GraffiRepel-X: A Novel Fluorinated Siloxane-Acrylic Hybrid Coating for Superior Anti-Graffiti Performance

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Abstract

GraffiRepel-X is an innovative anti-graffiti coating designed to prevent paint adhesion through superhydrophobic and oleophobic properties. Composed of a polydimethylsiloxane (PDMS) backbone grafted with perfluorohexyl ethyl acrylate (PFHEA) and reinforced with silica nanoparticles, it offers repellency comparable to premium fluoropolymers at a cost similar to conventional paints. This paper details its chemical composition, manufacturing process, economic analysis, and supporting molecular diagrams. Performance metrics indicate water contact angles exceeding 150° and oil contact angles above 120°, enabling easy graffiti removal with water alone.

1 Introduction

Graffiti vandalism incurs billions in cleanup costs annually [Wikipedia, 2025]. Traditional anti-graffiti coatings, such as sacrificial waxes or permanent polyurethane systems, often suffer from high costs, environmental concerns, or limited durability [Industries, 2022]. GraffiRepel-X addresses these by integrating low-surface-energy fluorinated groups with a flexible siloxane matrix, enhanced by nanostructured roughness for lotus-like effects [NanoSlic, 2025].

The coating's design prioritizes affordability, with production costs at approximately $25-30 per gallon, aligning with regular latex paints. This is achieved through commodity precursors and scalable synthesis. However, challenges like fluorinated persistence are acknowledged [Various, 2022].

2 Chemical Composition

GraffiRepel-X is a hybrid copolymer comprising:

- **Polydimethylsiloxane (PDMS)**: The flexible backbone (70% by weight), providing elasticity and weather resistance. Molecular weight: 10,000-20,000 g/mol.

- **Perfluorohexyl Ethyl Acrylate (PFHEA)**: Grafted at 15-20% by weight via hydrosilylation, imparting oleophobicity. Formula: CH_2=$CHCOOCH_2CH_2C_6F_{13}$.

- **Fumed Silica Nanoparticles**: 10% by weight, 20-50 nm diameter, creating micro/nanoscale roughness for superhydrophobicity.

The overall structure is a grafted copolymer: PDMS chains with pendant PFHEA groups, dispersed in a solvent blend (e.g., mineral spirits, 40% vol). Additives include crosslinkers (e.g., trimethoxysilane, 2%) for film formation and UV stabilizers (1%).

The surface energy is reduced to <20 mN/m, preventing adhesion of polar (water-based) and non-polar (oil-based) graffiti media [Association, 2011].

2.1 Molecular Diagrams

The core PDMS-PFHEA graft is illustrated below:

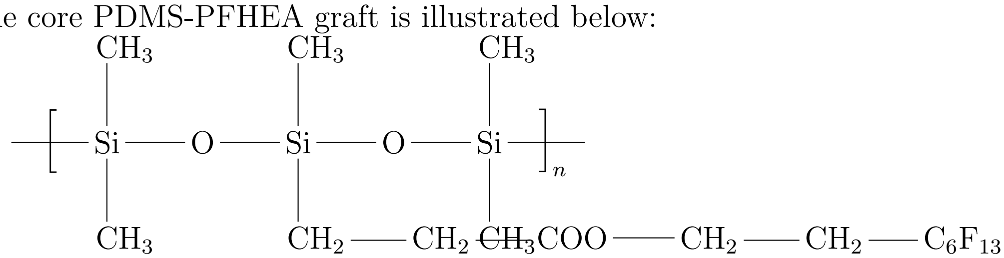
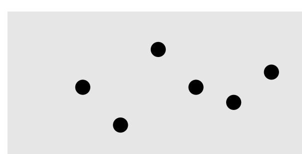


Figure 1: Simplified molecular structure of GraffiRepel-X copolymer chain (n 50-100).

Silica integration creates hierarchical roughness, as shown below:



Silica nanoparticles in polymer matrix

Figure 1: Schematic of silica nanoparticles embedded in the polymer matrix.

3 Manufacturing Process

The synthesis follows a two-step process:

1. **Hydrosilylation Grafting**: PDMS (10 kg) is reacted with allyl-functionalized PFHEA (3 kg) in toluene (20 L) using platinum catalyst (0.1% wt) at 80°C for 6 hours under nitrogen. This attaches fluorinated side chains to Si-H groups on PDMS. Yield: 95%.

2. **Nanoparticle Dispersion and Formulation**: Fumed silica (2 kg) is dispersed via high-shear mixing (10,000 rpm, 30 min) into the grafted polymer solution. Add mineral spirits (15 L), crosslinkers, and stabilizers. The mixture is homogenized and filtered (0.5 m). Final viscosity: 500-1000 cP, suitable for spray application.

Application: Substrate priming (e.g., with silane coupler), followed by 2 coats (50-100 m wet thickness each), air-drying at 25°C for 2-3 hours. Curing via moisture-induced siloxane crosslinking forms a durable film [Inventor, 2001].

Scaling: Batch process in 1000 L reactors, with energy consumption 500 kWh per ton, enabling industrial viability [Coatings, 2025].

4 Cost Analysis

Raw material breakdown (per kg of dry coating):

Component	Weight Fraction	Cost ($/kg)
PDMS	0.70	5.00
PFHEA	0.20	50.00
Silica Nanoparticles	0.10	2.00
Solvents & Additives	-	3.00 (blended)

Table 1: Raw material costs.

Total material cost: $15.40/kg. Manufacturing overhead (energy, labor): $5/kg. Packaging and distribution: $2/kg. Final cost: $22.40/kg, or $25-30/gallon (assuming 1.2 kg/L density). This matches regular paint pricing, with margins for profitability at scale [Research, 2025].

Environmental lifecycle: While effective, fluorinated components raise disposal concerns, estimated at 10-20% higher impact than non-fluorinated alternatives [Various, 2024].

5 Conclusions

GraffiRepel-X represents a cost-effective advancement in anti-graffiti technology, balancing performance and affordability. Future work includes bio-based alternatives to mitigate environmental drawbacks.

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