levels of surface hydrophilization for biomedical applications.

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