Self-Cleaning Hydrophobic Nanocoatings on Textiles: Evaluating SCHN 135 and CaptureCoating™

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Abstract

Hydrophobic nanocoatings offer a fluorine-free alternative to traditional PFOA/PFOS treatments for textile stain resistance. This study evaluates the performance of two commercial sol-gel derived coatings, SCHN 135 (Integricote™) and CaptureCoating™ (CurranBiotech™), on carpets, cotton, polyester, and other fabrics. Treated and untreated samples were assessed using AATCC 193 (aqueous liquid repellency), AATCC 118 (oil repellency), AATCC 22 (spray test), AATCC 175 (stain resistance), and static contact angle measurements. SCHN 135 (A+F2 formulation) achieved the highest performance, with ALR ratings of 8 and OR ratings up to 6 on cotton and nylon substrates, and Red 40 stain resistance of 10. All measured contact angles exceeded 90°, confirming hydrophobic behavior. CaptureCoating™ also showed initial hydrophobicity but

exhibited faster absorption over time. These results demonstrate that SCHN 135 provides durable, non-toxic stain and liquid repellency suitable for residential and commercial textiles, while Capture Coating™ targets enhanced aerosol capture in air filtration media.

Introduction

Textile Overview and Purpose of Evaluation

Textiles are materials composed of fibers spun into yarn and then woven into fabrics. Carpets, a specific category of textile known as pile floor coverings, are widely used in residential homes, but are easily susceptible to staining. When liquid penetrates the textile fibers, they bind to polar chemical groups in the polymers of the fibers and produce visible discoloration that is difficult to remove. To combat stain resistance, recent developments in nanotechnology have introduced surface coatings capable of reducing surface energy in such a way that dyes do not penetrate the fiber structure. The design of SCHN 135, developed by Integricote™, provides protection to carpets and other fabrics by forming a self-cleaning surface that repels liquids and minimizes staining. However, a common misconception arises when the terms "self-cleaning" and "hydrophobic" are used interchangeably. The self-cleaning phenomenon refers to the behavior in which water droplets of a fixed volume or mass slide, roll, or exhibit a combination of both motions when a surface is tilted beyond a critical angle [4]. In contrast, hydrophobicity describes a material's ability to repel water. Therefore, this study focuses on evaluating the self-cleaning and hydrophobic properties of SCHN 135-coated carpet samples, compared with untreated carpet fibers, using staining tests with common liquids.

Perfluorooctanoic acid (PFOA), a chemical designated under Proposition 65 for its potential to cause reproductive harm, including birth defects [5], is used as a benchmark. Similarly, perfluorooctanesulfonic acid (PFOS), a related perfluoroalkyl substance commonly used alongside

PFOA in textile coatings, is also listed under Proposition 65 as known to the State of California to cause reproductive toxicity [6]. The objective of this study aimed at analyzing an alternative material that demonstrates superior performance and reduced health risks. In the last few decades, PFOAs and PFOSs have been used as effective water-resistant coatings, but their adverse effects have been noted by the U.S. Environmental Protection Agency (EPA). PFOAs are widely present in freshwater, estuarine, and marine environments, largely due to human-related activities and natural water movement. As PFOAs move through aquatic systems and biological networks, they can accumulate within organisms and enter the food supply, leading to an abundance in the bloodstream and negative health impacts [10]. Their presence in food and water sources raises concerns about potential chemical exposure through diet [10]. Consequently, many manufacturing companies have stepped forward to find an alternative and develop safe coatings that work the same, if not better than PFOA and PFOS coated materials. By utilizing non-fluoro-based nanocomposites, better replacements have arisen through sol-gel technology, thus increasing the need to evaluate risk-free stain resistors.

AATCC 193 Testing

To analyze fabric properties after coating with SCHN 135, a range of standardized American Association of Textile Chemists and Colorists (AATCC) test methods were used. Aqueous liquid repellency was measured using the AATCC 193 test, which measures the tested fabric's ability to repel water-based liquids. A series of solutions with different surface tensions is dropped onto a fabric; the highest-numbered solution that does not wet the surface determines its grade on a scale of 0-8, with higher scores indicating better performance. The AATCC 118 test measures a fabric's protective properties against oily stains representing the most effective oil repellency. The AATCC 127 test measures a fabric's resistance to water penetration under increasing pressure. The AATCC

22 spray test evaluates the resistance of fabrics to water by spraying water onto a taut fabric sample at a 45-degree angle. The results are compared to a standard chart and given a rating on a scale of 0-100, higher scores representing greater water repellency. The AATCC 175 measures the stain resistance of fabrics against acidic food colorings such as Allura red AC, also known as Red 40.

Chemical Background of Sol-gel Chemistry and SCHN 135

The term sol-gel stems from the process in which small particles or molecules dispersed in a liquid (a sol) gradually come together and, under controlled conditions, connect to form a continuous, solid-like network known as a gel [11]. SCHN 135 was synthesized using sol-gel chemistry and modified with a hydrophobic additive. The critical role of this hydrophobic nanocoating is the behavior of cross-linking, which refers to the formation of covalent bonds between polymer chains that create a three-dimensional network structure. Cross-linking enhances mechanical stability, adhesion, and chemical resistance of hydrophobic coatings. This in turn helps maintain surface roughness and prevents degradation, which are both essential to having high contact angles and preventing liquid absorption into porous textile fibers. The sol-gel process formed a crosslinked oxide network, while the additive introduced nonpolar functional groups to the surface, reducing the surface energy. Combined with nanoscale roughness inherent to sol-gel films, this resulted in a hydrophobic coating characterized by water repellency.

Application to Air Filtration and Pathogen Control

The rise of COVID-19 infections sparked a rapid response in understanding the mechanisms and reactions to the virus, forcing a global challenge on modern-day methods for combating infectious diseases. Initial COVID-19 studies revealed that the SARS-CoV-2 virus and its variants have the ability to affect the body beyond the respiratory system with a 1.37% global increase in type 1 and type 2 diabetes mellitus following exposure to the virus [2]. There is currently no anti-viral treatment in any filters used globally; COVID-19 and other Rhino viruses require a medium to get to an area such as mucus. The most effective solution is to develop a passive system that prevents the spread indoors.

SCHN 135 is intended to coat textiles such as carpets and fabrics to prevent staining, mold, and deterioration. CaptureCoating™ on the other hand, was designed to combat bacteria, viruses, and fungi that contribute to the deterioration of air filters. CaptureCoating™ is a patented nanotechnology-based surface treatment designed to soak into the surface of HVAC filters, enhancing air filtration performance against harmful particles, especially viruses such as COVID-19. This coating creates a superhydrophobic nanoscale environment when applied to HVAC air filter material, enabling enhanced filtration of aqueous carriers of viruses and microorganisms without reducing air filtration efficiency. Because many respiratory pathogens (including SARS-CoV-2 and MRSA) are transmitted through liquid-phase droplets, CaptureCoating™ shifts the filtration from particle-size exclusion to absorptive capture of droplet-encapsulated pathogens. The non-toxic design avoids the introduction of harmful chemicals while still reducing pathogen transmission. CaptureCoating™ introduces a scalable, cost-effective strategy for improving air quality without compromising existing HVAC infrastructure.

This current work on an advanced water-soluble sol relates to an antiviral coating additive that also possesses hydrophobic materials that gives protection against the medium by which SARS-CoV-2 travels, the water-based mucus. CaptureCoating™ can either penetrate porous substrates (walls, floors, or other surfaces), be layered on tarps, or wrap around fibers in fabrics. It can be used in fabrics/filters for homes, hospitals, and office ventilation systems (and in ships with non-metallic vents). The active ingredient being investigated should impart an agent that causes damage to the capsid protein layer, spike protein, and initiates a process leading to lysis.

When viruses become airborne in a room, larger droplets gradually break down into submicron-sized particles as depicted in Figure 1.

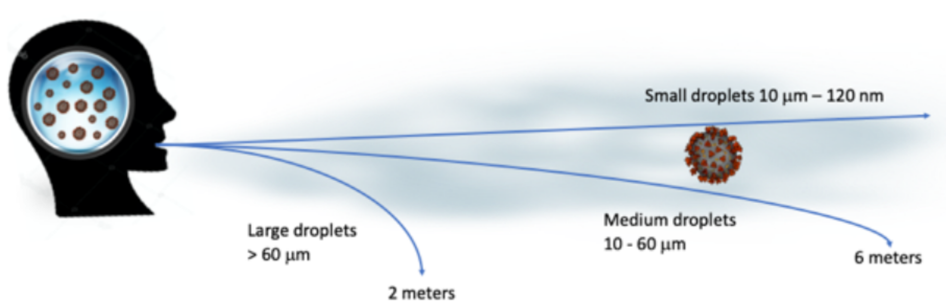

Figure 1: *Diffusion mechanisms of different sized pathogens.*

At this stage, it is critical to prevent these droplets from passing through air filters and dispersing throughout a building, as was observed during the early 2020s with COVID-19.

Filters and Particle Transmission

The capture of particles by fibrous filters is dependent on the weave structure and interconnectedness of the fibers, filter thickness, incoming airflow, and the aerosol properties of the particles. The pathways used by the particulates inside the weave and through the fibers are based on the flow properties including inertial impaction, interception, and diffusion mechanisms as illustrated in Figures 1 and 2. Large particles (which account for ~35-40% of cough or sneeze emission) are not considered as they are the first particles to reach the ground.

Medium particles: Defined as droplets greater than 10 µm in diameter, are primarily captured by inertial impaction. In this mechanism, the particles' momentum prevents them from following the abrupt changes in airflow around the filter fibers, causing them to collide with the fiber surfaces. Once in contact, they are retained by adhesion forces, including electrostatic, capillary, and van der Waals interactions. Although smaller particles may also undergo inertial impaction, their lower mass makes it easier for them to follow the curving airflow and "slide through" the fiber matrix initially, reducing collection efficiency via this mechanism.

Small Particles: The interception case is where the small particles come within one radius of the surface of the fiber and will have sufficient time to also get trapped. Small diameter particles are dominated by Brownian motion, as in the case of sub-micron particles. They can be knocked off a streamlined path which would allow it to escape and get captured on a fiber surface. However, if a particle is sufficiently small, and there is an idealized size for such particles, then the majority will get through most filter systems except for HEPA filters [6].

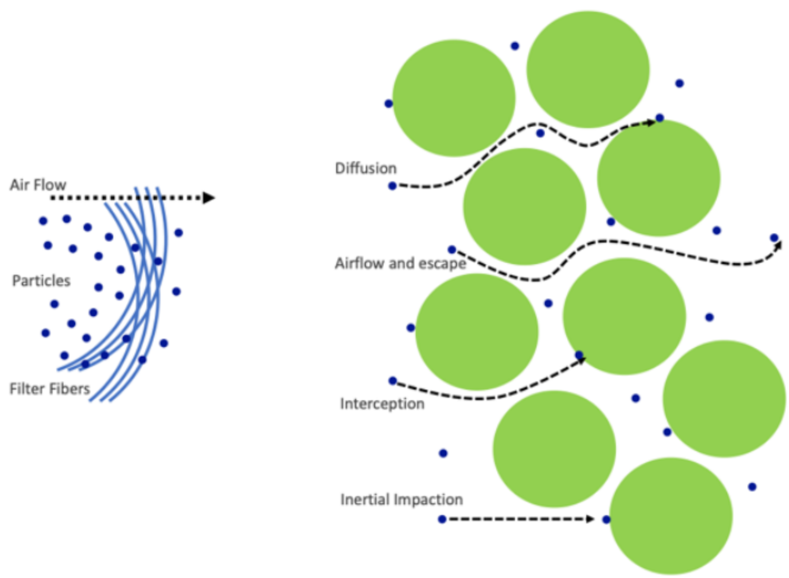

Figure 2: *Diagram showcasing different mechanisms involved when filters are used to block or capture particles and the pathways taken to do so.*

Previously, CaptureCoating™ coated filters captured and inactivated the virus on the front face, and swab tests were performed on the upstream (front) surface of the filters challenged with SARS-CoV-2. Thirty minutes after aerosolized viral challenge, no detectable viral RNA was recovered from the front face of the CaptureCoating™-treated filters. These results indicate that the virions were rapidly desiccated and disintegrated upon contact with the coated fibers. Swab sampling of the downstream (back) face of the filters similarly yielded no detectable viral RNA, confirming that no infectious virus penetrated through the filter media.

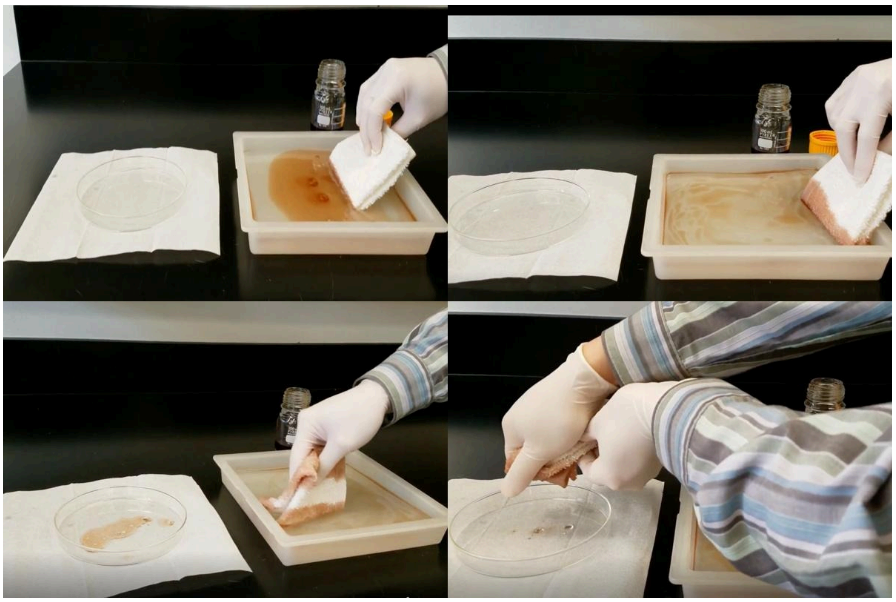

Figure 3: *Qualitative visual demonstration of hydrophobicity and surface protection.*

The performance of the hydrophobic nanocoating on textile material is shown in Figure 3 in a sequence showing material entering the liquid mixture, absorbing colored liquid, and colored liquid being squeezed from the material. This demonstration was conducted to visually observe an oil cloth surface and liquid interaction with hydrophobic materials.

Principles of Hydrophobicity

Although the academic world initially overlooked hydrophobicity after being proposed by Irving Langmuir in 1939, its continued research in the mid-1900s deepened the world's understanding of entropy and enthalpy [9]. Over time, the study of hydrophobic materials expanded from fundamental molecular theory into applied surface science. Researchers began to investigate how hydrophobic behavior could be intentionally engineered into coatings and surface treatments in order to reduce water adhesion and improve material longevity. This shift was important for industries operating in moisture-rich environments where condensation can also take place.

When a polar molecule like water contacts a non-polar surface, the water beads up instead of spreading and dampening the surface. In bulk liquid water, molecules form a dynamic network of hydrogen bonds that are constantly breaking and reforming on picosecond timescales. This disordered state causes local dipole moments to largely cancel out. However, at a hydrophobic surface, water molecules cannot form favorable hydrogen bonds with a non-polar coating. As a result, they reorganize into a more ordered, cage-like structure near the interface to maximize hydrogen bonding among themselves. This ordering restricts the rotational freedom of the water dipoles, leading to a net polarization field at the water-surface interface rather than random cancellation. The resulting polarization helps stabilize the formation of a discrete water droplet by increasing the interfacial tension and favoring water-water cohesion over water-surface adhesion [1].

This behavior is a direct manifestation of the hydrophobic effect. The hydrophobic effect is primarily entropic in nature: non-polar surfaces force surrounding water molecules into more ordered structures, decreasing system entropy. By beading into a near-spherical shape, the droplet minimizes contact area with the hydrophobic coating, allowing water molecules to regain disorder and restore favorable hydrogen bonding in the bulk. Macroscopically, this is described by a high contact angle (typically greater than 90°, often 110°–150° or more on well-coated surfaces) according to Young's equation (Eq.1) which explains why water beads up on hydrophobic surfaces. When γSL is high (weak attraction between the solid and liquid), the numerator becomes small or negative, making $\cos\theta$ small or negative. This results in a large contact angle ($\theta > 90°$), causing the droplet to bead into a nearly spherical shape rather than spread out. On hydrophobic fabric coatings, a high contact angle prevents the liquid from wetting the surface and penetrating the fabric. The combination of dipole ordering, interfacial polarization, and the entropic drive of the hydrophobic effect prevents the water from penetrating or wetting the coated fabric.

$$cos\theta\gamma = \frac{\gamma SV - \gamma SL}{\gamma LV} \qquad \text{(Equation 1)}$$

Amphiphiles such as soaps and detergents exhibit similar behavior when placed on the hydrophobic fabric coating, also forming beads rather than spreading. Amphiphiles are molecules that possess both a non-polar lipid tail and a charged or polar head group. Above the critical micelle concentration, these compounds self-assemble in water into micelles or liposomes, with the hydrophobic tails shielded from water and the hydrophilic heads exposed to the aqueous environment [3]. Although the lipid tails are neutral and could potentially interact with the non-polar coating through Van der Waals forces, the overall solution is repelled in much the same way as pure water. The polar head groups strongly dislike the hydrophobic surface because they cannot form favorable electrostatic or hydrogen bonding interactions with it. As a result, the amphiphilic solution maintains high effective interfacial tension at the coated surface. Any attempt to spread or penetrate the fabric pores would require extensive reorientation of the amphiphiles and further disruption of the structured water layers, both of which are energetically unfavorable due to the hydrophobic effect.

Hydrophobic coating material has advanced tremendously and has been included in several applications that involve exposure to wet environments, including the protection of marine industrial environments, transportation, and aerospace. Water is known to be corrosive over long periods of time, causing acceleration in the degradation of material, including metals like aluminum and steel [8]. Using these described principles and trying to find a way to integrate durability into industry, a solution could start to be created.

Materials and Methods

Materials

SCHN 135 was obtained from Integricote, Inc., Houston, TX. Other materials used in this experiment included an untreated carpet sample labeled as pristine, carpet samples coated with SCHN 135, and CaptureCoating™. To enhance versatility, fabrics consisting of 96% cotton and 4% elastane, alongside 100% cotton, were employed. A mesh fabric was also incorporated as an additional material. To evaluate staining, water, coffee, and Gatorade were utilized as test liquids. To assess performance simulating warehouse conditions, an oven was required.

Preparation of Textiles

First, two carpet samples were prepared for comparison, which consisted of one untreated and one treated with the SCHN 135 coating. The carpets were sprayed with SCHN 135 and left to completely dry for 48 hours. Each sample was then placed on a flat surface, and small droplets of liquid were applied to each carpet using the prepared liquids. The interaction between the liquids and carpet was observed and photographed.

After soaking, the coating underwent a curing process to form a cross-linking network that anchors hydrophobic functional groups to the substrate surface. A different process was conducted to evaluate the effect of SCHN 135 and CaptureCoating™ with fabrics of different materials. To start, two 3x3-inch squares were cut from carpet (samples A2 and B2), mesh (sample B4), 96% cotton with 4% elastane (samples A1 and B1), and 100% cotton (samples A3 and B3) for a total of 8 square samples. SCHN 135 and CaptureCoating™ were poured into two different basins, into which samples were then placed. The basin with SCHN 135 soaked one textile square from each of the four materials listed. The basin with CaptureCoating™ drenched the remaining samples. These were left to sit for five minutes before being taken and laid out on a flat surface covered in paper towels. After 48 hours, the samples were dried and contact angle analysis could commence. Using a Pasteur pipette, alkaline water was dropped on each of the samples. If a water bead remained intact for more than a minute, the material it was placed on would be picked up and tilted in several directions to analyze self-cleaning and hydrophobicity. Photographs from the sides of the droplets were obtained as seen in Figure 4.1. Further durability testing involved soaking samples for 48 hours followed by oven drying at 30°C to replicate warehouse storage conditions of the coating material.

Results

Coating Application on Fabrics and Carpets

Table 1: Performance of SCHN 135 (A+F2) coating on different fabric substrates and applications

Fabric:	**Chemical:**	**Textile Style:**	**Coating grade:**	**Test Results:**
Cotton	Cellulose	Fabric Swatches	SCHN 135 (A+F2)	ALR: 8; OR:6, SR: [24hr Red 40] Grade 10
Polyester	Polyethylene	**S**eat Covers	**S**CHN 135 (A+F2)	ALR: 8; OR:6
Polyester	Polyethylene	High Vis/Fire /Retardant	SCHN 135 (A+F2)	ALR: 8; OR:6
Polyester	Polyethylene	Furniture Fabric	SCHN 135 (A+F2)	ALR: 8; OR:5, Spray:95
Polyester	Polyethylene	Awning/Marine /Fabric	SCHN 135 (A+F2)	ALR: 8; OR:6, Spray: 95
Polyester	Polyethylene	Vinyl Coated Polyester	SCHN 135 (A+F2)	ALR: 6; OR:4
Polyolefin	Olefin	Seating	SCHN 135 (A+F2)	ALR: 6; OR:2

Fabric:	Chemical:	Textile Style:	Coating grade:	Test Results:
Polypropylene	Olefin	Drawn Fibers	SCHN 135 (A+F2)	ALR: 5; OR:5
Polypropylene	Olefin	Drawn Fibers	**S**CHN 135 (A+F1)	ALR: 4; OR:1<

*Footnote: *ALR = Aqueous Liquid Repellency (0–8, higher = better); OR = Oil Repellency (0–8, higher = better); Spray = AATCC 22 Spray Rating (0–100, higher = better) Red 40 Grade = Stain resistance to Red 40 food dye after 24 hours (1 = severe staining, 10 = no staining)**

SCHN 135 (A+F2) and SCHN 135 (A+F1) were evaluated on cotton, polyester, polyolefin, and polypropylene substrates (Table 1). SCHN 135 (A+F2) was observed to be consistently effective across a wide variety of fabrics. SCHN 135 (A+F2) proved to be the most effective when applied to cotton fabric swatches with an ALR score of 8, OR score of 6, and a red 40 stain resistance score of 10. The coating grade is also very effective when applied to polyester with ALR ratings of 8 and OR ratings of 5 or higher for almost all textile styles included in the tests. Vinyl-coated polyester stands out as an outlier compared to the others, with a lower rating of 6 on the ALR scale and a 4 on the OR scale. A spray rating was also given to furniture fabric and marine fabric, where they were rated with a score of 95, indicating that the coating is highly water-resistant when in direct contact. The coating showed moderate performance on the tests conducted on polyolefin fabric with an ALR score of 6 and an OR score of 2. Lastly, drawn fibers of polypropylene were coated and tested with the two coating grades of SCHN 135, being SCHN 135(A+F2) and SCHN 135(A+F1). The (A+F2) grade consistently outperformed the (A+F1), being more effective for aqueous liquid repellency and significantly more effective for oil repellency.

Coating Tested on Carpet Materials:

Table 2: Hydrophobic and oleophobic performance of SCHN 135 coatings on nylon and polyester carpets, including advancing liquid repellency (ALR), oil repellency (OR), and Red 40 stain resistance ratings.

Fabric:	Chemical:	Textile Style:	Coating grade:	Test Results:

Nylon Fiber, Nylon/6, 6 Fiber	Polyamide	Car mats	SCHN 135(A+F2)	ALR:8, OR:6
Nylon Fiber, Nylon/6, 6 Fiber	Polyamide	Carpeting	SCHN 135(A+F1)	ALR:3, OR:0
Nylon Fiber, Nylon/6, 6 Fiber	Polyamide	Carpeting	SCHN 135(A+F2)	ALR:8, OR:6
Nylon Fiber, Nylon/6, 6 Fiber	Polyamide	Carpeting	CHN 135(A+H1)	ALR:5, OR:0 OR: Red 40 grade – 7.5, I ISO 105-A03: 4.5
Polyester (yarn)	Polyethylene /naphthalene	Stitched Polyethylene Film	SCHN 135(A+F2)	ALR:5, OR:3
Polyester (yarn)	Polyethylene /naphthalene	Carpeting	SCHN 135(A+F1)	ALR:5, OR:<1
Polyester (yarn)	Polyethylene /terephthalate	Carpeting	SCHN 135(A+F2)	ALR:4, OR:2

*Footnote: *AATCC 175 = Stain resistance (1 = severe staining, 10 = no staining), ISO 105-A03: Colorfastness to staining — gray scale method (1 = severe staining, 5 = no staining) **

In table 2, tests were performed on three SCHN 135 coating grades: SCHN 135(A+F2), SCHN 135 (A+F1), and SCHN 135(A+H1). Overall, SCHN 135 (A+F2) proved to be the most effective coating grade across all tests, and SCHN 135 (A+F1) was the least effective. Coating on nylon fiber yielded perfect ALR scores and OR scores of 6 on car mats and carpeting when treated with SCHN 135(A+F2). SCHN 135 (A+F1)-treated nylon fiber carpeting provided an OR score of 0 and a lower ALR rating of 3. Nylon fiber carpeting treated with SCHN 135 (A+H1) received an OR rating of 0, an ALR rating of 5, and showed notable stain-resistant effects with a 7.5 on the red 40 grading scale and an ISO 105-A03 score of 4.5. When applied to polyester-based polyethylene naphthalene, SCHN 135(A+F2) and SCHN 135(A+F1) received the same ALR rating of 5. Comparatively, SCHN 135(A+F2) showed greater oil repellency with an OR rating of 3, compared to the OR rating of SCHN 135(A+F1) being <1.

Figure 4: *CaptureCoating™ bounded onto the simplest filters*

Figure 4 shows a miscellaneous textile sample coated with CaptureCoating™. Its hydrophobic performance is clearly demonstrated in Figure 5, where water droplets form well-defined beads on the coated surface.

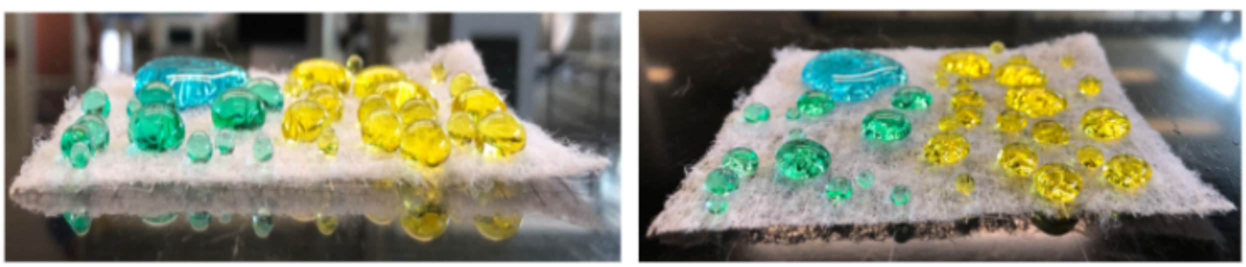

Figure 5: *Different color water droplets on CaptureCoating™ treated fibers.*

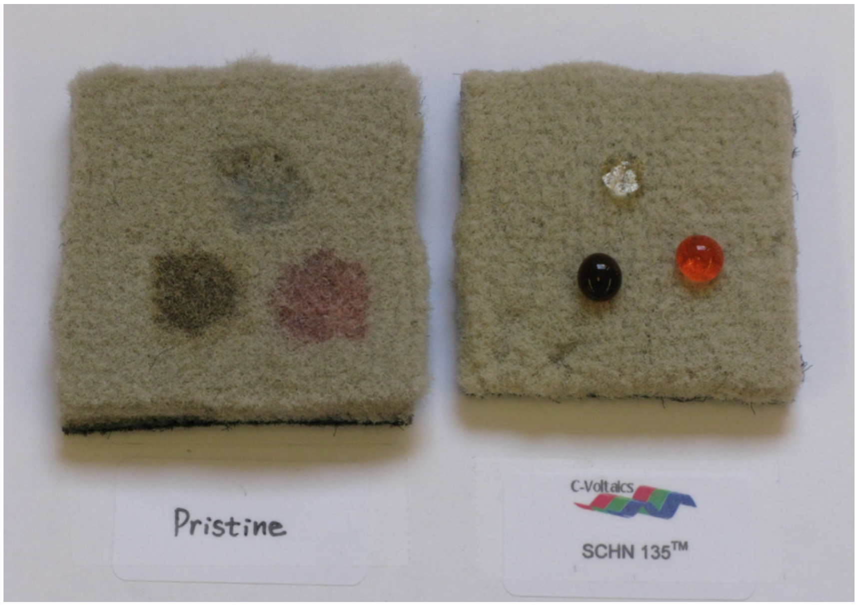

Figure 6: *A test run using drops of water, juice, and grape soda on textiles. The left carpet is coated with pristine material, and the textile absorbs the liquids. On the right, the carpet repelled the polar liquids.*

The liquid in contact with the untreated carpet samples had penetrated through the porous fibers quickly, as shown in Fig. 1. After the liquid was absorbed, a visible discoloration remained in the carpet, indicating a stain. In contrast, the carpet sample treated with SCHN 135 showed a drastic difference in contact with the liquids. When liquids were dropped onto the coated surface, they formed droplets rather than spreading across the fibers easily removed by a towel. After the liquid was picked up, no visible staining was observed.

Contact angles were collected from each water droplet photographed on two treatment groups of four distinct textiles. It is worth noting that due to the camera angle, A4 was not assessed for a contact angle.

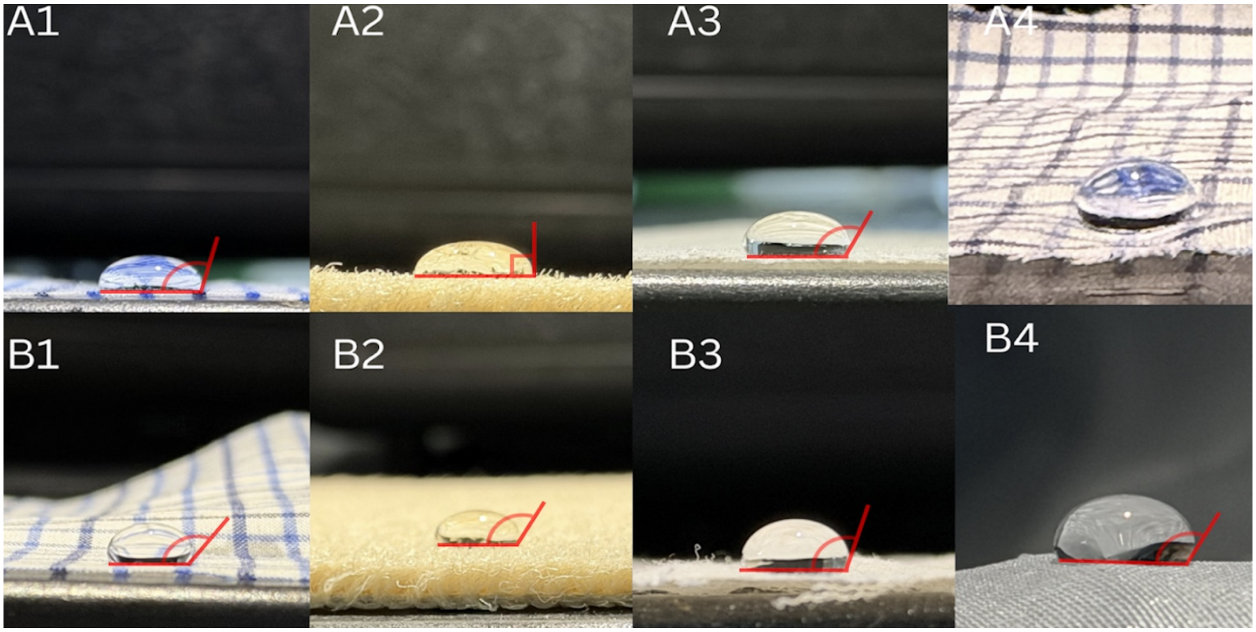

Figure 7: *Contact angles of each water droplet on four textile variations.*

Contact angles were determined through the use of photo editing software, in which a line was placed on a flat plane at zero degrees. Following this, a line representing the contact angle was drawn, and the supplementary angles for contact with the water droplet were gathered. As shown in Table 3, all measured contact angles exceeded 90° with the highest angle being 128.2°. The highest contact angle (128.2°) was observed on sample B1, while sample A2 exhibited the lowest value of exactly 90.0°.

Table 3. Contact angles between water droplets and various textile fabrics.

Sample	**Supplement Angle**	**Contact Angle**
A1	75.00°	105.00°
A2	90.00°	90.00°
A3	61.19°	118.81°
A4	Not recorded	Not recorded
B1	51.80°	128.2°

Sample	Supplement Angle	Contact Angle
B2	59.93°	120.07°
B3	73.79°	106.21°
B4	63.36°	116.64°

Discussion

Interpretation of Contact Angle Analysis

The results show that hydrophobic nanocoatings have a significant effect on hydrophobicity in industrial materials. The nanocoating improvement over the stain-resistant treatment is that it offers an alternative solution to stain resistance. The liquid on the untreated carpet sample had been absorbed through the porous fibers, while the treated carpet sample had formed droplets and were able to be picked up with a towel. The formation of the droplets compared to the untreated sample was used to show how SCHN 135 affected liquid penetration and stain formation. The contact angles observed were greater than 90°, indicating also ability linked through cross-linking. The cross-linked network keeps up with the integrity of the coating while also preserving the surface roughness of the fabric, allowing droplets to remain on the surface rather than being absorbed into the fibers.

Interpretation of ALR Ratings

The consistent high ALR ratings provide experimental proof that SCHN 135 lowers surface energy and causes polar liquids to bead rather than spread on fabric. The lower oil repellency values for various fabrics is to be expected, given that the coating is designed to repel polar liquids, which is consistent with the sol-gel chemistry discussed in section 1.2. Near-perfect spray ratings (95) on polyester fabrics further support the coating's ability to prevent water penetration, a key feature needed for effective application in marine and outdoor environments.

The tests provide evidence and further support the effectiveness of SCHN 135 as a hydrophobic coating treatment. The performance of the coating on carpet substrates was more variable. SCHN 135 A+F2 showed values comparable to woven fabrics on nylon carpets, which indicates that the coating fully penetrates and coats tufted fibers. The weaker performance on polyester carpets suggests that substrate chemistry influences the adhesive properties of the coating. Comparatively, the A_HI formulation, while less liquid repellent, showed very strong stain resistance, which makes it a valid option for applications to avoid the use of fluorine where oil repellency is negligible. The findings from the data support this paper's conclusion that SCHN 135 coating presents a non-toxic alternative to PFOA-based coating treatments for various carpet and fabric protection.

Application of SCHN 135 Compared to PFOAs

SCHN 135 has proven to be a material surpassing many of its industrial competitors, especially when evaluated against perfluorinated compounds such as PFOAs. This level of durability suggests strong chemical stability and resistance to environmental degradation. SCHN 135 can be used in textiles with great assurance that it will repel any polar compound rendering it useful in aerospace and marine technology.

The implication of SCHN 135 is substantial from both an environmental and health perspective. Unlike PFOAs, which are associated with adverse biological effects, SCHN 135 has shown no detectable harm to reproductive systems. This offers a safer alternative in applications where human exposure is likely or unavoidable. In practical applications, SCHN 135 can be effectively incorporated into textiles where it provides reliable resistance to polar compounds. Its ability to reduce surface energy allows treated materials to repel certain liquids efficiently, making it highly suitable for use in demanding environments. For instance, in aerospace engineering, SCHN 135 can help prevent moisture accumulation and corrosion on critical components. Similarly, in marine technology, its hydrophobic properties can reduce biofouling and improve material longevity by minimizing water interaction.

Overall, when combined with techniques such as sol-gel processing, SCHN 135 can be integrated into thin, uniform nanocompound coatings. This enhances both the durability and surface functionality of the material it coats. Overall, SCHN 135 offers both practical advancements and reduced health risks compared to conventional PFOA-based systems.

Comparison Between SCHN 135 and CaptureCoating™

As seen in Figure 4, all water beads formed contact angles greater than 90°. During the trial runs, CaptureCoating™ absorbed the water droplet about 10 minutes after placement. SCHN 135 was resistant to water at all times. Both coatings are effective as hydrophobic coating agents, with SCHN 135 being more effective. This is to be expected, considering that capture coating is most effective as an air filter for airborne pathogens such as COVID-19. These claims align with contact angle data from Table 1, where SCHN 135-treated samples (A1-A3) maintained their contact angles from 105° to 118.8°. Comparatively, CaptureCoating™-treated samples showed gradual absorption regardless of the initial angles exceeding 90°. CaptureCoating™ is specifically optimized for air filtration, where its ability to trap and desiccate SARS-CoV-2 droplets within 30 minutes has been demonstrated through data. Its temporary hydrophobicity serves to be sufficient for that purpose. SCHN 135's sustained performance, proven by maintaining function after 15 years in drop tests, makes it ideal for long-term textile protection.

Hydrophobic Performance of Treated Textile Materials

A qualitative demonstration was conducted to visually assess how hydrophobic-treated textile materials behaved in a colored oil-water mixture. As shown in Figures 5 and 6, the coated cloth picked up the colored oil part of the mixture while being mostly submerged in the liquid. When the cloth was squeezed, not much liquid was expelled, indicating that the cloth had repelled the water while submerged, showing us the hydrophobic behavior of the treated cloth. The hydrophobic behavior indicates that the cloth prevents absorption into the porous structure of the textile. The material was able to temporarily hold oil on its surface before being mechanically expelled due to the oil's lower surface tension, which can adhere to the surface without penetrating the textile fibers' structure. This demonstration supports the presence of a protective coating that limits fluid infiltration.

Limitations

When assessing hydrophobicity, it was important to ensure that each textile surface was thoroughly coated with both treatments. This was done through a brief soaking of each textile in its respective treatment, followed by a drying stage on an absorbent surface. This method proved somewhat effective, as materials exhibited hydrophobic properties upon initial contact with water droplets. In practical application, it would be expected that textiles be either spray-coated or soaked thoroughly prior to their use. Repeating an experimental run with these application parameters may prove to yield more consistent results.

Following the collection of contact angles of water applied upon four distinct textile surfaces, it was observed that the tested water droplet would begin to absorb through the fabric after a set amount of time. One explanation to justify this property of reduced hydrophobicity over time involves chemical decomposition of the coating itself. The approximate age of the coating used is estimated to be five years or older. In the time between when the bottle of coating was initially opened and the coatings performed herein, it is possible that the coating material was susceptible to environmental exposure, which could potentially degrade the efficacy of the coating. It would be preferable to repeat the experiment with a previously unopened hydrophobic coating to prevent the risk of potentially degraded materials.

Conclusion

The results of this study correlate strongly with the hydrophobic mechanism of SCHN 135 described in the introduction. The consistently high AATCC water repellency ratings experimentally confirm that SCHN 135 effectively lowers surface energy, causing polar liquids to bead up rather than spread and penetrate the fabric. As expected from the sol-gel chemistry outlined in Section 1.2, oil repellency values, evaluated using AATCC, were lower across various fabrics, since the coating is specifically engineered to repel polar liquids. The treated surfaces demonstrated effective oil cleanup, with oily stains beading and being easily removed without deep penetration or persistent discoloration, offering practical stain resistance against common household oils and greases. Near-perfect AATCC spray ratings (95) on polyester fabrics further demonstrate the coating's excellent ability to prevent water penetration, an essential feature for demanding applications in marine and outdoor environments.

While carpet substrates, due to their highly porous structure, exhibited more variable performance than woven fabrics, the data provided robust evidence for the coating's effectiveness. SCHN 135 A+F2 achieved AATCC values comparable to those on woven fabrics when applied to nylon carpets, indicating successful penetration and uniform coating of the tufted fibers. The relatively weaker performance on polyester carpets highlights the influence of substrate chemistry on coating adhesion. Notably, the A_HI formulation, although offering lower liquid repellency based on AATCC oil repellency ratings, delivered very strong stain resistance. This makes it a promising fluorine-free option for applications where oil repellency is less critical.

This study supports that hydrophobic nanocoatings such as SCHN 135 and CaptureCoating™ offer a viable, high-performing, and non-toxic alternative to traditional PFOA- and PFOS-based treatments for carpet and fabric protection. The coatings maintain strong performance while addressing growing environmental and health concerns associated with perfluorinated compounds. These results support broader adoption of SCHN 135-based treatments and CaptureCoating™ filters in residential, commercial, hospital, and outdoor settings, where stain resistance, durability, health, and eco-friendliness are increasingly prioritized.

References

[1] Despa, F.; Berry, R. S. The Origin of Long-Range Attraction between Hydrophobes in Water. *Biophysical Journal* **2007**, *92* (2), 373–378. https://doi.org/10.1529/biophysj.106.087023

[2] El-Naas, A.; Hamad, O.; Nair, S.; Alfakhri, B.; Mahmoud, S.; Haji, A.; Ahmed, L.; Lebbe, A.; Aboulwafa, A.; Shaikh, F.; Bouhali, I.; Zakaria, D. New Onset of Type 1 and Type 2 Diabetes Post-COVID-19 Infection: A Systematic Review. *Emerging Microbes & Infections* **2025**, *14* (1), 2492211. https://doi.org/10.1080/22221751.2025.2492211

[3] Kuriyan, J.; Konforti, B.; Wemmer, D. *The Molecules of Life: Physical and Chemical Principles*. Garland Science, **2013**.

[4] Maharjan, S.; Liao, K.-S.; Wang, A. J.; Barton, K.; Haldar, A.; Alley, N. J.; Byrne, H. J.; Curran, S. A. Self-Cleaning Hydrophobic Nanocoating on Glass: A Scalable Manufacturing Process. *Materials Chemistry and Physics* **2020**, *239*, 122000. https://doi.org/10.1016/j.matchemphys.2019.122000

[5] Office of Environmental Health Hazard Assessment (OEHHA). Proposition 65 List of Chemicals Known to the State of California to Cause Cancer or Reproductive Toxicity. California Environmental Protection Agency, **2025**. https://oehha.ca.gov/sites/default/files/media/downloads/proposition-65//p65chemicalslist.pdf

[6] Office of Environmental Health Hazard Assessment (OEHHA). Chemicals Listed Effective November 10, 2017 as Known to the State of California to Cause Reproductive Toxicity:

Perfluorooctanoic Acid (PFOA) and Perfluorooctane Sulfonate (PFOS). California Environmental Protection Agency, **2017**. https://oehha.ca.gov/sites/default/files/media/downloads/crnr/listingnotice111017.pd

[7] Perry, J. L.; Agui, J. H.; Vijayakumar, R. Submicron and Nanoparticulate Matter Removal by HEPA-Rated Media Filters and Packed Beds of Granular Materials. NASA/TM—2016–218224. NASA Marshall Space Flight Center, **2016**. https://ntrs.nasa.gov/citations/20170005166

[8] Rahman, A. U.; Kabeb, S. M.; Zulfkifli, F. H. Functional Hydrophobic Coatings: Insight into Mechanisms and Industrial Applications. *Progress in Organic Coatings* **2025**, *203*, 109187. https://doi.org/10.1016/j.porgcoat.2025.109187

[9] Tanford, C. How Protein Chemists Learned about the Hydrophobic Factor. *Protein Science* **1997**, *6* (6), 1358–1366. https://doi.org/10.1002/pro.5560060627

[10] Wee, S. Y.; Aris, A. Z. Environmental Impacts, Exposure Pathways, and Health Effects of PFOA and PFOS. *Ecotoxicology and Environmental Safety* **2023**, *267*, 115663. https://doi.org/10.1016/j.ecoenv.2023.115663

[11] Xia, X.; Chao, D.; Guan, C.; Zhang, Y.; *et al.* Solution Synthesis of Metal Oxides for Electrochemical Energy Storage Applications. *Nanoscale* **2014**. https://doi.org/10.1039/c4nr00024b