Interfacial segregation of PEG in hydrophobic polymers and its influence on protein adsorption

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Statement of Purpose: Poly(ethylene glycol), PEG, is often used to prevent biofouling. [1] Biofilms do not form on the surfaces of most PEG-containing polymers because PEG inhibits protein adsorption. However, there are instances in which proteins are adsorbed onto the polymer surfaces even when PEG is present. We attempt to explain this observation by studying the distribution of PEG at the surface using x-ray reflectivity (XRR) and grazing-incidence wide-angle scattering (GIWAXS). We also illustrate how these techniques can be used to understand protein adsorption onto polymer surfaces. X-ray results are correlated with those from quartz crystal microbalance, and their relevance to cell adhesion and biofilm formation are discussed.

Materials and Methods: A random segmented copolymer (Figure 1) in which a hydrophobic polymer, poly(desaminotyrosyl-tyrosine carbonate), PDTEC copolymerized with PEG segments was used.[2] PI_2DTEC, in which DTE is iodinated and has a different hydrophobicity, was also included. The polymer solutions were spread on an aqueous (PBS) surface in a Langmuir trough from a 3:1 chloroform/methanol mixture. Pressure-area isotherms were obtained to determine the conditions of gaseous-like, liquid-expanded and condensed phases of the polymer. Fibrinogen (Fg) was injected into the subphase covered by the monolayer to monitor the protein-polymer association. The X-ray measurements were carried out using synchrotron radiation.[3]

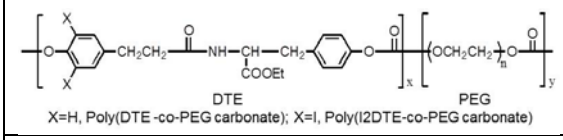

Figure 1. Formula for the library of tyrosine-derived poly-carbonates. Here, x is the mol% of desamino-tyrosyl-tyrosine ethyl ester, (DTE), and y is the mol% of poly(ethylene glycol) (PEG) and n is the length of the PEG block.

Results: Earlier results from our laboratory have shown that while 8 mol% PEG (1k) inhibits Fg adsorption in PDTEC, it does not in PI_2DTEC. Thus, the presence of PEG by itself does not make the material protein resistant and nonfouling.

XRR data shown in Figure 2 were used to extract the electron density profiles that are also shown in the figure. The extension of the polymer-subphase interface in the PEG-containing polymers as seen in these density profiles indicates the formation of a hydrophilic PEG layer beneath the hydrophobic DTE layer. Thus, the polymer orients on aqueous surfaces like an amphiphile at the air-water interface. The density profiles suggest partial phase separation of PEG at the air-water interphase in PDTEC and complete phase separation in PI_2DTEC. XRR results show that PEG forms a continuous 30 Å layer on the surface in PDTEC, but not so in PI_2DTEC.

XRR shows that Fg is adsorbed at the water-air interface with the long axis parallel to the interface. The behavior of Fg adsorption in the presence of PEG is different in PDTEC, but not in PI_2DTEC. In the presence of Fg, GIWAXS data during the first and the second compression of the Langmuir film remained unchanged only in PEG containing PDTEC indicating that Fg is not incorporated in the film, but is incorporated into PDTEC film without PEG, and into PI_2DTEC with or without PEG.

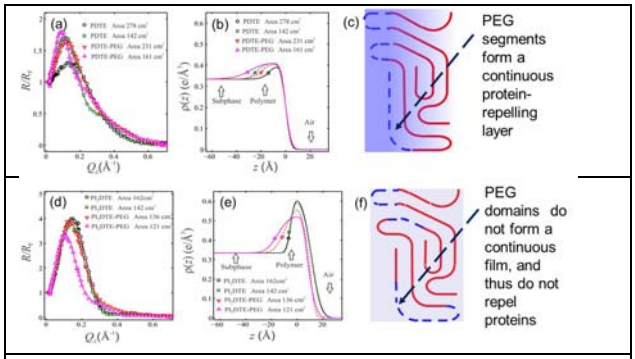

Figure 2. XRR data (a, d), the density profiles (b, e) and the postulated differences in the phase separation behavior (c, f) of PEG in PDTEC (Top panel) and PI_2DTEC (bottom panel). The blue color in Figures c and f depict the disposition of hydrated PEG domains.

Conclusions: XRR and GIWAXS can be used to study the structural details of the distribution and associations of proteins and polymers at surfaces. We find that the presence of PEG in the matrix by itself does not make a material protein resistant. Protein-repellency, and by extension cell-no adhesion and nonfouling induced by PEG is due to the formation of a continuous hydrophilic layer by the phase separated PEG segments, i.e., PEG needs to bloom to the aqueous interface.

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References:

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