The effect of formation of the liquid crystalline phase on the blood compatibility of a cholesterol modified silicone

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Cholesterol modified silicones were synthesized by grafting copolymerization of 10-Cholesteryloxydecanol onto polymethylhydrosiloxane (PMHS). Fourier transform infrared (FT-IR) spectroscopy, proton nuclear magnetic resonance (1H-NMR) spectroscopy and gel permeation chromatography (GPC) confirmed the chemical structures of polymers. Differential scanning calorimetry (DSC) and polarized optical microscopy (POM) results indicated the mesogenic properties of those polymers. The modified silicone with 45% 10-Cholesteryloxydecanyl (SC45) indicated obvious thermotropic liquid crystalline transform at about 122–124.9°C. The thermotropic liquid crystalline phase could be retained at room temperature via a special annealing/quenching process. The anneal-quenched film (SC45C) formed continuous liquid crystalline phase, whereas the unannealed films presented amorphous structure. The blood compatibility of the coatings was assessed from SEM observation of the platelet’s adhesion to coating surface and plasma recalcification time (PRT). The results revealed that the formation of the liquid crystalline phase could greatly improve the in vitro blood compatibility of the materials. The positive results of liquid crystalline onto haemocompatibility allow broad potential in biomaterials.

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1. Introduction

Polymeric materials have been widely used for artificial organs, medical devices and disposable clinical instruments [1], which have contributed significantly to the quality and effectiveness of health care system [2]. Silicone rubber-based material is one of the most important polymeric materials and is widely used for different applications including tubing, catheters, vascular graft, plastic reconstruction, encapsulation of electronic components and voice prostheses [3]. Among all these applications, silicone rubber showed outstanding flexibility and transparency as well as high structural resistance toward heat, ozone and chemical [4]. However, Silicone rubber-based materials are still prone to initiate the formation of clots, as platelets and other components of the blood coagulation system are activated. Despite decades of research, non-thrombogenic surfaces for blood-contacting polymers remain an elusive goal.

A potential solution to the problem of thrombogenic polymers may now be realized by creating liquid crystalline polymers that imitate the movable morphology of the natural biomembrane surface. Hall et al. [5] pointed that cell membrane, polypeptide, nucleic acid, inner surface of blood vessel and other biomembrane in the body, especially the surface of cell membrane contacting with blood frequently, are all mobile liquid-liquid crystal. Zhou et al. [6, 7] reported recently that the liquid crystal in the polymer-liquid crystal composite membrane appears to be beneficial in improving the blood compatibility and reducing the thrombogenicity.

It is well known that cholesterol is one of the most common membrane sterols in animals and plays important roles in regulating membrane fluidity and self-association of molecules in biological systems [8, 9]. In fact, cholesterol containing liquid crystalline materials have attracted more and more attention in biomaterials field [6, 7, 10]. This research is based on two facts: firstly, cholesterol has high thermodynamic affinity for the cell membranes and the ability to change the membrane’s permeability and fluidity [11]; secondly, the mesogenic character of cholesterol known for many of its derivatives [12].

In this paper, a cholesteryl-modified silicone was synthesized by grafting copolymerization of 10-Cholesteryloxydecanol onto polymethylhydrosiloxane. A
special annealing/quenched thermal treatment was used to prepare two couples of liquid crystalline samples and its controls. The effect of the liquid crystalline phase on the blood compatibility of cholesterol-modified silicones was then investigated via the platelet adhesion and plasma recalcification time.

2. Experiment

2.1. Materials

Cholesterol modified silicone (SC45, SC15) were synthesized by grafting copolymerization of 10-Cholesterylxydecanol onto polymethylhydrosiloxane. 10-Cholesterylxydecanol and polymethylhydrosiloxane (Table I) were dissolved in toluene (30 ml), a catalytic amount of hydrogenhexchoroplatinate (IV) hydrate/THF solution (the molar ration of Pt/THF was 1/10^3) was added to the above solution under nitrogen, and the reaction temperature was 50 °C (see Fig. 1). After 72 h, excessive methanol was added into the reaction system and the reaction continued for another 6 h to terminate the active silicon-hydrogen bond. On completion, the reaction was concentrated using a rotary evaporation followed by pouring the solution into large amount of ethanol to precipitate the polymers. The products were washed with ethanol repeatedly, and then dried under vacuum.

Table I Copolymerization data of the polymers, SC45 and SC15

<table>
<thead>
<tr>
<th>Sample</th>
<th>Molar ratio of Monomer^a/PMHS^a</th>
<th>Molar percent^b of attached monomer in polymers (%)</th>
<th>Mw^c</th>
<th>MWD^c</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC45</td>
<td>1:1</td>
<td>45</td>
<td>3.1 × 10^4</td>
<td>2.02</td>
</tr>
<tr>
<td>SC15</td>
<td>1:4</td>
<td>15</td>
<td>2.7 × 10^4</td>
<td>1.46</td>
</tr>
</tbody>
</table>

^a Monomer and PMHS mean 10-Cholesteryloxydecanol and polymethylhydrosiloxane (PMHS), respectively; ^b Calculated from 1^H-NMR; ^c Mw and MWD are molecular weight and molecular weight distribution, respectively and they were calculated from GPC results.

Fourier transform infrared (FT-IR) spectroscopy (E.S.P., MAGNA-IR560, Nicolet Instrument) of the cholesterol modified silicone showed absorption at 1267 cm\(^{-1}\) which is designated to Si—CH\(_3\) stretching in the main chain. The absorption at 2840 cm\(^{-1}\) was the contribution of aliphatic C—H stretching from the side chain. The disappearances of absorption at 3451 from O—H stretching and absorption at 2140 from Si—H stretching confirmed the success and completion of the reaction.

Proton Nuclear Magnetic Resonance (1^H-NMR) spectroscopy (500 MHz Bruker) of SC15, as a representative the copolymers, are shown in Fig. 2. The 1^H-NMR spectrum showed peak at 0.14, which was