Scientists Advocate PVDF Coatings for Navy Ships

Kerry Cole

Polyvinylidene fluoride (PVDF) coatings offer a significant advantage over traditional epoxy coatings in marine environments, providing better protection against corrosion, ultraviolet (UV) damage, and biofouling, all while being easier to apply and maintain, four American scientists assert in advocating for its use on U.S. Navy ships.

PVDF is a high-performance thermoplastic fluoropolymer. It's known for its excellent chemical resistance, high purity, and stability across a wide range of temperatures.

Its anti-corrosion properties are well known as it has a strong resistance to a broad spectrum of chemicals, acids, and bases, making it ideal for use in aggressive environments. However, it does not adhere well to steel.

The USS Somerset looms over a Naval Special Warfare boat in the San Diego Bay.

The scientists increased its potential for marine use by modifying PVDF so that it can be brushed, rolled, or sprayed onto metals and onto naval and marine epoxy and polyurethane coating to achieve the highest adhesion standards.

PVDF's compact molecular structure blocks moisture and salt ions more effectively than epoxy, offering 10,000 times better permeability, says Kevin Chung, CEO of AI Technology in Princeton Junction, New Jersey, USA.

"If you look at the permeability of water and moisture, even at one-tenth of the thickness it is still 1,000 times better in proximal moisture," Chung says. "In our experiment, we projected that for at least six to 10 years we don't envision any corrosion."

Unique Needs of Navy Ships

Chung highlights the cost savings and operational efficiencies of PVDF in marine environments, noting that it is also effective against biofouling.

"A coating that can prevent moisture and water laden with dissolved salts and other corrosive gases from reaching the steel surfaces, with or without traditional epoxy coating, will be an effective solution in preventing corrosion damage to the ship," he and his co-authors write in an AMPP 2024 conference paper titled "Field Applicable PVDF Corrosion Protection Coating for Marine Assets."

They add, "PVDF as top coating, added over existing epoxy marine and naval coatings, can greatly reduce the moisture passing through

The USS Dwight D. Eisenhower, a Nimitz class nuclear powered air craft carrier visiting Halifax Harbour.

the epoxy layer getting into contact with the steel at the steel-coating interfaces."

Chung's AI Technology colleagues Fred Lo, Thomas Pizanowski Jr., and Albert Chung contributed to the paper.

AI Technology, founded in 1985, is a company that specializes in developing and manufacturing advanced adhesive materials and thermal interface materials for various high-tech applications.

Kevin Chung, a materials scientist with a background in physics and chemistry, holds a Ph.D. from Rutgers University in New Jersey. He cites the notion that at any given time, about one-third of Navy ships are at sea on active deployment, a third are in port but ready or being prepared for deployment, and a third are undergoing significant repair, including damage from corrosion.

"It will give the Navy a lot more time that you can sail without the need for repair, so availabilities improve," he says.

He also points out that, unlike commercial ships, Navy ships have less choice of which routes to take or when to deploy to minimize exposure to corrosion.

The authors' paper cites research reporting that the Navy spends $3 billion a year fighting rust and other corrosion on ships as well as helicopters and jets that deploy on them.

Chung notes that ships have trouble with corrosion because water molecules are among the smallest of molecules.

"Epoxy coatings generally are good, but they are still very typically porous to this small molecular structure like salt water," he says.

Experimental Procedure

To find out how well the new PVDF coating protects against corrosion compared to traditional epoxy coatings, the researchers tested both coatings in harsh environments.

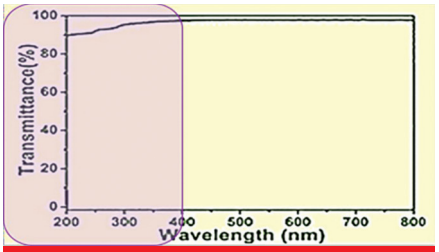
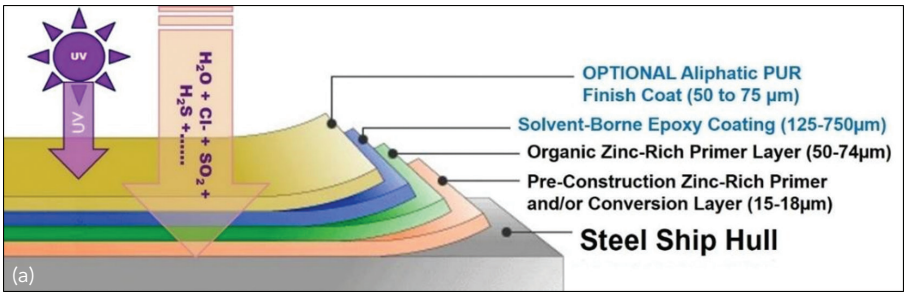


FIGURE 1 PVDF polymer with its higher energy molecular bonds of C-F absorbs very little UVA, UVB, and very slight UVC energy, the authors say, which is why PVDF coatings with 30% acrylic have been proven to last over 60 years or more when used under the Florida sun.

- **Protection below the waterline:** The researchers coated steel bars with epoxy and added an additional PVDF coating on top of some of them. They submerged these bars in



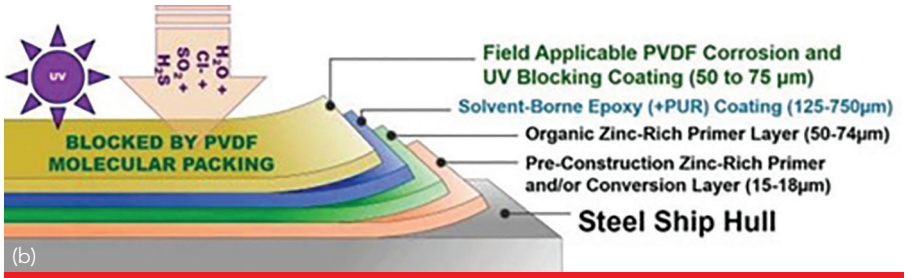


FIGURE 2 (a) represents traditional coating protection for a typical ship hull structure under typical environmental attack, while (b) represents the addition of a top coating of PVDF that is resistant to, and blocks, UV as well as blocking corrosive gases and dissolved ions laden in the moisture from getting into the steel primer interfaces.

salty water at 60 °C (140 °F) to simulate accelerated corrosion conditions. The results showed that the steel coated only with epoxy began to corrode, especially at the edges where the coating is thinner or damaged. However, the steel with the extra PVDF coating did not show any signs of corrosion. This shows that the PVDF coating provides a stronger barrier against saltwater and corrosive elements, especially at points where the epoxy coating might fail.

- **Protection above the waterline:** The researchers conducted another test to see how the coatings perform above the waterline, where the metal is exposed to UV, salt spray, and air. Again, they tested steel bars coated with epoxy, with some receiving an additional PVDF layer. The results showed that the areas with only epoxy coating corroded, while the parts with the PVDF topcoat showed no corrosion. The PVDF coating proved effective in preventing moisture and corrosive gases from reaching the metal, while resistant and blocking UV from reaching the underlying epoxy coating, making it a superior option in harsh marine conditions.
- **Biofouling protection:** To test for biofouling (the growth of marine organisms like algae and barnacles), they submerged steel coated with epoxy and PVDF in seawater for 30 days. The results indicated that the PVDF coating provided additional protection against biofouling compared to epoxy alone.

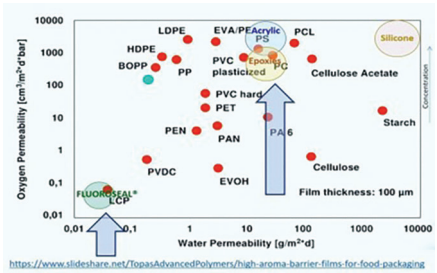


FIGURE 3 A representation of common polymers and their relative permeability. The PVDF coating is shown under the brand name FLUOROSEAL.

FIGURE 4 Fusion-bonded epoxy-coated (FBE) edges corrode quickly upon exposure to 5% salt water at an accelerated temperature of 60 °C (140 °F) after 50 h. The corrosion quickly propagated outward to other areas. The new PVDF Corrosion Protection Coating is used to coat on the side that was cut with exposed bare steel. No sign of corrosion is seen under the same salt-water condition. The PVDF Corrosion Protection Coating is transparent, having a thickness of approximately 30µm applied by brush and ambient dried.

FIGURE 5 Steel bars coated with epoxy coatings were partially coated with field applicable 100% PVDF topcoat (~50µm thickness). The portion protected by epoxy coatings only when exposed to salt-water (water with dissolved corrosive ions) suffered extensive corrosion in 65 days under the accelerated conditions of 60°C-5% saline solution. By comparison, epoxy-coated steel when top-coated with field-applicable PVDF coating showed no sign of corrosion. The accelerated conditions are roughly equivalent to two to three years of ambient temperature seawater submersion conditions.

PVDF Advantages

Chung points out the following advantages for PVDF:

- **Stronger barrier:** PVDF coating forms a more effective barrier than epoxy, blocking moisture and corrosive substances more efficiently. Even at a thinner layer (30 to 50 µm), it offers greater protection than a thicker layer of epoxy.
- **Flexibility:** The molecular structure of PVDF is more flexible, meaning it can withstand mechanical stress better than epoxy, especially at sharp edges or scratches.
- **Long-lasting and UV resistant:** PVDF is highly resistant to UV light and can last more than 60 years without breaking down, unlike some

FIGURE 6 The uncoated cut edge shows obvious corrosion on the steel edge and under the FBE coating near the cut edge. Steel with FBE epoxy coating sustained corrosion from moisture laden with corrosive gases quickly when any coated surfaces are scratched or peeled away, exposing the bare steel surfaces.

epoxy coatings that can degrade when exposed to sunlight.

- **Easy application:** The PVDF coating can be applied over existing coatings, providing additional protection without needing to remove the old coating.

Researchers' Conclusions

Chung and his fellow researchers conclude that the field-applicable, patent-pending PVDF coating technology provides a hydrophobic film and surface has been scientifically and experimentally proven to have these attributes:

- At 30 to 50µm thickness, the corrosion protection coating is 100x more efficient than 500µm (20mils) of epoxy coating in blocking moisture and moisture carrying dissolved salts and acidic gases.
- Even at 70% PVDF in the coating, it has been proven to withstand direct UV exposure for more than 60 years. The patent-pending 100% PVDF corrosion protection coating is now available in furthering the longevity in corrosion protection when applied over the epoxy coating as over-coat protection.
- The inherent hydrophobic property of PVDF polymer is maintained in the patent-pending field applicable coating technology to provide anti-fouling protection for below seawater line naval and marine assets.

These novel PVDF corrosion protection coatings can be used without changing long-established corrosion protection standards with epoxy or polyurethane coating. It is applied as a thin over-coat or top coating over the new and old protection coating to provide 100x corrosion protection. The inherent flexibility of the PVDF polymer with a Tg of -45 °C does not induce substantial mechanical or interfacial stresses or other deleterious effects on the underlying coating.

As a top coating in protecting the underlying coating and thus the steel ship hull and other marine infrastructure that are exposed to the marine environment, they have built-in capability not only to resist but also block UV from penetrating through to damage the underlying UV vulnerable epoxy and polyurethane coatings.

FIGURE 7 The top piece of epoxy-coated steel coated with field-applicable PVDF after 30 days' submersion in Chesapeake Bay, Maryland, during the month of June. The cut edge showed corrosion and initiated some biofouling growth and started to migrate to the other edge. The bottom piece of the other half of epoxy-coated steel without PVDF top coating showed substantially more biofouling growth along with more obvious brownish corrosion coloring.

"To be effective, you need the ability to block off water moisture," Chung says. "Most epoxy has high permeability, so therefore they build it very thick to make it more effective. PVDF's molecular structure is much more compact and very tough for moisture to penetrate." MP