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Proton Transport and Surface Acidification in Self-Disinfecting Sulfonated Multiblock Polymers

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ABSTRACT

Healthcare-associated infections remain a major public health challenge, motivating the development of self-disinfecting materials that can reduce persistent surface contamination. Upon hydration, self-disinfecting sulfonated multiblock polymers can establish a highly acidic polymer-water interface that rapidly inactivates microorganisms. Proton transport plays an important role in this mechanism because protons from sulfonic acid groups can migrate through hydrated pathways to the polymer surface and contribute to formation of the low-pH contact layer.

The purpose of this paper is to investigate what determines proton diffusivity in hydrated, self-assembled multiblock polymers and how these factors relate to the highly acidic surface environment required for self-disinfection. This review examines the molecular, morphological, processing, and environmental factors that influence proton transport and their relevance to surface acidification. The literature reviewed shows that sulfonation and polymer architecture influence hydration and self-assembly, while the connectivity and tortuosity of hydrated ionic domains govern pathways involved in proton migration. Hydration, temperature, casting solvent, and post-casting treatment can further alter swelling or morphology and thereby modify the transport environment. Recent studies of anionic multiblock polymers explore the links between proton availability, migration through hydrated pathways, access to the polymer-water interface, and surface acidification.

Overall, these studies support an important role for polymer structure, hydrated morphology, and environmental and processing conditions in proton transport and surface acidification. Further quantitative study of how proton diffusivity relates to surface acidification and antimicrobial performance could help to differentiate the factors that govern self-disinfecting behavior.

INTRODUCTION

Healthcare-associated infections remain a major public health challenge, causing tens of thousands of deaths and costing the U.S. healthcare system billions of dollars each year (U.S. Department of Health and Human Services, 2025). Contaminated environmental surfaces can often become hidden sources of infection and transmission in some healthcare settings (Otter et al., 2013). This concern has motivated efforts to develop antimicrobial surface technologies that can reduce the risks of persistent surface contamination.

Conventional strategies for reducing the presence of pathogens on surfaces include routine cleaning and chemical disinfection, as well as antimicrobial materials or coatings that incorporate active agents, such as metals or metal oxides (Otter et al., 2013; Cloutier et al., 2015; Peddinti et al., 2021). These approaches can reduce microbial contamination, but conventional disinfection is applied episodically and does not prevent subsequent recontamination while antimicrobial materials that release active agents can become less effective over time as their supply depletes and potential environmental leaking remains a key concern (Cloutier et al., 2015; Peddinti et al., 2021). The widespread use of some disinfectant ingredients, including quaternary ammonium compounds, has also drawn attention with regard to their potential environmental effects (Hora et al., 2020). These limitations indicate the need for self-disinfecting materials that maintain their antimicrobial abilities between cleanings.

Self-disinfecting anionic multiblock polymers provide an alternative approach. Their activity comes from sulfonic acid groups within the polymer rather than from antimicrobial agents such as metals or metal oxides (Peddinti et al., 2019; Peddinti et al., 2021). One such material is poly[*tert*-butylstyrene-*b*-(ethylene-*alt*-propylene)-*b*-(styrene-*co*-styrenesulfonate)-*b*-(ethylene-*alt*-propylene)-*b*-*tert*-butylstyrene] (TESET), a sulfonated pentablock polymer with the sulfonic acid groups located in the central styrenic block (Figure 1) (Peddinti et al., 2021). Upon hydration, TESET can establish a highly acidic polymer-water interface that rapidly inactivates a range of bacteria and viruses while retaining the robust mechanical properties characteristic of a thermoplastic elastomer (Peddinti et al., 2019; Peddinti et al., 2021).

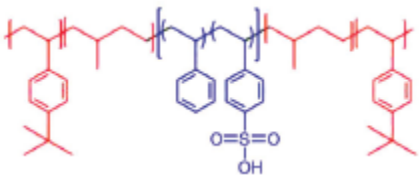


Figure 1: Chemical structure of the TESET pentablock polymer.

Note: Hydrophilic and hydrophobic moieties are colored blue and red, respectively. Reproduced from Scheme 1 of Peddinti et al. (2021).

These polymers consist of chemically distinct blocks that self-assemble into soft nanostructures, which facilitate hydration and proton transport that can contribute to surface acidification, as illustrated in Figure 2. Thermodynamic incompatibility between the blocks promotes microphase separation and the formation of distinct nanoscale domains (Peddinti et al., 2021; Yan and Spontak, 2022). In midblock-sulfonated TESET, the resulting morphology is composed of hydrophilic sulfonated domains within the polymer. Upon hydration, contiguous hydrophilic pathways allow protons from subsurface sulfonic acid groups to migrate toward the polymer surface (Peddinti et al., 2019; Wells et al., 2023b).

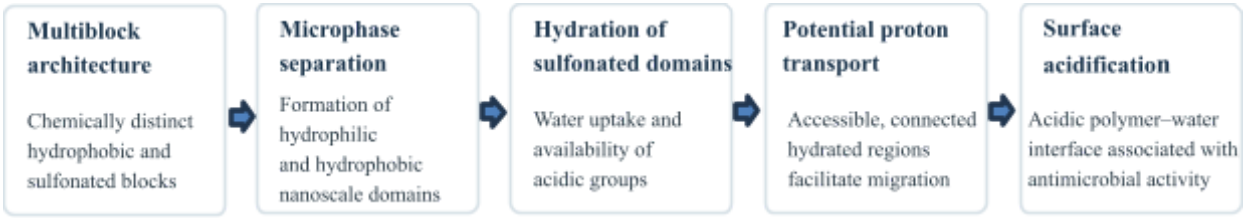


Figure 2: Schematic illustration of the processes from multiblock polymer structure to surface acidification

Note: Schematic drawing on findings from Mineart et al. (2015), Peddinti et al. (2019, 2021), and Wells et al. (2023).

Studies of these sulfonated polymers provide conclusive evidence linking highly acidic conditions with antimicrobial activity. Peddinti et al. (2019) reported that midblock-sulfonated TESET lowered the pH of the contacting solution to approximately 0.8 and rapidly inactivated Gram-positive and Gram-negative bacteria by at least 99.9999% in 5 minutes; the same study showed that antimicrobial performance depended on the degree of midblock sulfonation. Peddinti et al. (2021) subsequently demonstrated rapid inactivation of SARS-CoV-2 on TESET52, a TESET polymer with a degree of sulfonation (DOS) of 52 mol%, and likewise examined human coronavirus 229E (HCoV-229E) across several anionic block polymers.

The purpose of this paper is to examine what determines proton diffusivity in hydrated, self-assembled multiblock polymers and how these factors affect the highly acidic surface environment required for self-disinfection. More specifically, this review focuses on two questions: (1) Which molecular, morphological, and environmental factors influence proton transport in hydrated, self-assembled multiblock polymers? and (2) How do these factors contribute to establishing and maintaining the highly acidic surface environment required for self-disinfection?

This paper is structured as follows. Section 2 examines molecular, morphological, environmental, and processing factors relevant to proton transport in hydrated, self-assembled multiblock polymers. Section 3 considers how proton availability, delivery through the hydrated polymer, and accessibility of the polymer-water interface influences formation and maintenance of the highly acidic surface environment required for self-disinfection. Section 4 summarizes the main findings and remaining gaps.

FACTORS CONTROLLING PROTON DIFFUSIVITY IN HYDRATED, SELF-ASSEMBLED MULTIBLOCK POLYMERS

The studies reviewed here identify several features relevant to proton transport in sulfonated block polymers: the chemical groups that supply protons, polymer architecture, the amount of water present,

and the morphology and connectivity of the hydrophilic ionic domains (Chen et al., 2014; Zheng and Cornelius, 2016; Wells et al., 2023a). Before continuing, several relevant terms must be clarified. First, "hydrated" refers to the presence of water. In the case of the TESET polymer and other hydrophilic polymers, hydration occurs when water molecules are absorbed into the polymer matrix. Second, "self-assembled" is a term that reflects the ability of soft matter, including polymers and colloids, to spontaneously organize into well-defined structures, or microdomains, at nanoscale dimensions due to several different driving forces. For block polymers, self-assembly yields a wide range of different structures, or morphologies, due to the thermodynamic incompatibility between the blocks, or sequences, comprising the polymer. Lastly, "sulfonation" describes a chemical attribute in which a sulfonate group is chemically attached to another molecule. When its counterion is removed, the group becomes ionic and therefore highly hydrophilic. In the present scenario, the sulfonated middle block of TESET provides the protons that diffuse through the hydrophilic channels of the TESET nanostructure to the surface in the presence of water (Wells et al., 2023b).

The following subsections discuss proton availability and polymer architecture, pathway morphology and connectivity, and the effects of hydration, temperature, and processing history on the transport environment.

Proton Availability: Sulfonation and Polymer Architecture

The location of the sulfonated blocks within the polymer architecture governs how these polymers self-assemble and hydrate. Sulfonic acid groups provide the proton source, and their population determines how much acidic functionality is present. Polymer architecture is also associated with whether the sulfonated regions are water-accessible.

Peddinti et al. (2019) discussed midblock-sulfonated TESET alongside poly(styrene-ethylene-butylene-styrene) (SEBS)-type thermoplastic elastomers, in which the sulfonic acid groups are located in the endblocks rather than on the midblock. The authors reported that these endblock-sulfonated SEBS polymers exhibited inferior antimicrobial activity because, upon self-assembly into nanostructures, the sulfonated endblocks became isolated within a hydrophobic matrix and plasticized. In contrast, the sulfonated midblocks of TESET allowed considerable swelling in liquid water, while the swollen midblocks remained connected to glassy nanodomains that served as physical cross-links. These observations show that polymer architecture is associated with differences in hydration and self-assembly. However, because SEBS and TESET differ in polymer architecture beyond the location of the sulfonated blocks, this comparison does not isolate sulfonation location as the sole variable.

An important feature of the TESET architecture is that its sulfonated midblock can absorb water and swell while the polymer retains a physically connected network. The nonsulfonatable *tert*-butylstyrene endblocks remain intact in polar liquids and help maintain the integrity of the swollen network (Yan and

Spontak, 2022). The strong temperature dependence of swelling is discussed below in the section "Hydration, Temperature, and Processing History."

Sulfonic acid groups provide the acidity for lowering the pH of the aqueous environment in contact with TESET (Peddinti et al., 2019). Their placement within the polymer architecture is therefore important, as discussed above, but the population of sulfonated styrene units also varies with the DOS. For sulfonated styrenic block copolymers, the DOS describes the ratio of sulfonated styrene units to the total number of styrene units and is expressed as mole percent (Tsai et al., 2021). Peddinti et al. (2019) examined commercial TESET with 26 and 52 mol% midblock sulfonation and used a related, laboratory-synthesized poly(*tert*-butylstyrene-*b*-styrene-*b*-*tert*-butylstyrene) (TST) triblock polymer to extend the sulfonation range to 17, 40, and 63 mol%. The TST series was used specifically to examine the role of midblock sulfonation beyond the two available TESET compositions. From the bacterial inactivation results across these midblock-sulfonated polymers, the authors concluded that a minimum degree of midblock sulfonation between 26 and 40 mol% was needed to achieve maximum inactivation of all bacteria examined. While this result establishes that a critical reservoir of protons, regulated by the DOS in relatively thick polymer films, is required to achieve the maximum antimicrobial performance, it does not elucidate how the DOS and polymer morphology affect proton diffusion.

Connectivity and Morphology of Hydrophilic Transport Pathways

The morphology of the hydrophilic domains, including whether those domains join to form contiguous pathways through the material, constitutes an important structural consideration for proton transport in hydrated, self-assembled polymers. In this context, a connected pathway refers to a continuous hydrophilic route through neighboring ionic domains rather than a collection of isolated ionic regions. Wells et al. (2023a) suggested that, in TESET, the connectivity of the hydrophilic nanochannels governs the protons diffusivity from the midblock sulfonic acid groups.

Recent development of charged multiblock copolymers with robust mechanical properties provided new opportunities for technologies requiring amphiphilic attributes. Due to the presence of strong interactions, however, control over the phase behavior of such materials remains challenging, especially since their morphologies can be solvent-templated.

Casting solvent can alter the morphology and connectivity of ionic domains in sulfonated pentablock polymers. Advanced electron imaging transmission electron microscopy (TEM) and microtomography (TEMT) have been used to investigate how casting-solvent polarity influences the morphology of midblock-sulfonated pentablock ionomers. Three-dimensional analysis confirmed the coexistence of hexagonally-packed nonpolar cylinders and lamellae (Mineart et al., 2015). Wells et al. (2023a) describe tetrahydrofuran (THF)-cast TESET as having a combination of alternating lamellae and hexagonally-packed nonpolar cylinders in an ionic matrix, whereas toluene/isopropanol (TIPA)-cast films yield dispersed ionic microdomains within a hydrophobic matrix; consequently, the hydrophilic pathways

are less connected in the as-cast TIPA morphology. Wells et al. (2026c) attribute these morphological differences to solvent selectivity and evaporation kinetics, which determines how the polymer chains group together and how much time is available for those chains to self-assemble before the material hardens, respectively. The authors explain that balanced, polar THF mediates the strong incompatibility between the ionic and nonpolar blocks, allowing the polymer to approach its equilibrium morphology, whereas nonpolar, selective TIPA drives the sulfonated midblocks into discrete micelles before solvent evaporation restricts chain mobility. Similar solvent-dependent behavior has been reported for Nexar™, the commercial midblock-sulfonated pentablock polymer used as the TESET material in these studies. Dai et al. (2019) report that a low-polarity mixed casting solvent produces discrete, spherical ion-rich microdomains restricting proton transport, whereas a more highly polar casting solvent yields a mixed morphology containing open, continuous ion-rich pathways.

Studies of other sulfonated block polymers provide additional evidence that the structure and connectivity of hydrated ionic domains are associated with proton transport. In a model sulfonated triblock copolymer, Chen et al. (2014) measured proton conductivity under different hydration conditions, using a humidity-controlled environmental chamber and measurements in liquid water. The authors observed a discontinuous increase in proton conductivity when the membrane was transferred from nearly saturated humid air to liquid water. This increase coincided with a change in the internal structure of the hydrated channels, including the formation of a water-rich region within the channels. In a separate study, TEM and small-angle X-ray scattering (SAXS) were used to characterize solvent-dependent morphological changes in sulfonated pentablock ionomer films (Zheng and Cornelius, 2016). Here, SAXS provides information about nanoscale structural organization, including the spacing between polymer domains. In a sulfonated pentablock ionomer, internal morphology and connectivity govern water absorption and proton transport. Zheng and Cornelius (2016) reported that a transition from a random arrangement of ion domains to well-connected lamellar/hexagonal structures was accompanied by an increase in water uptake from 23 to 46 wt% and in proton conductivity from 4.5 to 47.8 mS/cm. Although these studies measured proton conductivity rather than proton diffusivity, they establish that changes in hydrated ionic-domain structure can occur with substantial changes in proton transport.

Additional evidence from TESET relates pathway connectivity to molecular diffusion through the hydrophilic domains. Wells et al. (2026c) studied poly(ethylene glycol) diacrylate (PEGda), a hydrophilic polymer that can be absorbed into the hydrophilic microdomains of TESET. The authors found that PEGda diffuses faster through THF-cast TESET than TIPA-cast TESET because of the highly connected hydrophilic pathways in the THF-cast materials. The diffusion activation energies are approximately 35–37 kJ/mol for THF-cast films compared with 46–47 kJ/mol for TIPA-cast films. Although these measurements pertain to PEGda rather than protons, they provide corroborative evidence that pathway connectivity is associated with molecular diffusion within TESET.

Hydration, Temperature, and Processing History

Hydration, temperature, and processing history can modify the state of sulfonated block polymers in ways that change the environment through which transport occurs. In TESET, hydration plays two roles: it supplies the aqueous phase needed for proton migration through hydrophilic pathways and can also reorganize ionic domains into well-connected networks (Wells et al., 2023b; Wells et al., 2026c). Temperature has been shown to strongly affect TESET swelling, whereas post-casting treatments such as solvent-vapor or hydrothermal annealing can alter the tortuosity of pathways associated with proton diffusion (Peddinti et al., 2019; Wells et al., 2023a).

The amount of hydration can affect water transport within sulfonated pentablock polymers. Dai et al. (2019) measured water diffusivity in TESET as a function of water activity and found that, in the neat polymer, the diffusivity initially increased with increasing water activity before reaching a plateau or shallow maximum. Although these measurements describe water rather than proton diffusion, they show that water diffusivity in TESET varies with the level of hydration.

Temperature has a pronounced effect on the swelling behavior of hydrated TESET. Peddinti et al. (2019) reported approximately 170% swelling at 23 °C and more than 1000% swelling at 70 °C for TESET52 cast from THF. Although the temperature dependence of TESET swelling is non-negligible and constitutes an important practical consideration, no study to date has endeavored to identify the underlying mechanism for this dependence or relate this temperature-dependent swelling to proton diffusion.

Processing history is relevant to proton transport because treatments applied after film formation can reorganize the polymer morphology and modify structural characteristics of the pathways that govern proton diffusion. For example, Mineart et al. (2016) showed that solvent-vapor annealing of midblock-sulfonated pentablock polymers cast from TIPA with THF can reorganize as-cast morphologies into well-ordered and oriented lamellae. Wells et al. (2023a) subsequently reported that pre-exposure of TESET to solvent-vapor or hydrothermal annealing alters the tortuosity of pathways responsible for proton diffusion. These studies reveal that, as a consequence of the high thermodynamic incompatibility between the blocks in TESET, various post-treatments are immensely valuable in refining or altogether changing the as-cast morphologies of this polymer over time frames that are industrially relevant. Although changes in morphology directly affect microdomain connectivity and thus proton transport, a precise relationship between morphology and proton diffusion remains lacking. Another, often overlooked, benefit of these post-treatments is that the polymer can be re-dissolved and re-used, which is very important in a circular economy.

FACTORS GOVERNING FORMATION OF THE HIGHLY ACIDIC SURFACE ENVIRONMENT REQUIRED FOR SELF-DISINFECTION

The formation of a highly acidic surface environment for self-disinfection requires several features of the hydrated polymer and its interface with water. The studies examined here provide evidence for three aspects of this process: the availability of protons from sulfonic acid groups within the polymer, the movement of protons through hydrated pathways toward the surface, and access of water and protons to the polymer-water interface where the low-pH contact layer forms.

Proton Supply and Acidification Capacity

Sulfonic acid groups provide the protons for acidification in the TESET systems. Peddinti et al. (2019) reported that TESET26 and TESET52 initially lowered the pH of phosphate-buffered saline (PBS) to approximately 0.8. The authors concluded that this ability to lower the pH was largely responsible for rapid bacterial inactivation in TESET. This finding likely applies to similar TST polymers.

The DOS describes the reservoir of sulfonic acid functionality present in the polymer and therefore the acidic functionality available to contribute protons to surface acidification. Peddinti et al. (2021) stated that the interfacial pH-drop mechanism depends on the number of sulfonic acid moieties present on each polymer molecule, expressed as DOS; Peddinti et al. (2019) showed that antimicrobial performance varied across polymers with different DOS values under the tested conditions.

Repeated exposure to PBS can also reduce the ability of TESET to maintain a very low pH. Peddinti et al. (2019) found that TESET26 and TESET52 initially lowered the pH of PBS to about 0.8, but the pH increased with repeated cycling. By the fifth cycle, TESET26 was near pH 1.5 and showed no evidence of antibacterial activity, whereas TESET52 still produced 99.94% inactivation. The observed increase in pH upon cycling is attributed to complexation of mobile cations in PBS with sulfonic acid groups in the polymer. This conclusion has been corroborated by independent tests aimed at fully neutralizing the polymer, and thus eliminate its antimicrobial properties, with various ions differing in valence, but chemical verification of the existence of chemical complexes in the polymer is not yet available. An interesting outcome of the study by Peddinti et al. (2019) is that the fully neutralized TESET52 polymer can be recharged upon exposure to an aqueous acid for a time that depends on the acid concentration. As an example, a dilute HCl(aq) solution similar to lemon juice would require about 30 minutes to promote full recharge of the polymer.

Film thickness provides another way to examine the proton reservoir available for surface acidification while holding DOS constant. Wells et al. (2026a) studied TESET with 52 mol% sulfonation at a fixed 2-min exposure time and found that antimicrobial efficacy increased with film thickness and then reached a plateau for films about 100 micrometers thick. The authors defined the onset of this inactivation plateau as a critical thickness, L*, estimated at approximately 63-65 micrometers by two methods. The proton

partition coefficient – the ratio of protons in the aqueous contact layer to those available in the sulfonated polymer film – reached a fitted-curve maximum of 0.43 at approximately 62 micrometers, in favorable quantitative agreement with the onset of the inactivation plateau.

Wells et al. (2026a) expect that L* may depend on exposure time, temperature, and microbe type. Under the 2-min conditions studied, films thinner than L* contained too few protons to lower the pH sufficiently inactivate more than 80% ampicillin-resistant *Escherichia coli* (AREC), whereas in thicker films not all available protons contributed to lowering the contact-layer pH within that time. The authors suggested that within thicker films, a swelling gradient could develop, impeding protons deeper in the film from reaching the surface, and they identified direct in-situ proton-diffusion measurements such as pulsed-field-gradient nuclear magnetic resonance (PFG-NMR) to examine this possibility.

These studies indicate that surface acidification depends not only on the amount of sulfonic acid functionality present, but also on whether that proton supply remains available during repeated aqueous exposure and can transport to the surface within the relevant time.

Proton Delivery Through the Hydrated Polymer

The antimicrobial properties of TESET depend on the diffusion of subsurface protons through hydrophilic channels upon hydration. These channels constitute contiguous pathways, rather than discrete and isolated microdomains, for protons to diffuse to the film surface, where they acidify the aqueous surface contract layer. Wells et al. (2023b) included a TEM image illustrating the polymer's internal morphology, displaying contiguous ionic microdomains. The authors reported that, upon hydration, protons from subsurface sulfonic acid groups migrate through contiguous hydrophilic pathways to the polymer surface and lower the surface pH below 1.0. Their surface imaging results using scanning electron microscopy (SEM) and atomic force microscopy (AFM) further revealed hydrophilic microdomains extending from the film interior to the surface, which the authors identify as pathways through which protons migrate to the surface upon hydration.

As discussed in Section 2, pathway connectivity is associated with proton transport in TESET. More recent experiments with TESET containing mineral oil provide complementary evidence. Wells et al. (2026b) used solvent-vapor annealing (SVA) after film formation to reorganize TIPA-cast TESET/mineral-oil blends. The authors reported that SVA promoted highly ordered lamellae, as discerned from SAXS, and that the SVA-treated blends possessed better connectivity of the hydrophilic microdomains. They associated this greater connectivity with improved short-time antimicrobial performance because it facilitates proton transport. As a concrete example, the solvent-vapor-annealed TESET/MO10 blend (containing 10 wt% mineral oil) resulted in 0.80% AREC survival after 2 min and 0.038% after 5 min.

Another important consideration is that the polymer morphology can altogether change after the dry, as-cast film comes in contact with liquid water. This is particularly relevant in the case of highly nonequilibrated morphologies, such as the one generated in the TIPA cosolvent. In this case, discrete ionic microdomains transition into irregularly-shaped and highly contiguous channels in a non-thermodynamic morphological transformation. Wells et al. (2026c) examined, upon water exposure, initially dispersed ionic domains in TIPA-cast TESET transform into contiguous but irregular hydrophilic channels. In the same experiments, PEGda uptake occurred during this transformation, and the authors linked the changing morphology with a higher diffusion-energy barrier compared to THF-cast TESET.

Surface Accessibility and Maintenance of the Acidic Interface

The polymer-water interface is relevant to surface acidification because this is where the highly acidic contact layer forms. Wells et al. (2023b) used X-ray photoelectron spectroscopy (XPS), a surface-sensitive method for measuring elemental composition, to examine the TESET52 surface before and after 5 min of exposure to PBS. The measured oxygen concentration increased from 2.37 to 2.84 atomic%, while sulfur increased from 0.55 to 0.70 atomic%. The authors described these changes as 20-27% hydration-induced increases in hydrophilic species at the polymer surface. These results indicate that hydration changes the surface composition of TESET52, although the XPS measurements do not directly measure proton transport. Such environment-induced surface reconstruction is commonly encountered with soft materials.

Surface access can also be physically obstructed. Wells et al. (2026b) studied TESET/mineral-oil gels and reported that when mineral oil resides on the film surface, it blocks water from diffusing into the material to activate TESET and prevents protons from diffusing to the top contact layer. Low-voltage scanning electron microscopy showed extensive mineral-oil coverage on the as-cast blend surfaces, which supported the authors' interpretation that the oil physically obstructed access to the TESET surface. Antimicrobial efficacy decreased with increasing oil content; at 50 wt% mineral oil, AREC survival ranged from 53.8 to 90.2% after 5 min, whereas neat TESET reached the minimum detection limit of 99.9999% under the study conditions. This work demonstrates that obstruction of water into the polymer hinders proton diffusion, which, in turn, lowers the antimicrobial effectiveness. The authors do not, however, endeavor to elucidate the corresponding molecular-level mechanism or accompanying proton diffusivity.

CONCLUSIONS

Contaminated surfaces in healthcare settings can lead to the spread of infectious pathogens, putting patients at risk of serious and potentially life-threatening infections. A major advantage of self-disinfecting sulfonated block polymers is that their antimicrobial activity arises from the polymer's inherent acid functionality rather than relying on added chemicals. Studies of TESET demonstrate rapid microbial inactivation, supporting the potential of this approach for self-disinfecting surfaces in high

traffic areas. However, a key limitation is that antimicrobial effectiveness depends on the formation and maintenance of a sufficiently acidic polymer-water interface, which requires sustained proton availability and transport through hydrated polymer pathways.

The studies considered here identify polymer chemistry and architecture, hydration, hydrophilic-domain connectivity and tortuosity, and processing history as factors relevant to proton transport in sulfonated block polymers. For TESET specifically, much of the evidence considered here comes from morphology, swelling, surface acidification, or antimicrobial behavior. For surface acidification, the evidence consists of proton availability, diffusion through hydrated pathways, and access to the polymer-water interface. These observations connect the proton transport environment with development of the acidic surface for self-disinfection.

The main limitation is that direct proton-diffusion measurements are sparse in the TESET studies reviewed. This makes it difficult to quantify how strongly morphology and environmental or processing conditions alter proton diffusivity, or how changes in proton diffusivity can be linked to surface acidification and antimicrobial performance. Direct proton-diffusion measurements under well-characterized conditions could help clarify these relationships.

For future research, two considerations must be explicitly addressed. One is how polymer structure and hydration quantitatively affect proton transport in TESET, and the other is how proton transport within the polymer determines the rate and persistence of surface acidification and, ultimately, antimicrobial and self-disinfecting performance. Further investigation of these relationships could help clarify the fundamental mechanisms governing self-disinfection and guide the development of multiblock polymers with improved antimicrobial performance.

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