New Hull Coatings Cut Fuel Use, Protect Environment

Office of Naval Research Exploring Cutting-edge Technologies

U.S. NAVAL WARSHIPS and submarines rely on critical design factors such as top speed, acceleration and hydroacoustic stealth to achieve their mission. Biofouling, caused by a host of marine organisms attaching themselves to a ship's hull, dramatically reduces ship performance and costs the U.S. Navy millions of dollars each year in added fuel consumption and extensive maintenance efforts.

Researchers are learning from nature how to combat the problem. The Office of Naval Research (ONR) is currently exploring two emerging technologies that may be effective at biofouling prevention with much less environmental impact than traditional biocides.

A Tale of Two Coasts

On the East Coast, ONR is funding research at the University of Florida where Anthony Brennan, professor of material science and engineering, has been investigating why some marine animals, such as whales, harbor barnacles and others, such as sharks, stay relatively clean. Brennan discovered that the unique pattern of shark skin contributed to its ability to fend-off microorganisms.

"What you see is this cross pattern which repeats itself all the way across," Brennan said. "So when organisms come along, they are unable to find a position which is stable for them to land."

With this insight, Brennan started modeling shark skin patterns in his laboratory. The idea led to the development of a new biomimetic technology called Sharklet, which has shown extremely positive results in inhibiting marine growth. The significance of his work really hit home during a visit to Pearl Harbor.

"I saw a Navy ship going by . . . flowing with green algae," Brennan said. "I thought, 'that's why we are doing this research, to stop that biofouling . . . to give our Navy the ability to perform at a higher level.'"

The biodiversity of different ocean environments also creates unique challenges. So, across the country on the West Coast, ONR is working with Shaoyi Jiang, Boeing-Roundhill professor at the University of Washington, on biofouling prevention coatings that incorporate zwitterionic, or mixed-charge, compounds with ions that alternate perfectly between positive and negative charges.

"Unlike antifouling coating, our coating does not leach any biocides," said Jiang. "Unlike the fouling and release coating, our coating is also effective even on stationary surfaces."

Zwitterionic compounds are stable and easy to handle in both laboratory and field tests. They've shown excellent resistance to the attachment of biomolecules and microorganisms. The result is that naturally occurring proteins, bacteria, algae, barnacles and tube worms do not bind to this unique surface.

"The ultimate solution is to stop the barnacle settlement process before it happens," says Steve McElvany, program manager for ONR´s Environment Quality program. "We are really trying to look very far forward to get the ultimate solution that's good for the U.S. Navy and the oceans."

Inventive biofouling prevention systems will help conserve fuel, minimize the Navy's carbon footprint, reduce the risk of transporting invasive aquatic species and prevent toxic biocides from entering surrounding environments.

Benefits for the Navy

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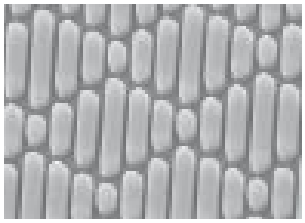
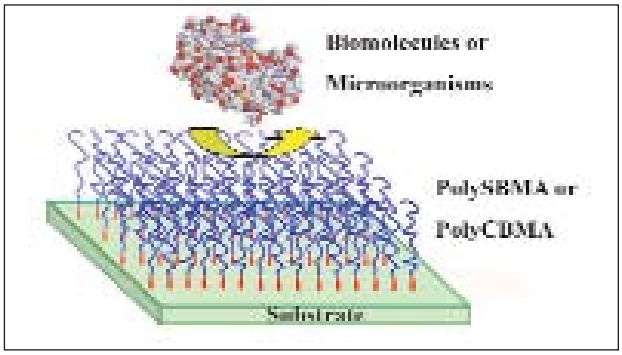
Ships affected by biofilm—the mildest version of biofoul—can add up to 20 percent drag. Once barnacles and other large organisms begin to attach, the drag can increase to more than 60 percent. This increases fuel consumption and resulting green house gas emissions.

Benefits Beyond

In the same manner in which the attachment of marine organisms fouls marine vessels, airborne microorganisms attach to surfaces, colonize, and can become destructive on land. Both the Sharklet pattern and Zwitterionic coating inhibit the settlement of barnacles and also inhibit the growth of bacteria.



The unique pattern of Sharklet makes microorganisms unable to attach themselves.
Sharklet Technologies



Uniformly mixed charged groups in zwitterionic materials resist biomolecules and microorganisms.
Dr. Shaoyi Jiang

This unique attribute has applications in hospitals and high-touch areas in health care where it is critical to inhibit the survival and transference of bacteria to protect patients from infections. Future applications for ONR-funded marine biofouling prevention technologies may be in the design of medical devices or hygienic surfaces found in hospitals and food preparation areas.

"This technology spreads beyond the hull of the ship . . . there is a great opportunity to extend this technology to the public," said Brennan.

The Need for Improvement

The Naval Surface Warfare Center at Carderock, MD estimates that biofouling reduces vessel speed by up to 10 percent. Vessels can require as much as a 40 percent increase in fuel consumption to counter the added drag. For the Navy, that translates into roughly one billion dollars annually in extra fuel costs and maintenance to keep its ships free of barnacles, oysters, algae and other debris.

Previous biofouling prevention methods used toxic coatings, or biocides, to clear barnacle colonies from the ship exteriors. Although effective in the short-term, biocides can take a toll on the environment.

Tributylin (TBT)-based ship paints were the principal marine antifouling agent until relatively recently. Developed in the 1970's, these paints were found to cause irreversible damage to marine life, leading to a global ban in 1998. The introduction of TBT into the marine environment impacted everything from the sex characteristics of small aquatic life to the hearing of whales. The Navy discontinued use of TBT in the 1990's, well before the international ban.

Today, nearly 70 percent of the world's industrial shipping and recreational boating fleet use copper-based paints as an antifouling strategy. These bottom paints are designed to slowly release, or leach, copper into surface waters to kill and slow the growth of microorganisms. As a result of the leaching, copper and other

Regular barnacle removal and hull cleaning contributes to a reduced lifespan for the ship.
Photographer's Mate 3rd Class Erika Jones

metals have sometimes compounded to toxic levels within our ocean, lake and waterway floors. Studies show that dissolved copper in many harbors and waterways affect the growth, development and reproduction of marine life as well as impact humans who work in those environments or eat the fish and crustaceans caught in contaminated waters.

Current environmentally acceptable antifouling coatings of interest to the Navy are low copper, copper-free, and foul-release coatings, which do not contain biocides. All anti-fouling coating systems must comply with current and future federal, state and local air emission regulations. They must eliminate or significantly reduce copper emissions, be U.S. Environmental Protection Agency registered, and obtain approval from the Navy and Marine Corps Public Health Center.

ONR: Reaching New Heights

By discovering how nature beats the barnacle naturally, ONR is pioneering an environmentally friendly way of optimizing vessel performance and dramatically reducing fuel costs. And that's where ONR's investment in biofouling prevention technologies has made significant gains.

Jiang and Brennan acknowledged the open environment and multidisciplinary research approach that ONR and its program managers encourage from principal investigators.

"The ONR program provides an excellent environment and infrastructure for collaborations," said Jiang. "ONR has brought together biologists, geneticists, chemists, material engineers, chemical engineers, physicists and we end up sharing. It says a lot about our Navy to have that forethought to reach beyond what everybody sees in front of them and go for something new and innovative that will help the Navy and benefit the world."

Chris Dettmar also contributed to this article.

CONTACT

Peter Vietti
Office of Naval Research
703-696-5031
onrcsc@navy.mil