

Engineering Osteophilic and Osteoinductive Surfaces on Metallic Implant Scaffolds

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INTRODUCTION: The factors that confer nonfouling character to a surface have been the subject of much discussion. We investigate protein interactions with surfaces using physico-chemical approaches based on classical colloid and surface chemistry, with concepts such as DLVO theory. We are trying to understand protein adsorption or repellence in terms of interfacial forces and how those forces relate to surface chemistry, chain packing density, and other properties. We present key results and how they relate to interfacial interpretations of protein resistance.

METHODS: Si wafer and Teflon FEP substrates were coated with plasma polymer layers from either heptylamine or propanal, to create a functionalized interfacial bonding layer onto which various PEG molecules were covalently linked by cloud-point grafting as in [1]. As a comparative, charged hydrogel layer, polyacrylic acid was also grafted onto an amine plasma layer. Some PEGs were methoxy terminated; others possessed functional end groups that were then modified further. Antibacterial furanone compounds were immobilized onto both types of hydrogels as described in [2]. Characterisation of the coated surfaces was by XPS, ToF-SIMS, and AFM interaction force measurements with a silica probe attached to the cantilever. Protein adsorption experiments were performed with solutions of albumin, fibrinogen or lysozyme; XPS and ToF-SIMS were used to probe for adsorbed proteins.

RESULTS AND DISCUSSION: XPS analysis of the PEG modified surfaces showed that high density PEG coatings had been produced. After immersion in protein solutions, no XPS N 1s signals were observed. By ToFSIMS, however, small contributions from ammonium ions derived from amino acids were observed. Their intensities (relative to PEO signals) differed between grafts of 5 kDa, 20 kDa and 40 kDa methoxy-PEGs, with the lowest MW giving the best protein resistance. Both for this and dialdehyde-PEG, the residual protein contributions are extremely low and perhaps caused not by the intrinsic properties of the coatings, but, instead, by unavoidable coating defects induced eg by dust particles. The higher MW PEGs may pack less closely. AFM interaction force measurements against a silica sphere showed a net repulsive force at all separations for closely packed PEG coatings. Using the MWC model [3],

the observed steric forces were compared with theoretical predictions, and this enabled determination of the average distance between PEO grafting sites. For dense grafts, this distance was substantially less than twice the Flory radius, confirming the presence of stretched PEG brushes.

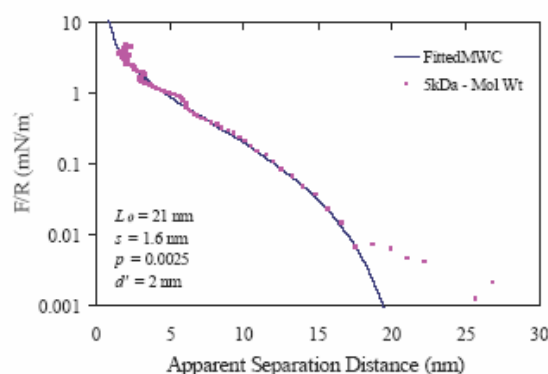


Fig 1: Experimental data (dots) and MWC scaling theory fit (line) for a 5kDa mPEG graft coating.

Functionalized PEGs enable the covalent immobilization of other entities such as oligopeptides and charged small molecules. Of interest is how such entities on top of the PE layer modulate interfacial forces and properties, and protein interactions [4]. PEG grafts have also been compared with other grafted polymer hydrogel layers. Of particular relevance is the fact that polyacrylamide graft coatings analogously showed extremely low protein adsorption [5], which tends to suggest that the interpretation of non-fouling in terms of hydrogen bond acceptance but no hydrogen bond donors [6] needs revision. What is the practical significance of non-fouling coatings? We have observed that furanones immobilized onto various hydrogel spacers inhibit bacterial colonization even when the construct was not protein repellent.

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