

Mesoscopic sponge-like topology engineered onto polypropylene promotes retention of bound protein: Material synthesis, characterization and utility

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ABSTRACT

The interaction between biopolymers and plastic surfaces defines an area of much interest. In this study, the oxidative activation, surface engineering and protein binding ability of polypropylene derivatives were examined. Figure 1 shows the superimposed carbonyl regions of an ATR-FTIR spectrum of polypropylene, whose surface was subjected to a time-course oxidation. Oxidation yields increased gradually, affording a maximum signal after 18h. Three distinct carbonyl types were noted. On the basis of spectral data & established reaction chemistries, the oxidation products appeared to be limited to alcohol, ketone, carboxylic acid and potentially ester groups (Pavia *et al.*, 1979).

The SEM micrographs of figure 2 showed no significant changes of topology over the first

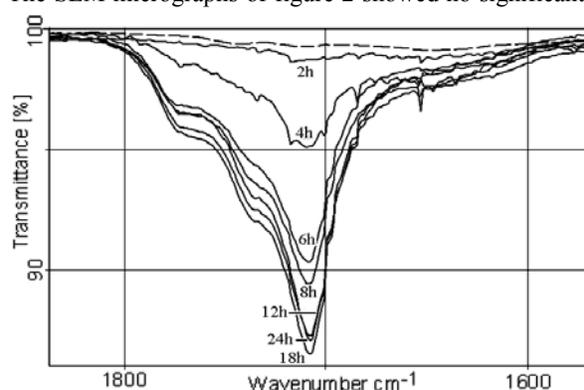


Fig. 1: ATR-FTIR spectra of oxidized polypropylene

8h of reaction. In comparison, minor changes had developed by 10h, in the form of sparsely distributed mesoscale bulges. A brief period of dramatic change occurred thereafter, as evidenced by the sponge-like mesoscale topology at 12h. The transformation was noteworthy in that it reflected the release of material stresses, which had accumulated during reaction. When the brevity of this dramatic change was assessed against the continual

accumulation of oxidation products, the underlying mechanism pointed to an oxidative phase separation (Hellan, 1984). Further oxidation (14h) did not alter the appearance. Several oxidized surfaces were treated with hydrolyzed aminopropyltriethoxysilane, yielding an aminated surface. Of these, some surfaces were reacted further with ninhydrin, yielding the corresponding aldehyde surface. Interactions between protein and each surface were assessed by the extent to which a trace-labeled fluorescent albumin derivative could be loaded and retained following several washings. A negative control surface, i.e., native polypropylene, did not retain fluorescence after the washings. In contrast, the oxidized, aminated and aldehyde-bearing surfaces retained substantial fluorescence. A related experiment was conducted using mesoscopically flat surfaces to ascertain if the sponge-like topology alone had promoted protein retention. This time, the protein-loaded aminated surfaces lost all fluorescence after the washings. In contrast, oxidized and aldehyde-pendant surfaces still retained fluorescence, presumably by forming imine bonds with

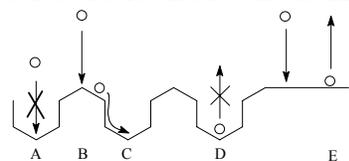


Fig. 3: Mode of protein retention

protein. Thus, the contribution of a sponge-like topology proved sufficient, yet vital, to achieve retention in the absence of any covalent bonding. Zeolite-related work by Takahashi *et al.* (2001) gave a physical basis to rationalize protein retention along a sponge-like topology. In this model (Figure 3), surface structures are depicted to be on the order of protein size. Direct entry of protein to the base of a crevice (A) is portrayed as difficult. Instead, protein is envisaged to adsorb at the tips, where wettability is highest (B) and to migrate to the base (C). The better shape complementarity of the base is presumed to stabilize protein-surface interactions, imparting irreversibility to the process in comparison to a flat surface (i.e., scenarios D vs. E). The findings implied that the routine use of reaction-induced phase transformations could aid in the development of alternative mesoscale topologies with refined binding traits. Such chemical approaches should therefore complement established methods based on lithography, self-organization and solvent casting.

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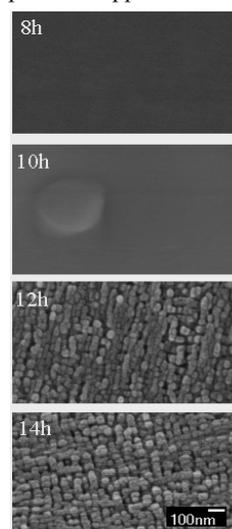


Fig. 2: SEM images of oxidized polypropylene