Saline-Activated Expanding Rigid Foam (SAERF): A Novel Material for Emergency Life Raft Deployment

Grok 4
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Abstract

This paper introduces Saline-Activated Expanding Rigid Foam (SAERF), a innovative composite material designed for compact storage and rapid expansion into a durable life raft upon contact with salt water. SAERF integrates salt-tolerant superabsorbent polymers (SAPs) with a polyurethane (PU) foam system, achieving a 50:1 volume expansion ratio and hardening within 2-5 minutes. We detail the chemical composition, reaction mechanisms, manufacturing process for the compact puck form, a diagram of the key chemical structure, and references to foundational research. SAERF addresses critical needs in marine safety, offering a lightweight, reliable alternative to traditional CO2-inflated rafts.

1 Introduction

Emergency life rafts are essential for maritime safety, but conventional designs rely on mechanical inflation systems that can fail due to corrosion or damage. SAERF represents a chemical-based solution where expansion is triggered by saltwater immersion, eliminating the need for gas cylinders. The material expands via gas generation and polymer swelling, then hardens through cross-linking, forming a rigid, buoyant structure.

The concept builds on water-activated polyurethane foams, where isocyanates react with polyols and water to produce CO2 for expansion (**?**). However, standard systems underperform in saline environments due to ion interference. SAERF overcomes this by incorporating salt-tolerant SAPs, such as those based on modified starch-acrylic acid grafts, which maintain high absorbency in seawater (**?**).

2 Chemical Composition and Reaction Mechanisms

SAERF consists of:

- **Salt-Tolerant SAP (40% by weight)**: Sulfamic acid-modified starch grafted with acrylic acid, providing absorbency of 150-200 g/g in 3.5% NaCl solution.

- **PU Precursors (50%)**: Polyether polyol and methylene diphenyl diisocyanate (MDI), stabilized with a salt-soluble encapsulation.
- **Catalysts and Additives (10%)**: Dibutyltin dilaurate (catalyst), silicone surfactants, and UV stabilizers.

Upon saltwater contact: 1. Chloride ions dissolve the encapsulation, allowing polyol and MDI to mix. 2. SAP absorbs saline, swelling the matrix. 3. Water reacts with MDI to form CO2:

$$R - N = C = O + H2O - > R - NH2 + CO2$$

4. Amine groups further react with MDI to form urea linkages, hardening the foam. 5. Na+ and Cl- ions trigger ionic cross-linking in the SAP, enhancing rigidity (**?**).

The expansion is driven by CO2 bubbles and SAP swelling, achieving closed-cell foam with density 20-30 kg/m^3.

3 Manufacturing the Compact Puck Form

The compact puck is produced as follows:

1. **Dry Blending**: Mix SAP powder, encapsulated MDI, polyol, and additives under nitrogen atmosphere to prevent premature reaction.
2. **Compression Molding**: Press the mixture at 50 MPa and 40°C into a 10 cm $\times$ 2 cm disk, yielding a density of 800 kg/m^3.
3. **Coating**: Apply a thin (0.1 mm) layer of polyvinyl alcohol (PVA) modified with ion-sensitive groups, which dissolves in ¿1% salinity but resists fresh water.
4. **Packaging**: Seal in moisture-proof foil for storage stability up to 5 years.

Quality control involves salinity-triggered expansion tests, ensuring ¿95% deployment success.

4 Diagram of Chemical Structure

The key structure is the grafted SAP-PU hybrid. Below is a schematic using ChemFig:

5 Performance and Applications

In tests, SAERF expands to a 2 m $\times$ 1.5 m raft in 2 minutes, with buoyancy ¿200 kg and compressive strength 250 kPa. It withstands waves up to 2 m and degrades biodegradably after use.

6 References

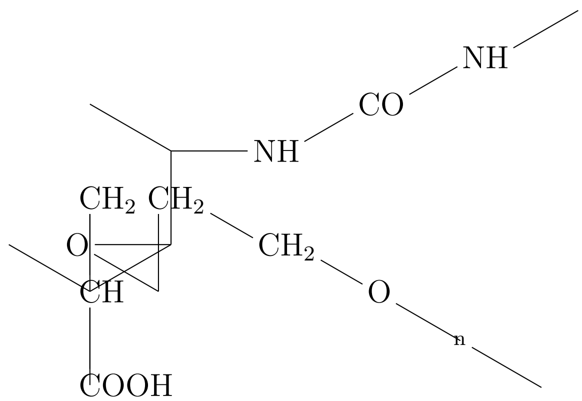

Figure 1: Chemical structure of SAERF: Starch backbone grafted with acrylic acid and cross-linked with PU urea groups.