Biological Investigation of PEG-Containing Siloxane Materials by Metal-Free Click-Chemistry

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Statement of Purpose: Silicone elastomers are frequently used as a biomaterial, owing to their stability, high oxygen permeability and ease of processing; however, their high hydrophobicity limits their appropriateness in some applications. Specifically, hydrophobic surfaces can adsorb greater amounts of protein and lipid, such as in contact lens applications, and this fouling can result in the failure of the biomaterial. It is therefore desirable to introduce hydrophilic moieties, such as poly-ethylene glycol (PEG), to increase the utility of these polydimethylsiloxane (PDMS) materials. However, due to compatability issues between the silicone and hydrophilic polymers, conjugation and crosslinking of these materials can be quite difficult. It has been shown that a metal-free click reaction can be used to create various PDMS-PEG coplymers; the purpose of this study is to examine how the hydrophilicity of these materials influences protein adhesion and cell viability, and thus determining which are best suited for biomedical applications.

Methods: Pendant azidoalkylsilicones, dialkyne-terminated silicone chains and monoalkyne-terminated PEG were synthesized according to the procedure by Rambarran et al.[1] to create PEG-modified silicone elastomers. Propiolate-functional PEGs of different molecular weights were attached onto the PDMS backbone in different ratios, leaving residual reactive azide groups. Propiolate-terminated PDMS was subsequently added to consume the available azido groups and bridge the PEG functional crosslinker to create elastomeric materials. The pre-polymer mixtures were homogenized with a small amount of $CHCl_3$ and/or toluene, cast in a glass Petri dish and allowed to cure in a 60 °C oven for 24 hours. Various materials were created and tested, with two shown here for illustrative purposes. Their compositions are shown in Table 1.

Table 1. Sample PDMS-g-PEG elastomer compositions.

Material	PEG	Stoichiometry (Azide: PEG)	PDMS Alkyne	PEG Wt%
50-750-8	813 g/mol	1:0.5	7800 g/mol	14.4
25-350-4	406 g/mol	1:0.25	3600 g/mol	8.4

Hen egg lysozyme (HEL) and bovine serum albumin (BSA) were conjugated to I^{125} using the iodine monochloride method [2]. The materials, having a surface area of 0.633 cm^2, were incubated for three hours in a 1mg/mL protein solution, comprising of 10% labeled protein. Surfaces were rinsed three times then counted using an automated gamma counter, with the radioactivity converted to micrograms of protein per area for quantification.

Results: The material properties, as determined by transparency, shore hardness and contact angle, were varied based on the composition of the materials. For example, the material 50-750-8 was transparent, flexible and not tacky, having a contact angle at 300 seconds of 76 ± 6° and Shore OO hardness of 70 ± 2. The material 25-350-4 was transparent, firm and not tacky, having a contact angle at 300 seconds of 50 ± 2° and a Shore OO hardness of 68 ± 1. This shows that while the mechanical properties are similar in the materials, they differ in their wettability based on the type and amount of PEG incorporated.

Figure 1 shows that the protein adsorption for the 25-350-4 material, which was highly wettable, is greatly reduced relative to the control materials for both proteins examined. This is likely due to the mobile PEG chains, which create a large protecting area, and also give the material its high wettability. Conversely, the 50-750-8 material, which had low wettability, shows similar adsorption for BSA but increased deposition for HEL. Given the greater swelling of this material, it is likely this smaller HEL protein was able to penetrate into the material, resulting in protein levels greater than a monolayer.

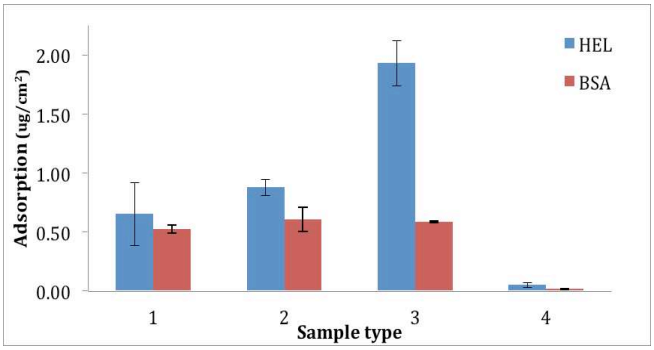

Figure 1. HEL and BSA Adsorption for **1**:Sylgard, **2**:Click elastomer with no PEG, **3:**Material 50-750-8, **4**:Material 25-350-4 (n=4 for each material).

Conclusions: The incorporation of lower molecular weights of PEG, balanced with crosslink density, was more indicative of lower contact angles than simply the amount of PEG in the materials. The PEG-PDMS materials that exhibited low contact angles showed significant reductions in both lysozyme and albumin protein adhesion. These highly wettable silicone elastomers show great potential as improved biomaterials.

References:

[1] Rambarran T. Macromolecules. 2012;45:2276-2285.
[2] Luensmann D. Mol Vis. 2010;16:79-92.