Be green,
be cool!

MARITIME ACADEMY

Antifouling for Ships

Extra fuel costs due to fouling – Staggeringly high

$ 30,000,000,000

There is a treasure out there…

But we are all ignorant

Naval Architect

Superintendent

Ship Master

So we study anti-fouling

We read...

We google...

Scary terminology ?

Which of these terms are you familiar with?

Self-polishing Co-polymers

Low-surface energy coatings

Surface Treated Coatings

Ask your mother…

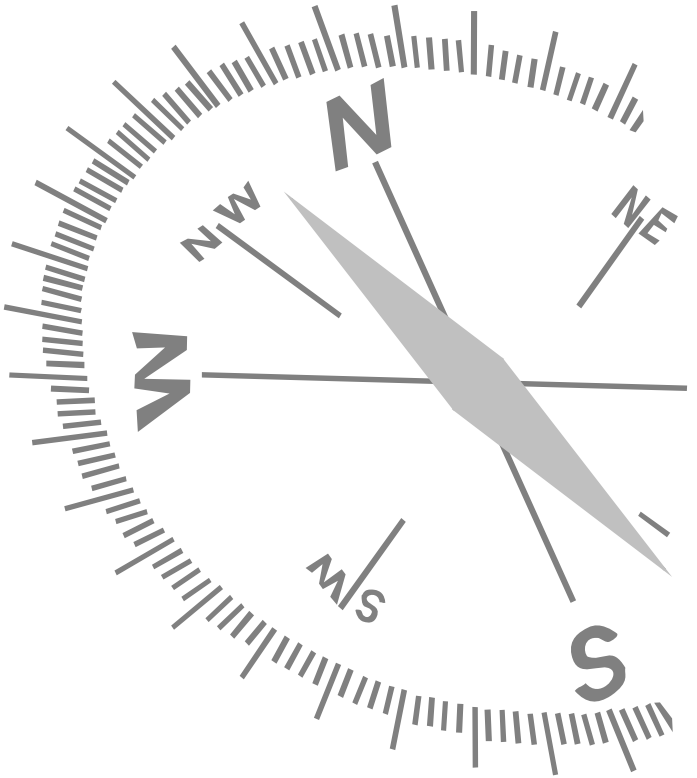
Self-polishing
Co-polymers

Surface Treated Coatings

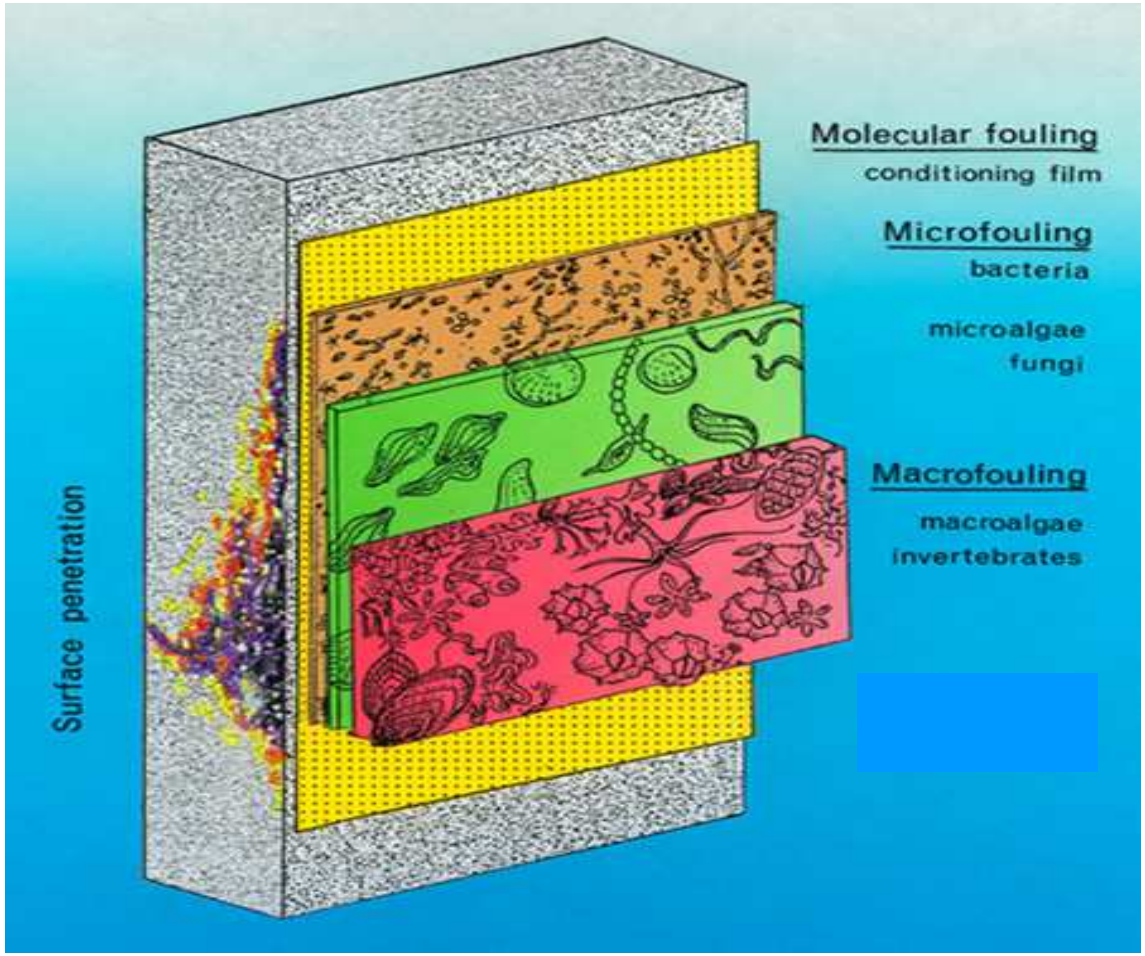
Low surface
energy coatings

Navigator

- Fouling
- A problem solved – or so we thought
- Copper-based coatings
- Alternatives ?
- Quiz

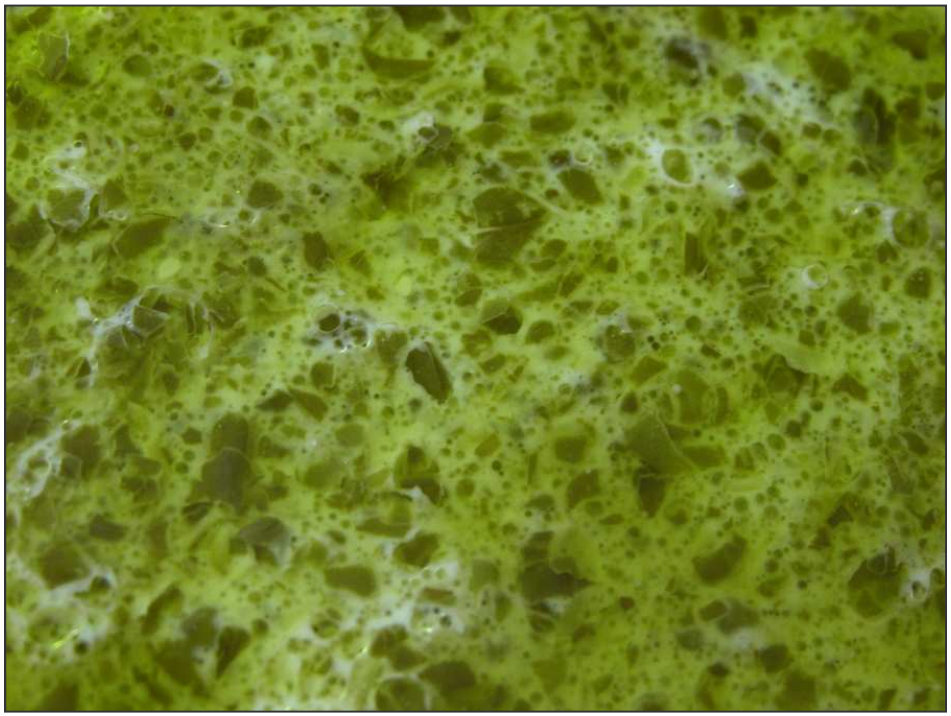


Marine fouling increases gradually



Soft fouling: Slime

Microscopic to macroscopic: bacteria, fungi, protozoa, algae



Soft fouling: Grass & other

Multi-cellular green and brown algae - most heavily near waterline

- with depth more brown than green

Source: Niall Benvie

Hard fouling: Barnacles

Acorn barnacle: Conical hard shells with jagged tops

Source: Arran Edmonstone

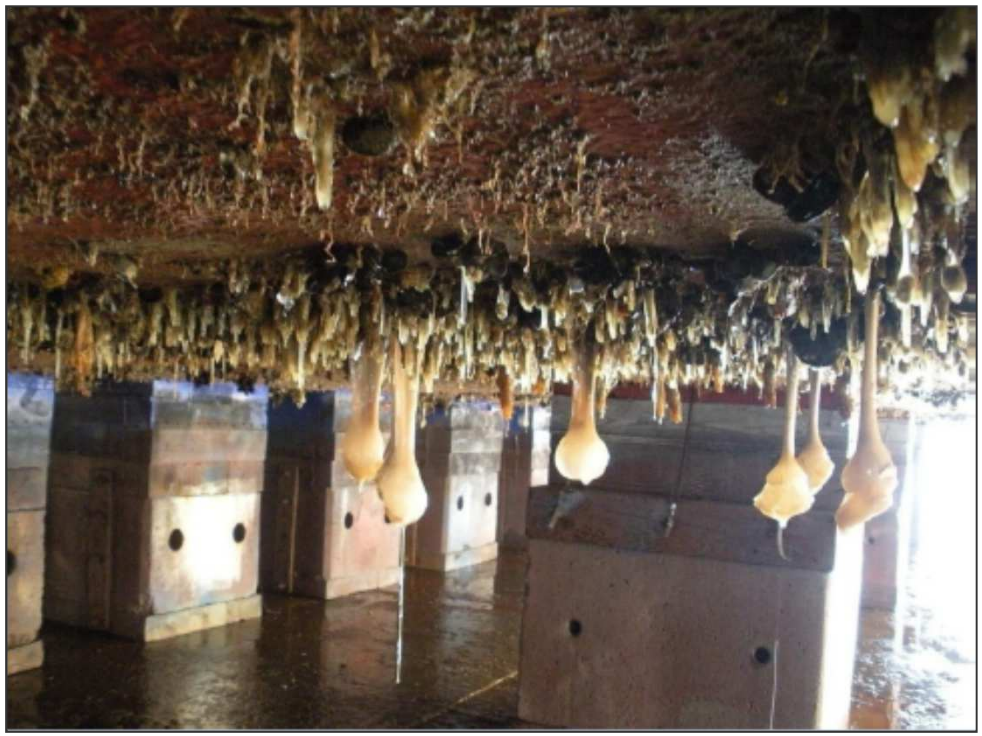
Hard fouling: Tubeworms

Intertwined tubes lying along or projecting out from hull

Source: NOAA library

Heavy fouling may double resistance

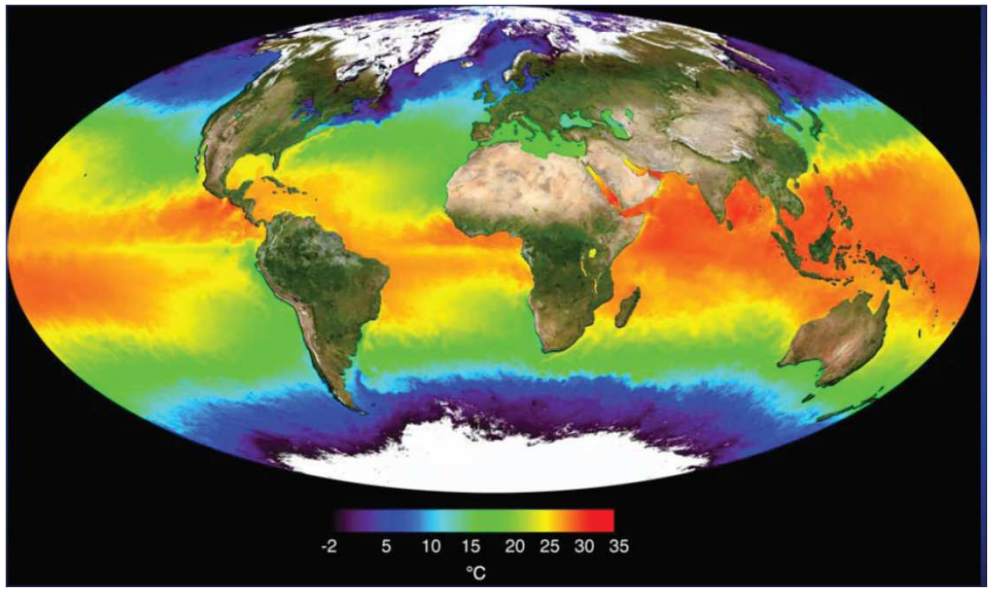
- much higher roughness
- increased surface



Source: Limnomar

Fouling depends on many factors

- Idle time
- Speed
- Operational area
- Temperature
- Salinity
- Antifouling
- ...



Source: International Paint

Significant associated penalty for fuel consumption

Illustrative example for a frigate:

NSTM Rating	Description	Increase in power at 15 kn
0	Hydraulically smooth surface	0%
0	Typical as applied antifouling coating	2%
10 - 20	Deteriorated coating or light slime	11%
30	Heavy slime	21%
40 – 60	Small calcareous fouling or weed	35%
70 – 80	Medium calcareous fouling	54%
90 – 100	Heavy calcareous fouling	86%

* Schultz, M.P. (2007), Effects of coating roughness and biofouling on ship resistance, Biofouling 23(5-6), pp.331-341
NSTM = Naval Ships' Technical Manual

Quiz-time

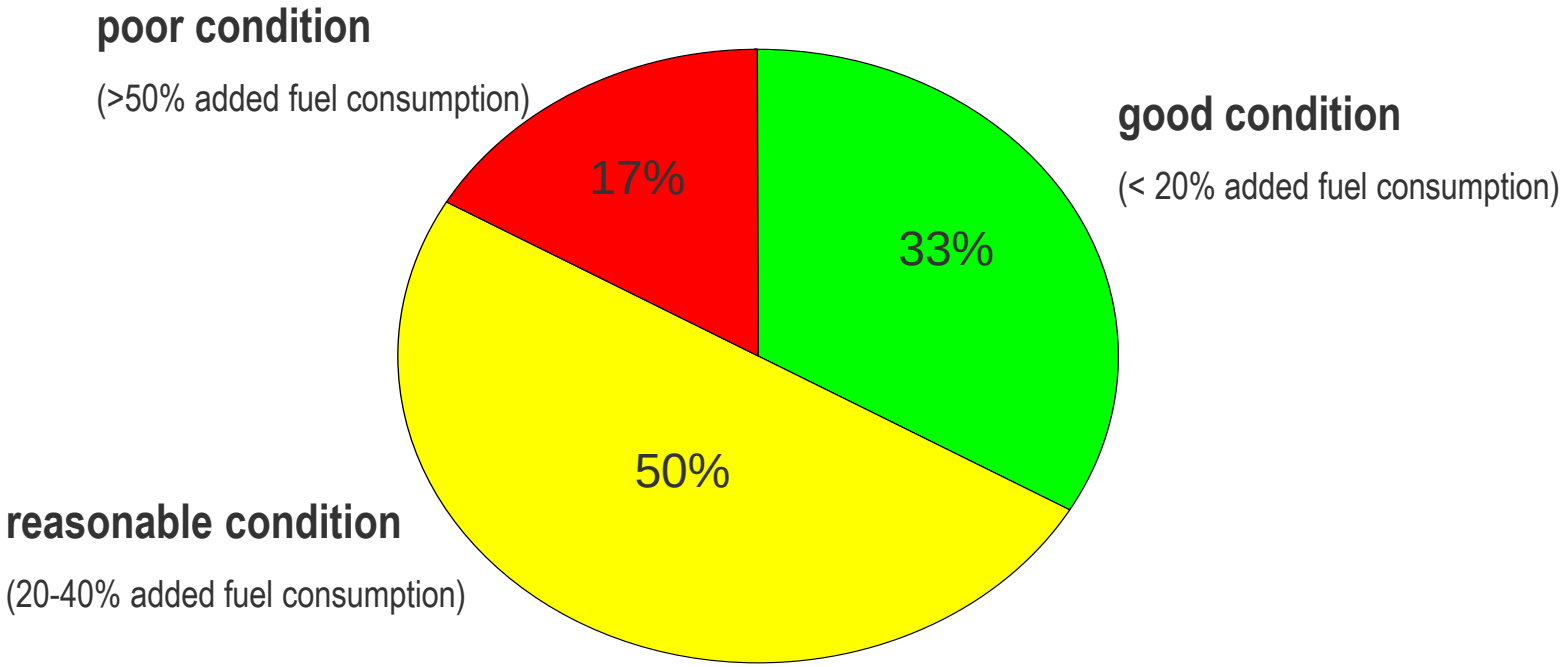
Estimate the percentage of the world fleet in poor coating condition

(with more than 50% added resistance due to poor coating)

a) 7%
b) 17%
c) 27%
d) 47%

Only 1/3 of the world fleet in "good" condition

Condition of the world fleet (estimate*)



* Munk, T. (2006). Fuel conservation through managing hull resistance. Motorship Propulsion Conf, Copenhagen

Navigator

- Fouling
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- Copper-based coatings
- Alternatives ?
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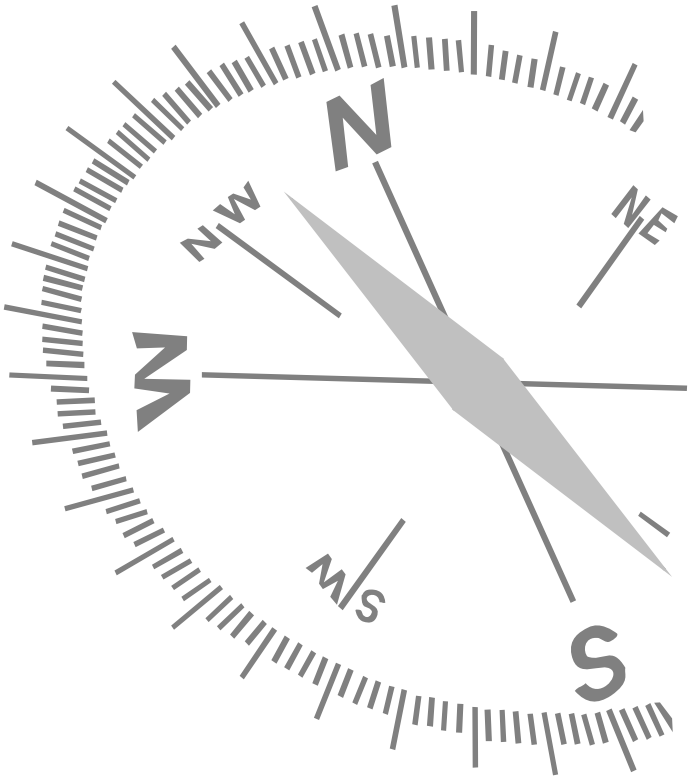


Paint – It took ages before it worked (halfway)

~300 BC Greeks use **tar and wax**

1625 1. Patent in history for antifouling paint
(William Beale in U.K.)

-1865 300 such patents registered - all of them **ineffective**!

1860- hot plastic paints based on copper compounds as antifoulants

1900 **"Italian Moravian"** (hot plastic paint)
Problem: expensive and short life-span

>1945 **Cold paints** by US Navy developed
(18 months between dry-dock times)

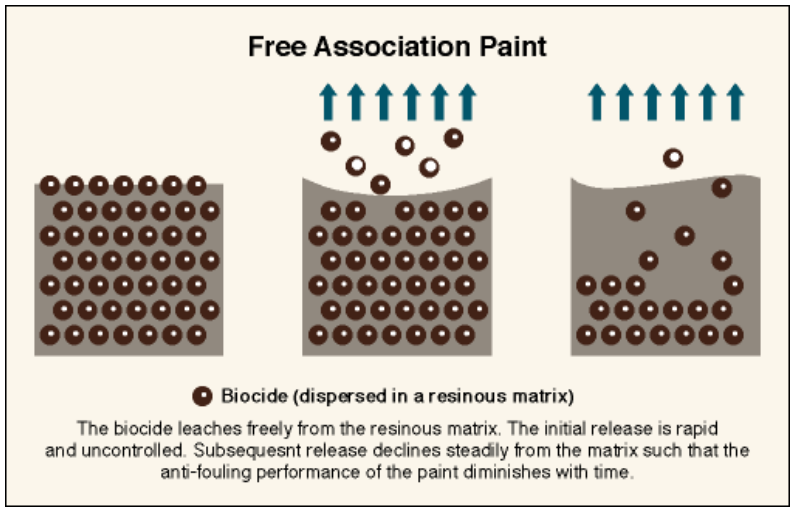
Organotin (TBT) was "wonder weapon"

Principle of paints:

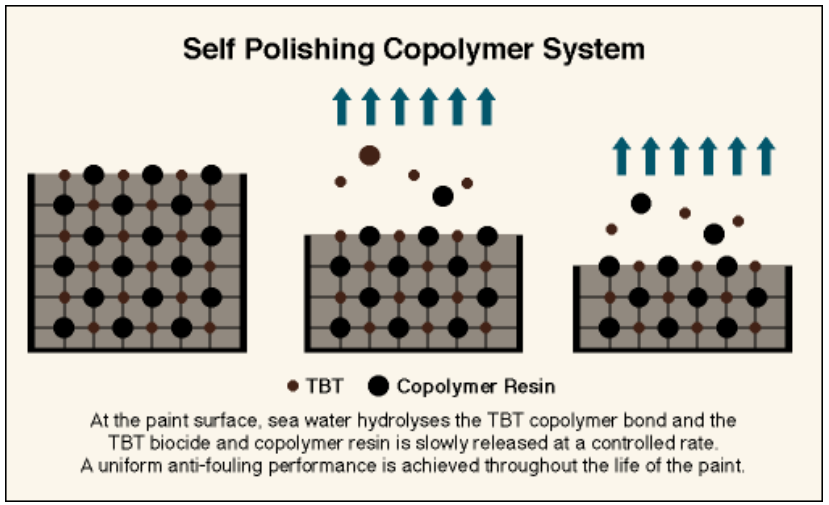
mix toxic substance with the paint which kills marine life

~ 1960 organotin (TBT) paints commercialised

~ 1980 self-polishing copolymer (SPC) organotin paints rule



old



modern

TBT = Tributyltin (organotin compunds)

TBT paints

Advantages:

☺ no contribution to corrosion of steel and aluminium

☺ up to 5 years fouling-free performance

☺ easy to apply and relatively cheap

But...

long-term impact on marine life

TBT = Tributyltin (organotin compunds)

Go back to square 1…

IMO banned TBT coatings

Now we are back to square 1

TBT banned since 2008

Navigator

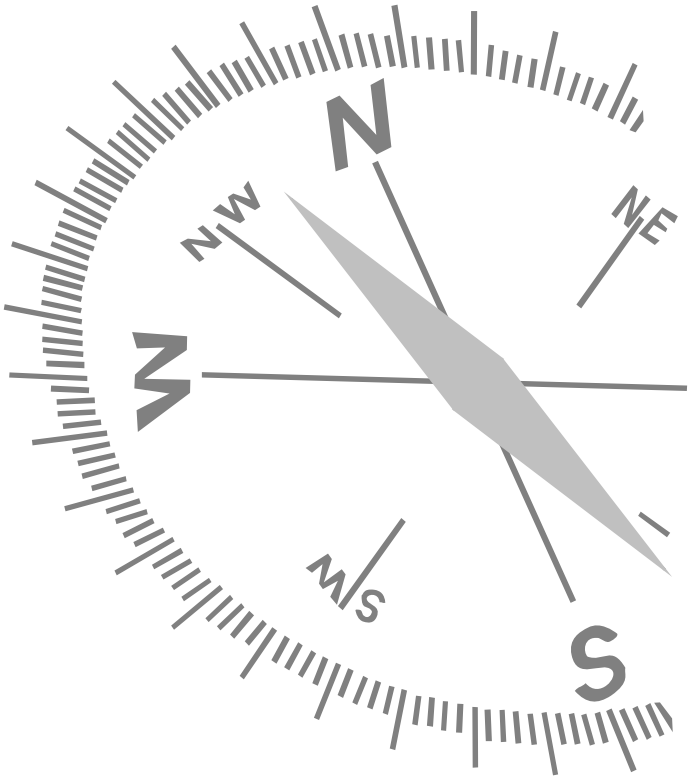
Fouling

A problem solved – or so we thought

Copper-based coatings

Alternatives ?

Quiz



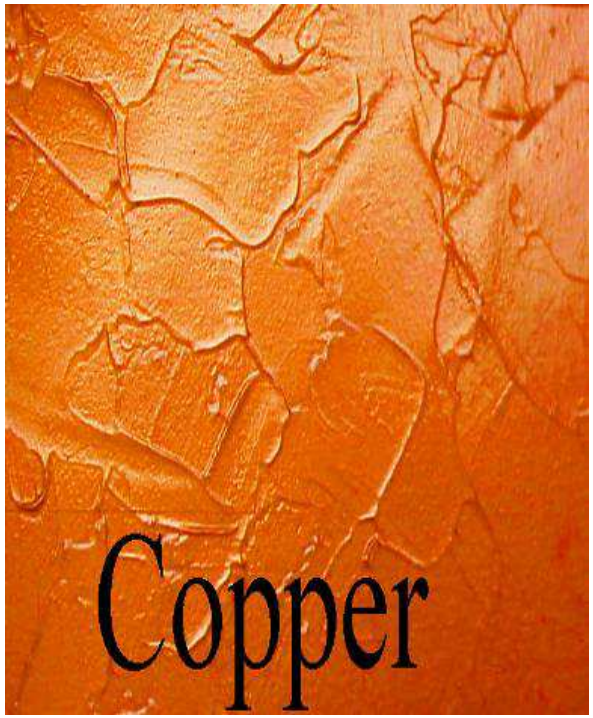
Percentage of ships using copper-based coatings

Estimate the percentage of ships worldwide using copper-based coatings [in 2011]

a. 30%
b. 50%
c. 70%
d. 90%

Copper-based paints

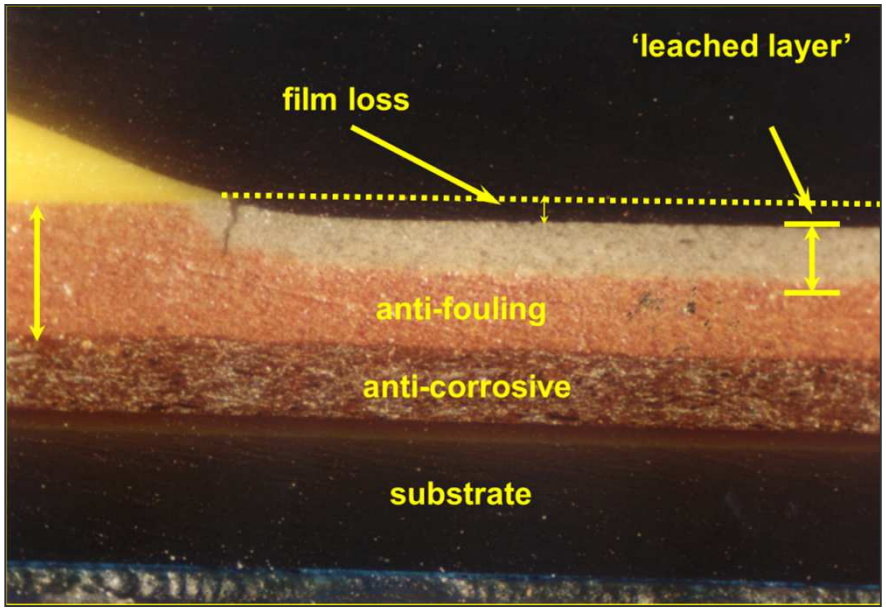
- biocide, but less effective than TBT
  more paint, more poison needed
- enhanced with biocide “boosters”
  (herbicides, fungicides, ...)

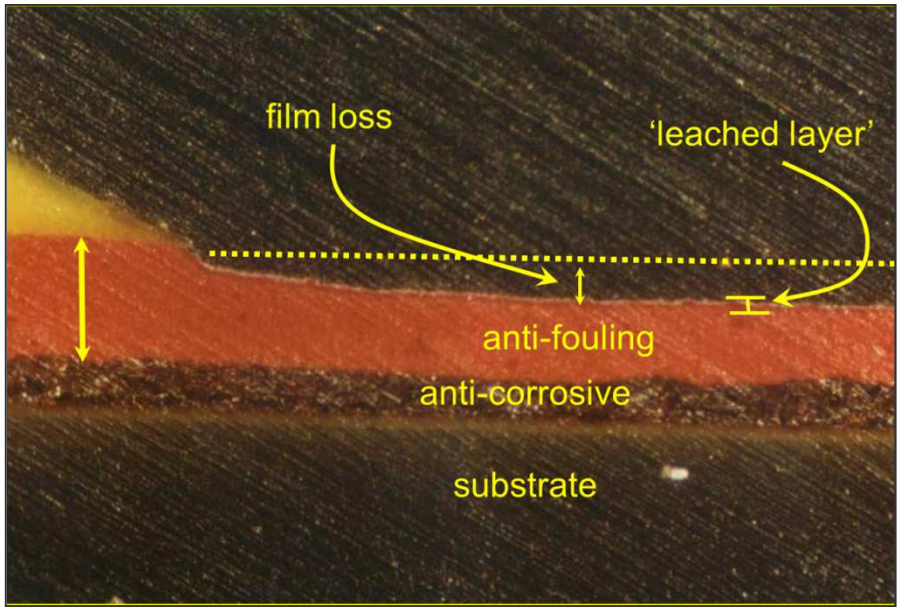


Copper-based paint ≠ Copper-based paint

Performance (and prices vary)

Example: leached layer





Silyl matrix

Source: Akzonobel

Copper-based coatings not universally liked

"The TBT problem is replaced by another problem." (1999)

[Namely other biocides]

But even Greenpeace admits now that copper coatings far **less problematic** than TBT

Don’t panic

Good news

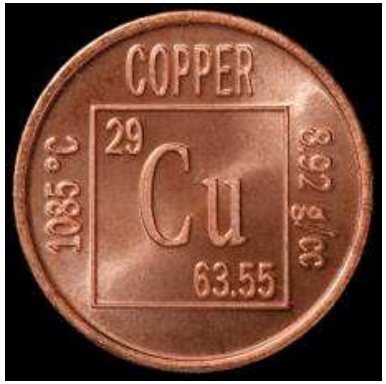
- Ban requires alternatives
- Copper-coatings are OK

Bad news

- Not sustainable
- Not universally accepted as no problem“ coatings

Copper-based paints – The bans start...

In addition, many ports forbid underwater cleaning for hulls with copper-based paints



copper-based coating

+

underwater cleaning

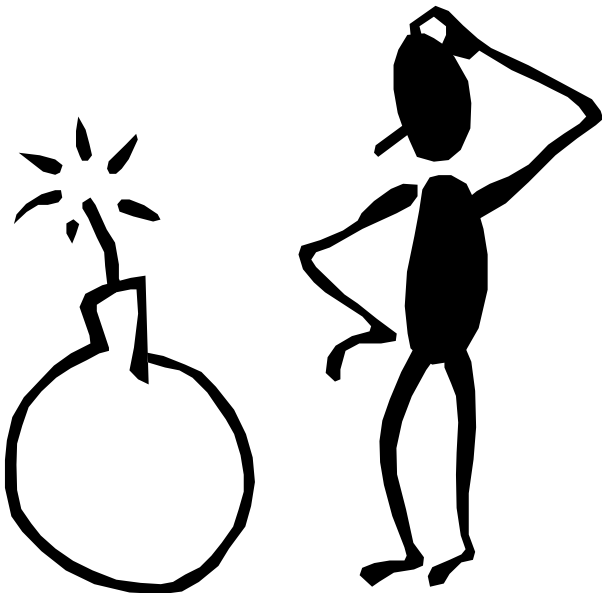
=

forbidden

Alternatives ?

So what do we do now?

What alternatives have you heard of already?



Navigator

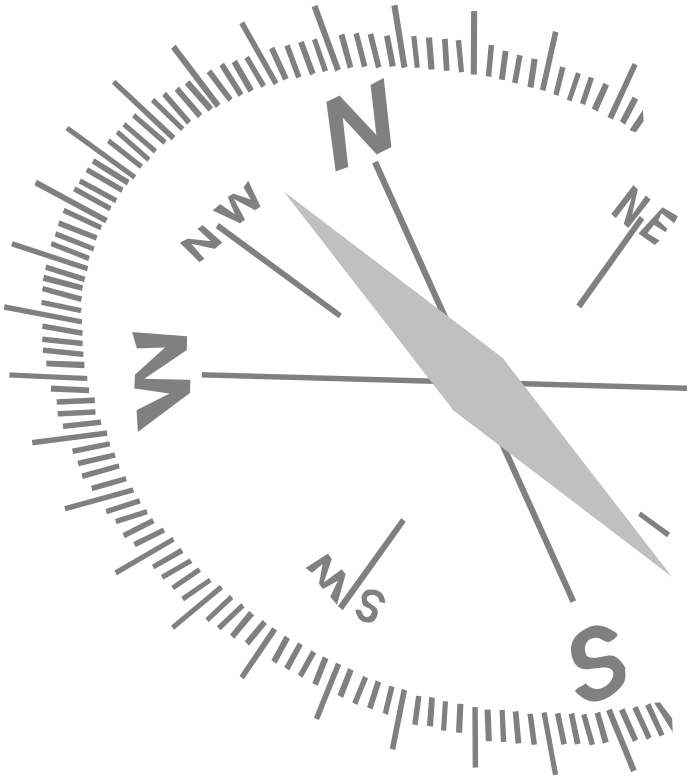
Fouling

A problem solved – or so we thought

Copper-based coatings

Alternatives ?

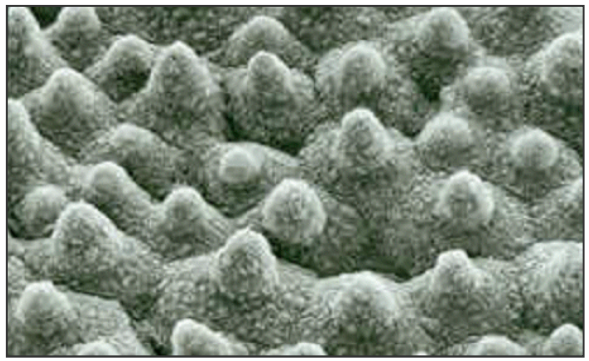
Quiz



LSE paints

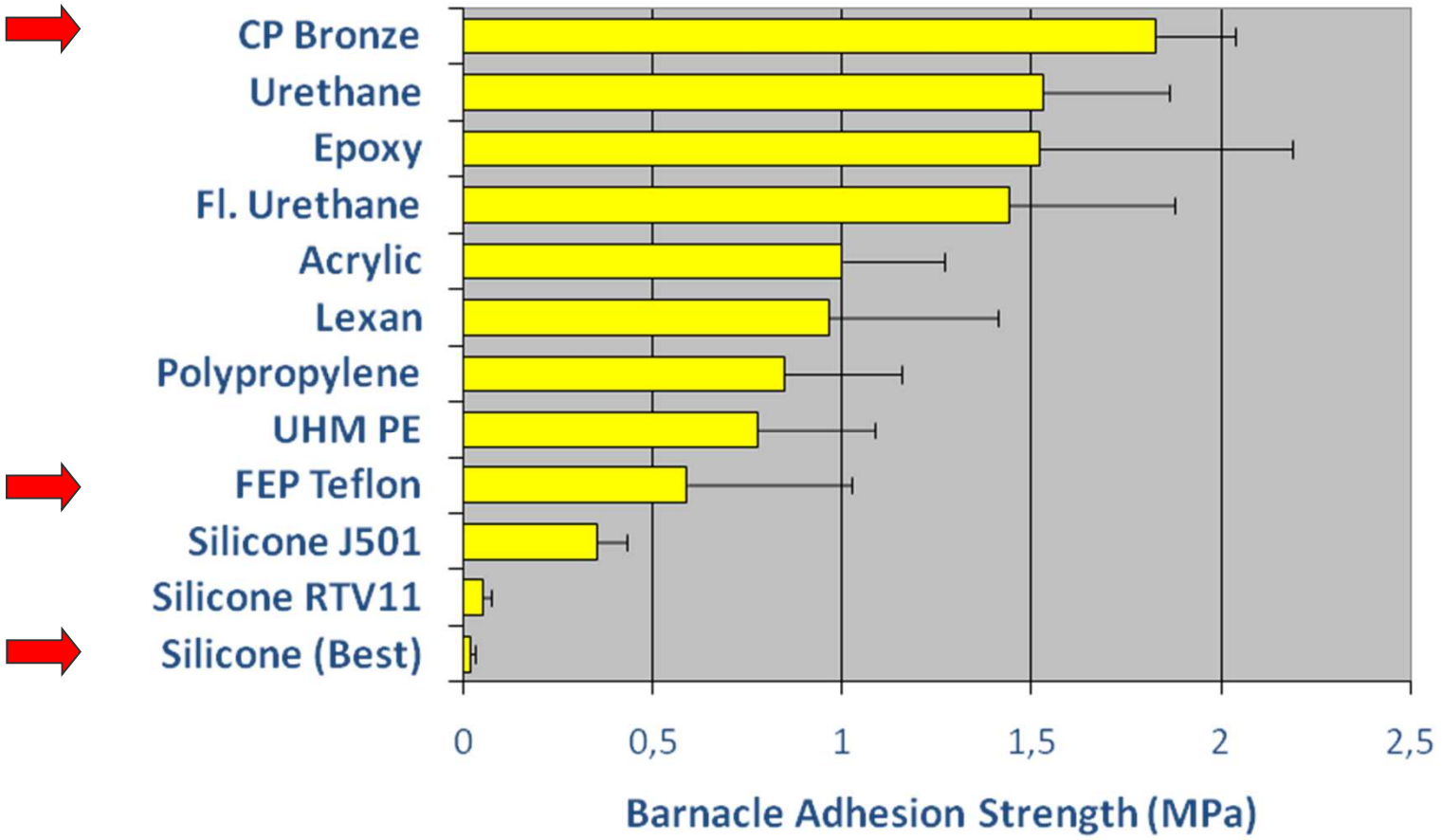
- a.k.a. foul release paints
- often based on fluorinated silicone elastomeric polymers
- fouling prevented by making adhesion of slime mechanically difficult
  removal of fouling easy by low-pressure rinsing or wiping
- contains no biocides
- remains active as long as coating undamaged

Problems: mechanically sensitive
costly
ineffective at low speed



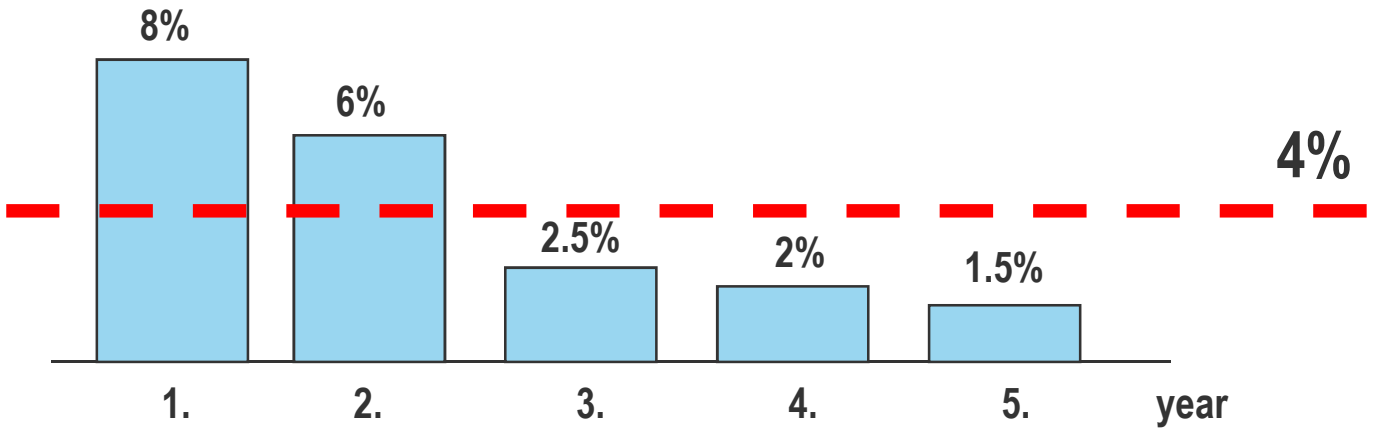
LSE = low-surface energy

In fact, it is “Super-Teflon”



Performance decrease over time

Typical performance history for VLCC



Average over docking intervals !

VLCC = Very Large Crude Carrier = Supertanker

Still, we need shear stress

Condition for fouling release:

Adhesion Strength < (Hydrodynamic) Shear Forces

Key question:

What ship speed is required for fouling release?

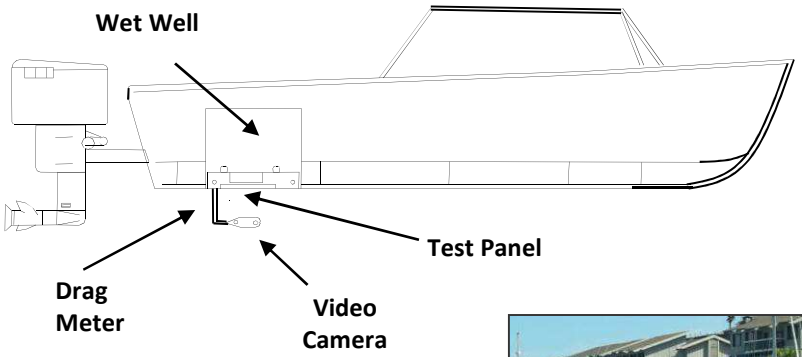
Source: photosfan.com

One test is worth a 1000 expert opinions

Florida Institute of Technology test facilities for marine antifouling

Static immersion

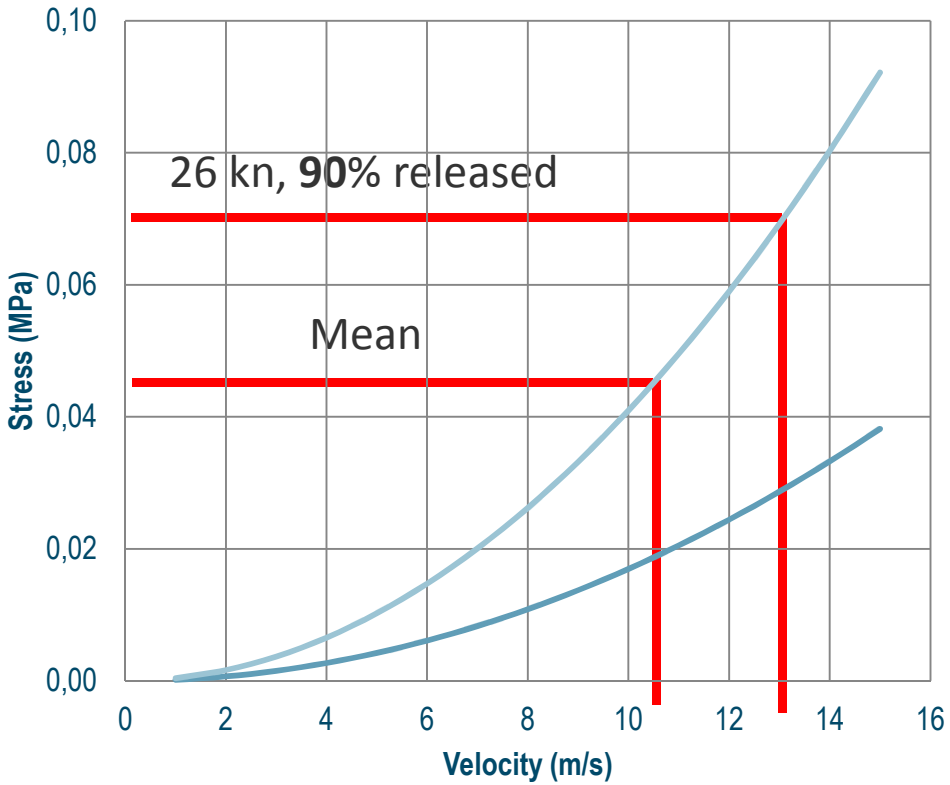
Dynamic immersion



Source: Geoff Swain (FIT)

90% fouling released at 26 kn – Is that good enough?

Example result of test



Some barnacles still stick on “non-stick” paint

Remember:

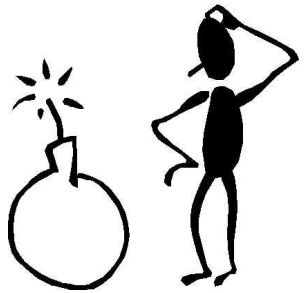
Parts of ship have local velocity well below ship speed

Sheltered regions need different solutions

- Sea chests
- Bow thruster
- ...

Very low speed

Difficult to clean



Source: Limnomar

We have many more options

Many other avenues have been explored – Which ones to pick ?

Electro-conductive paint

1891 Edison patents his ideas for DC antifouling system

1907 US patent for electric protection of ship hull

Very strong currents needed, systems uneconomical

1967 revival in Japan, seawater electrolysed directly

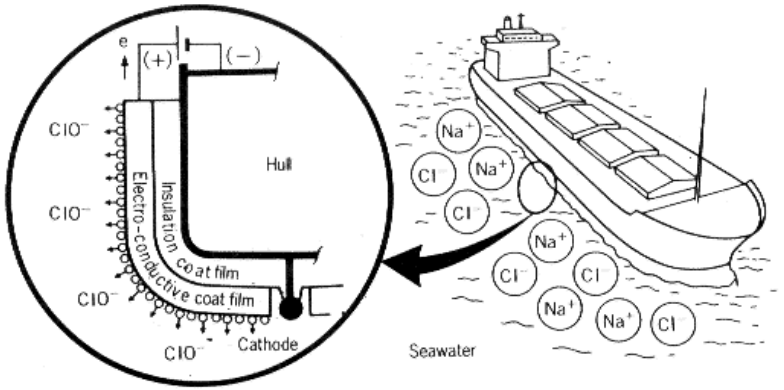
efficient and uniform dispersion not possible; abandoned

1990s MAGPET system at Mitsubishi developed

Problems:

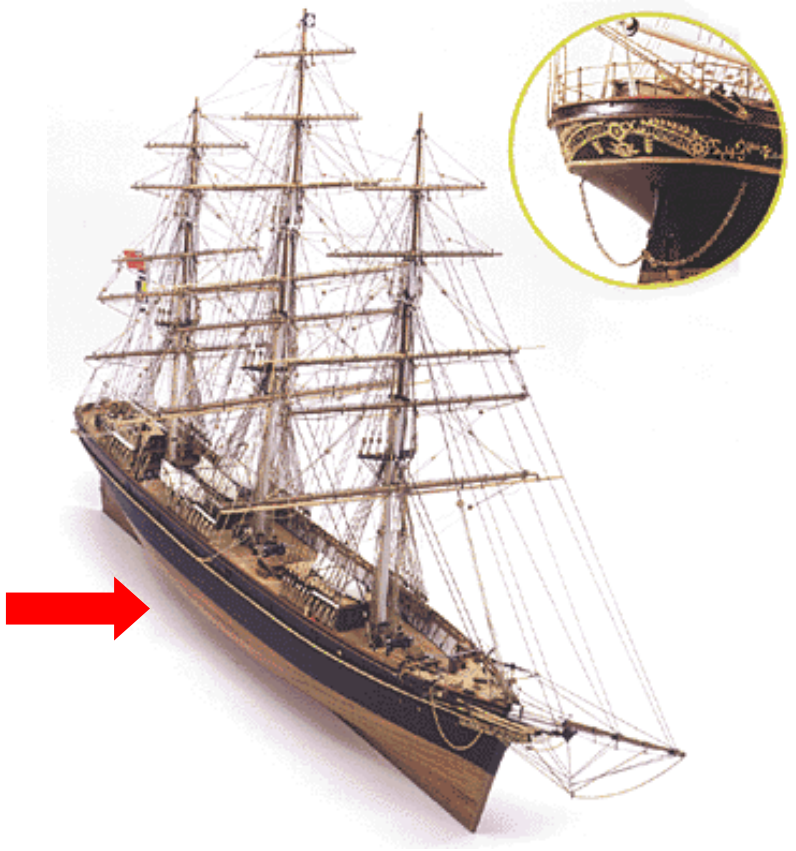
expensive

ineffective in fresh water (port)



Sheathing

~300 B.C.	Greeks nail lead plates on ships
-1700	lead sheathing, but not very effective
1760-1850	copper sheathing for navy
1850-	advent of steel ships: corrosion problems



Sheathing

Renaissance after 1980:

1980 Japan: Cu-Ni alloy sheathing 6 months effective

1982 USA: Cu alloy sheathing similarly (in)effective

1995 Japan: Cu-Beryllium sheathing effective

Problem: High installation cost

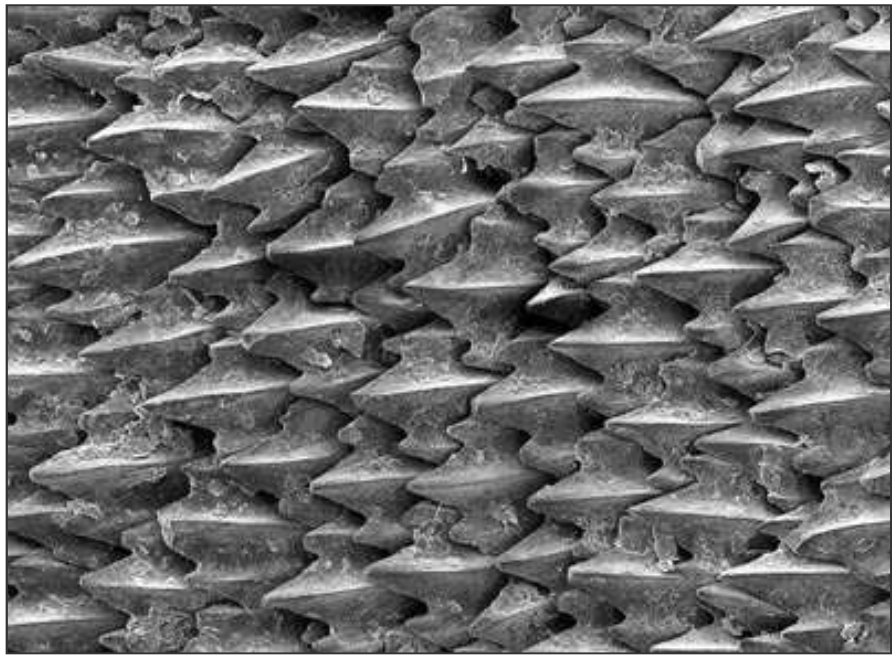
source: www.copper.org

How about Mother Nature?

Since “bio” is so fashionable...

Quiz-time

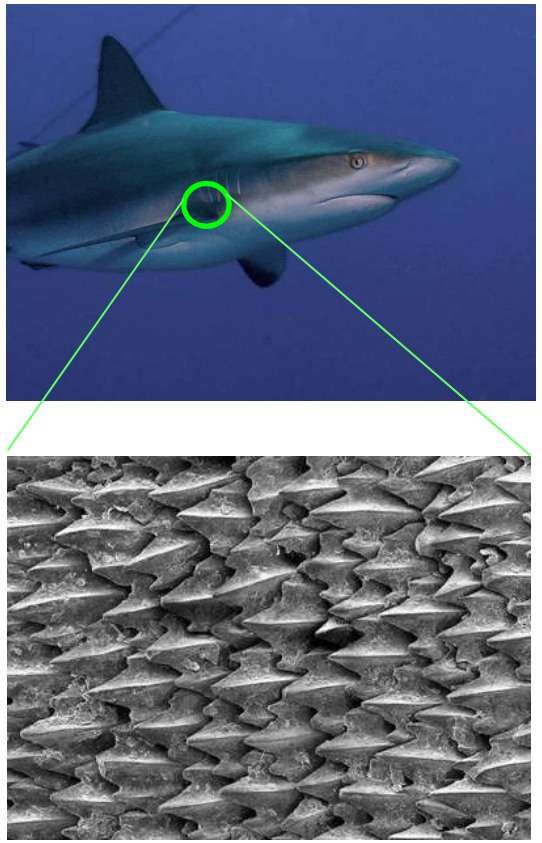
What do you see ?



Biologically inspired solutions: Shark skin

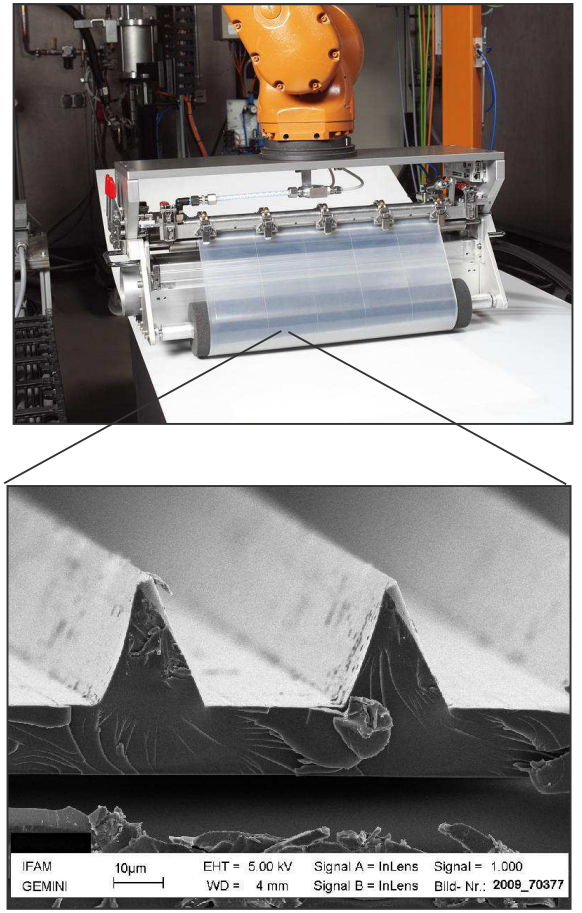
Surface structure of e.g. shark skin makes adhesion difficult for marine organisms

Efforts to recreate these effects industrially



HAI-TECH Project – Riblets for resistance reduction

- Riblet varnish
- R&D project for ship applications (2012)



Source: Fraunhofer IFAM

Applied to “ship-like” structures (= floating dock)

- Can handle welds & “hungry horse” look
- R&D project for ship applications (2012)

Open questions:

- Deterioration in time
- How to keep micro-fouling away

Source: Fraunhofer IFAM

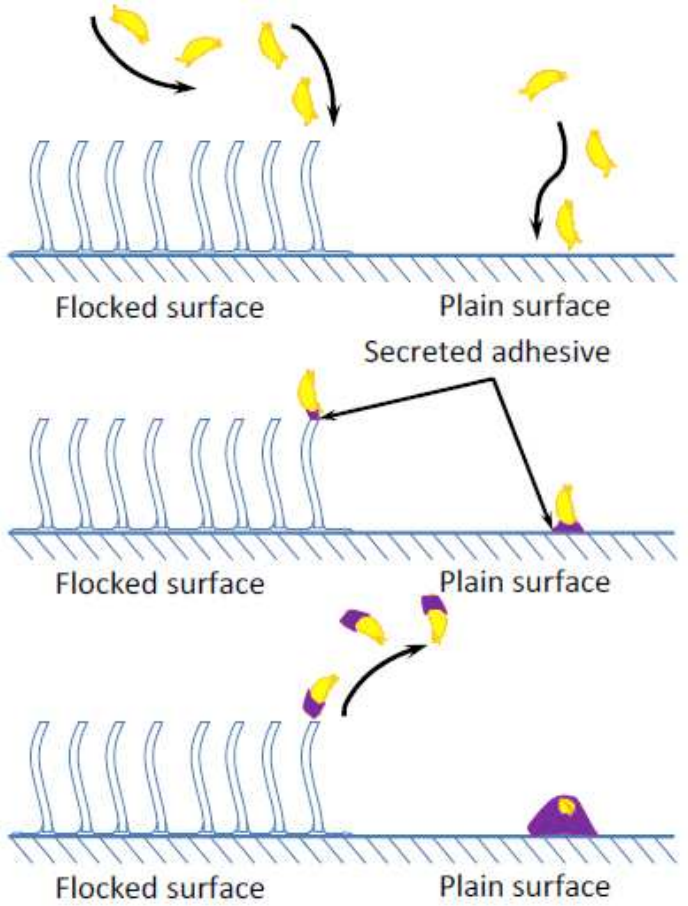
Quiz-time

What do you see ?

Biologically inspired solutions: Flocked surface

Flocked surface

Makes settlement of algae, larvae, etc. difficult



Source: Micanti

Biologically inspired solutions: Flocked surface

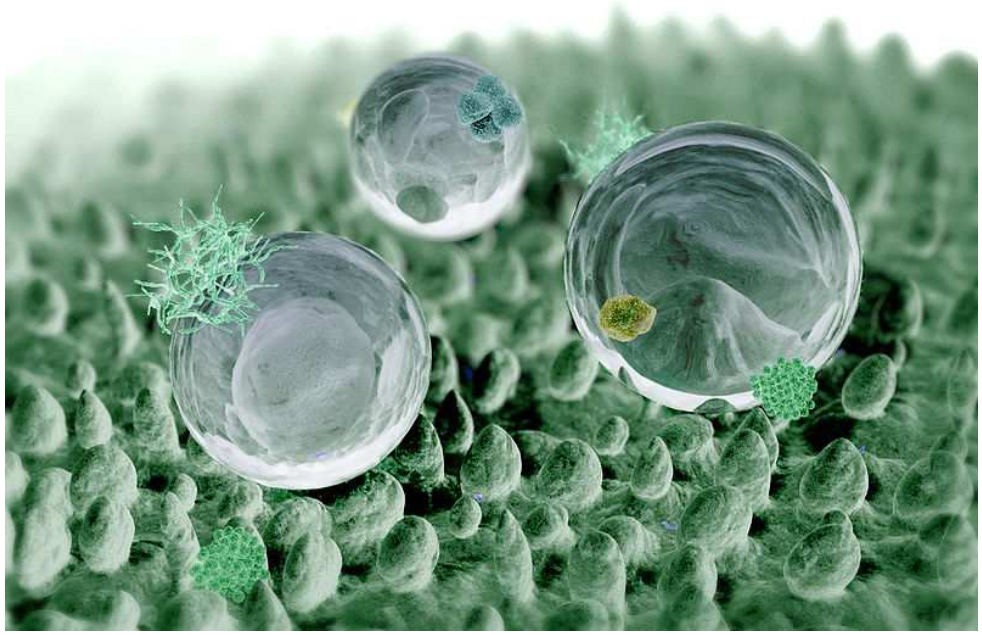
Foil applied to hull

- Endures >5 years
- Non-toxic
- Vendor claim: no increase in roughness

Source: Micanti

Quiz-time

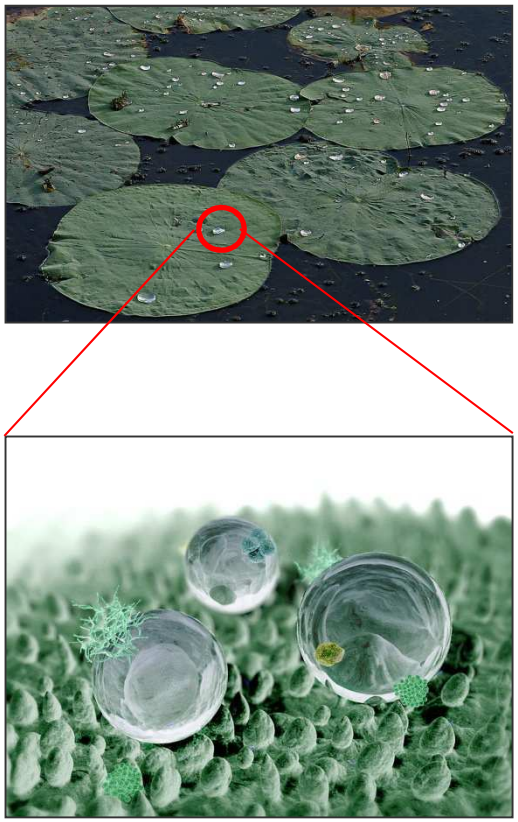
What do you see ?



Biologically inspired solutions: Lotus effect

Super-hydrophobic surfaces of e.g. lotus leaves repels water and water-borne organisms
"Lotus effect"

Efforts to recreate these effects industrially



Nano-coatings

- water-repellent
- dirt-repellent
- “anti-graffiti” coatings
- increasingly popular for ships
- fuel saving effect not (yet) higher than LSE

Source: University of Illinois Urabana-Champaign

Quiz-time

What do you see ?

Biologically inspired solutions: Hard shell

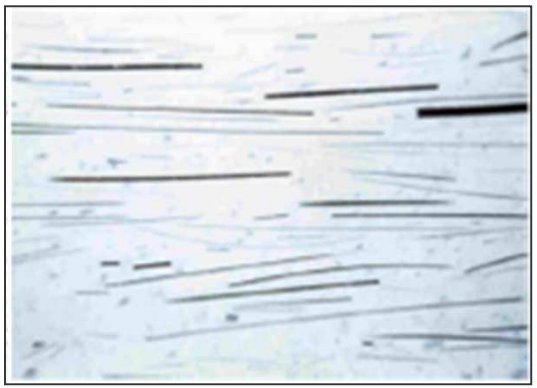
Hard shell & grooming,
e.g. turtles

Efforts to recreate nature by robust hard coatings and cleaning robots

Source: Andre Seale

STC Coatings = Hard coating & cleaning

- hard, durable coatings thanks to glass flakes
- fouling removed by (frequent) cleaning
- cleaning improves smoothness according to vendor
- life-long coating “with only minor touch-ups”
- commercially marketed: “ECOSPEED®”



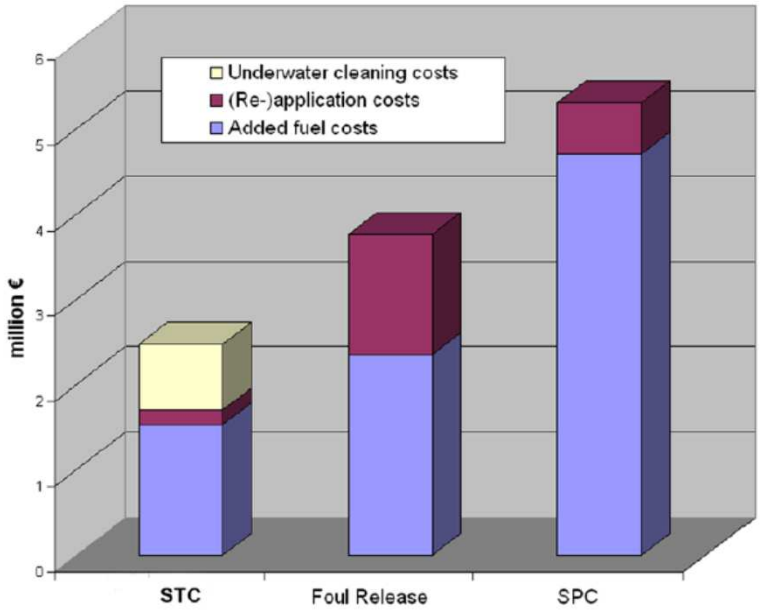
Problems: Not enough experience

Only vendor claims

STC = Surface Treated Composite

Vendors claim the new wonder weapon is found

Case study for 1000 TEU container ship, savings over 25 years

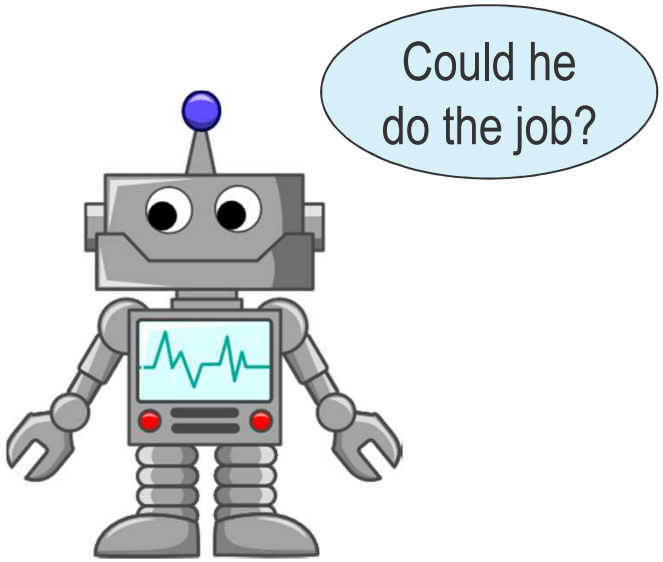


... but do we trust the vendor?

Source: HYDREX
STC = Surface Treated Composite; SPC = self polishing copolymer (typical copper paint)

Frequent cleaning possible

- Diver cleaning now state-of-the-art
- Costs?



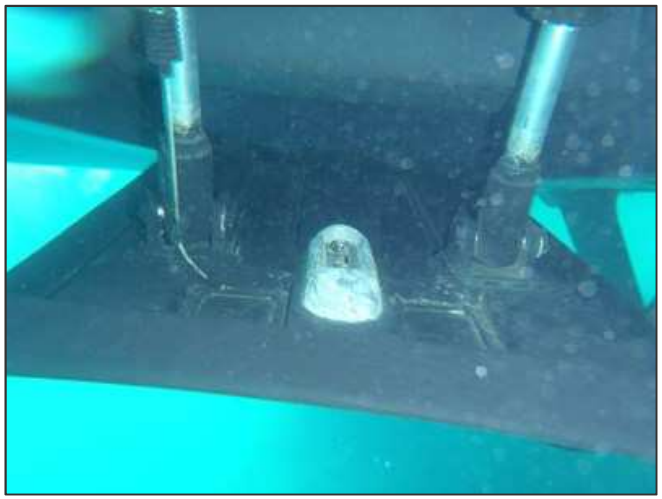
Finally autonomous robotic grooming seems to be within reach

- Grooming recommended every 1-3 weeks

Source: Searobotics

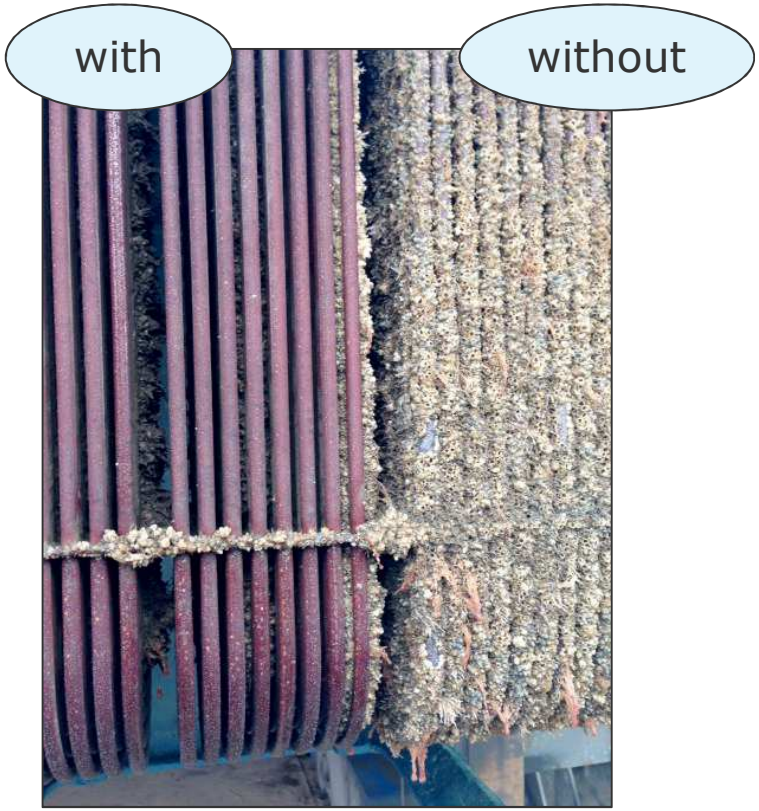
Good vibrations? – Ultrasonic cleaning

- Ultrasonic vibrations destroy cell membranes
- Spacing every 6-8 m
- Particularly attractive for internal antifouling
- EU project CLEANSHIP



Source: H2OBoatcare

Seems to work nicely on pipes, sea chests, ...



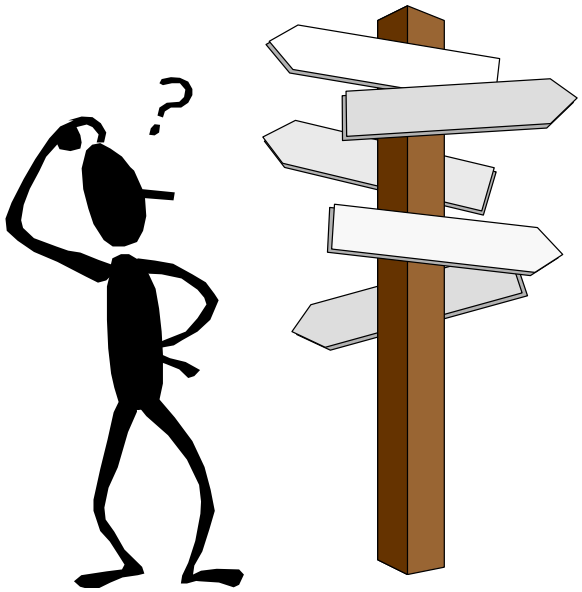
Source: Hainca

Prediction is difficult...

Alternatives contending:

- nano-technology paints
- LSE paints
- STC paints
- Transducer
- yet another new idea?

So far no “winner”
universally accepted



LSE = Low Surface Energy
STC = Surface Treated Composite

Navigator

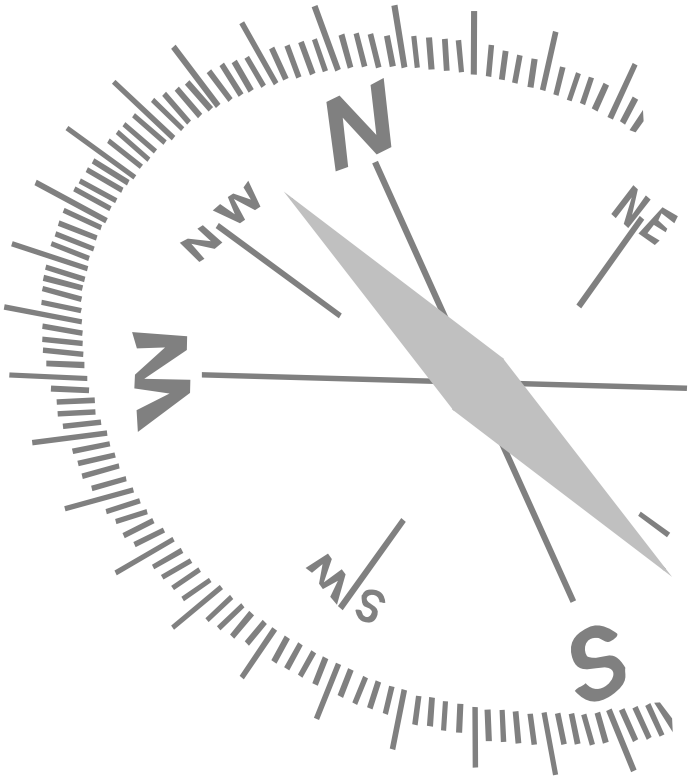
Fouling

A problem solved – or so we thought

Copper-based coatings

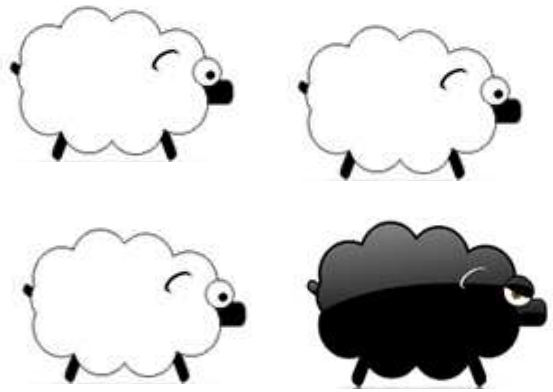
Alternatives ?

Quiz



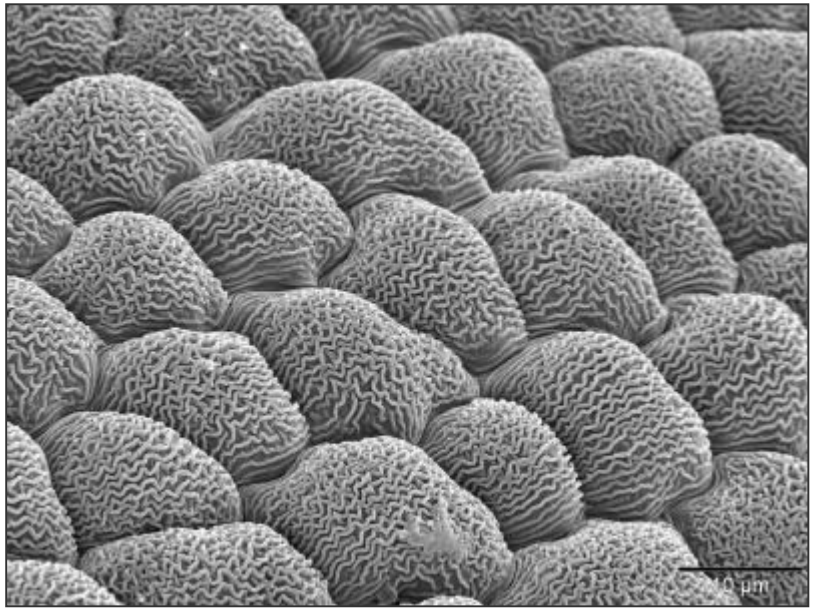
Quiz: Do you know your antifouling ?

What is not a coating?



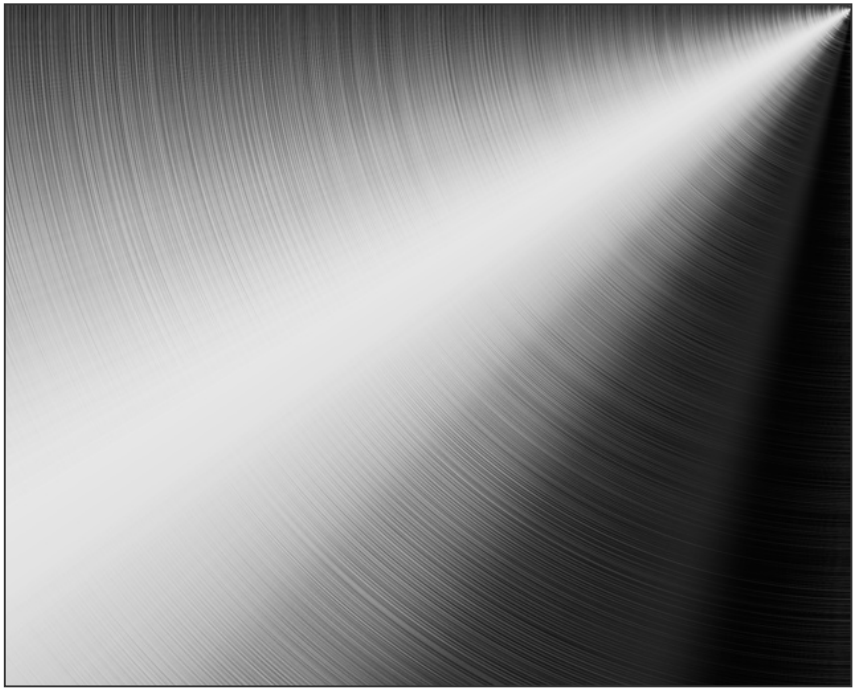
a. LSD
b. LSE
c. SPC
d. STC

Paint roughness is expressed in ...



a. nanons
b. microns
c. klingons
d. picons

Blasting to bare steel after 10 years may give...

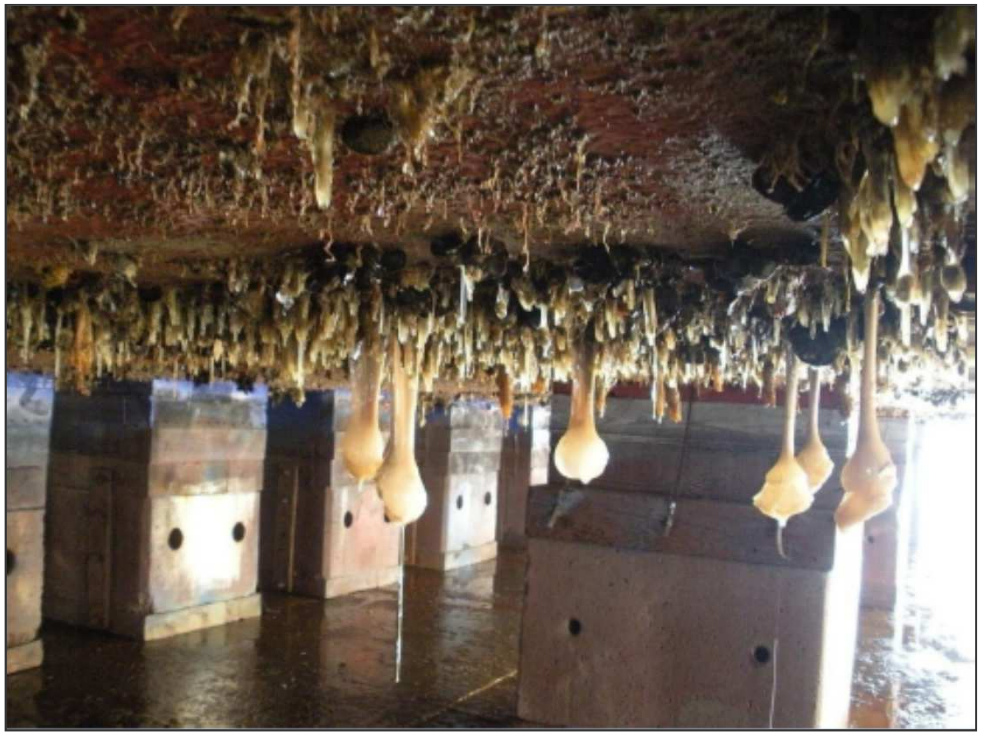


a. 2-3% improvement
b. 5-15% improvement
c. 35-45% improvement
d. 85-95% improvement

Barnacles form part of...

a. slime
b. molecular fouling
c. microfouling
d. macrofouling

What do you see?



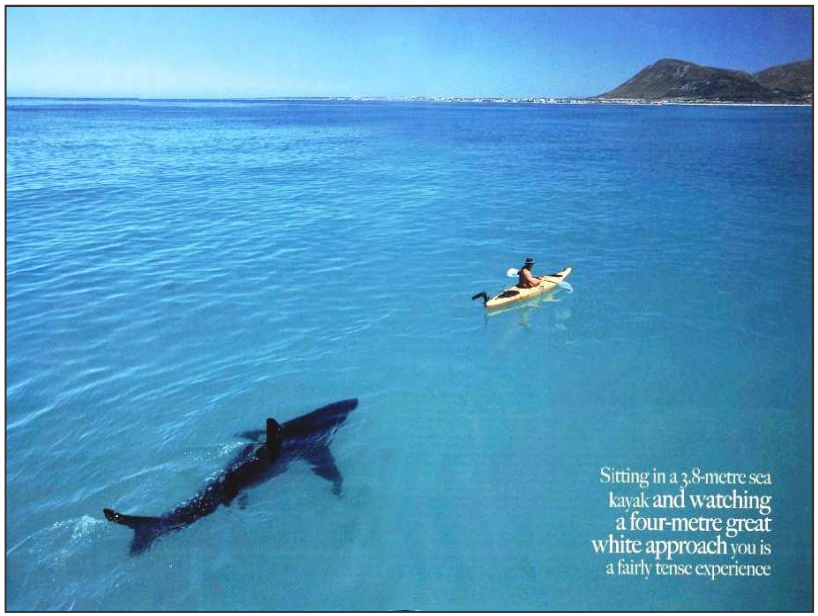
a. slime
b. molecular fouling
c. microfouling
d. macrofouling

What is the estimated % of the world fleet in poor...

coating condition (with more than 50% added resistance due to poor coating)

a) 7%
b) 17%
c) 27%
d) 47%

Little grooves mimicking shark skin are called…



a. rib eyes
b. riptides
c. riblets
d. ribbons

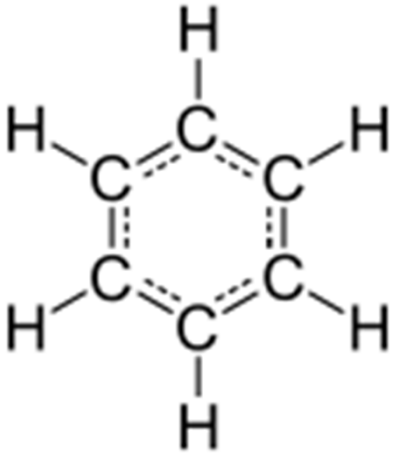
The first patent for antifouling paint was issued in...

a. Germany
b. Japan
c. UK
d. USA

What was the name of a hot plastic paint?

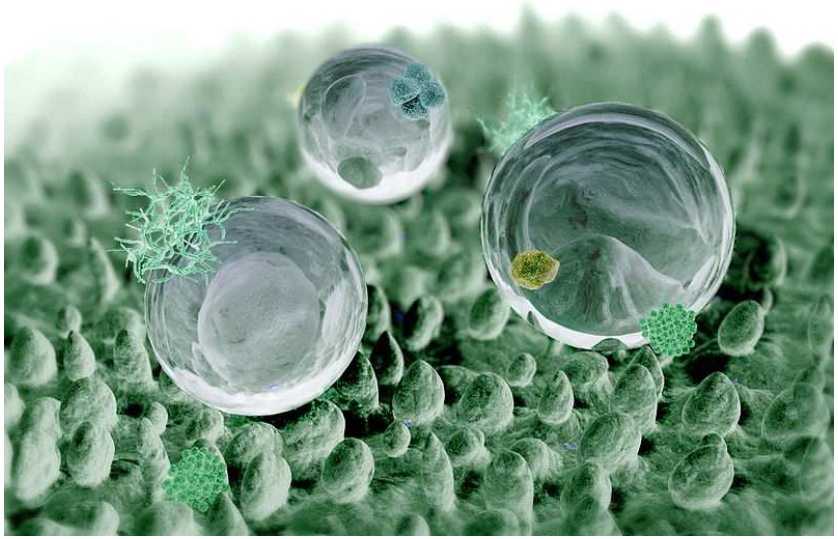
a. Italian Moravian
b. Moravian Italian
c. French Bohemian
d. Bohemian French

What does the “B” in TBT stand for?



a. Benzedrine
b. Benzene
c. Beryl
d. Butyl

Nano-coatings are...



a. super-hydrophobic
b. super-hydrophilic
c. super-hydrodynamic
d. super-hydrologic

In 2011 the most popular alternative to TBT coatings were...

a. zinc-based paints
b. copper-based paints
c. LSE paints
d. STC paints

Percentage of ships using copper-based coatings

Estimate the percentage of ships worldwide using copper-based coatings (in 2011)

a. 90%
b. 80%
c. 66%
d. 50%

What paints are banned for recreational craft...

... in Washington State

a. acrylic paints
b. foul release coatings
c. copper-based paints
d. ceramic coatings

For a VLCC, an LSE coating may save initially X% fuel

What has been given as saving potential vs. a standard antifouling paint?

a. 12%
b. 8%
c. 4%
d. 1.5%

The five-year average...

...for the same VLCC will be close to...

a. 0.5%
b. 1%
c. 4%
d. 6%

Which university has test facilities for marine antifouling?

a. Florida Institute of Technology
b. Massachusetts Institute of Technology
c. Australian Maritime College
d. TU Hamburg-Harburg

STC coatings contain....

What's inside?

a. antifoulants
b. glass
c. acryl
d. boosters

Electro-conductive paints ...

a. ... are banned in California
b. ... incompatible with copper
c. ... often combined with biocide “boosters”
d. ... ineffective in fresh water

The Greeks nailed … plates on ships for antifouling

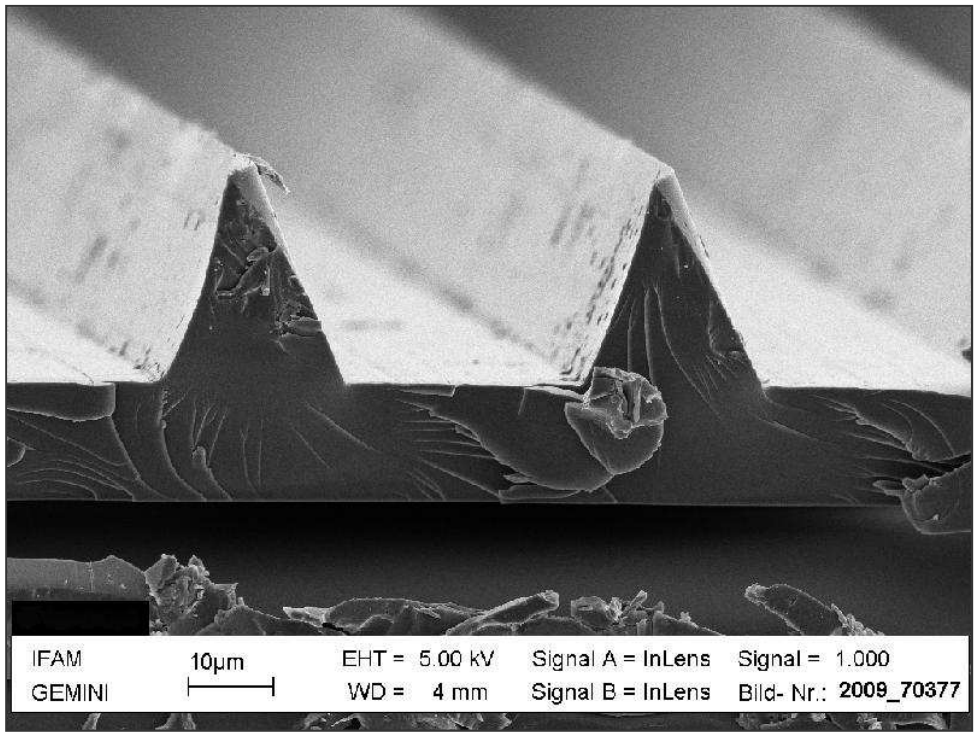
a. Lead
b. Steel
c. Beryllium
d. Bronze

The Royal Navy used ... sheathing on its ships

18th century frigate

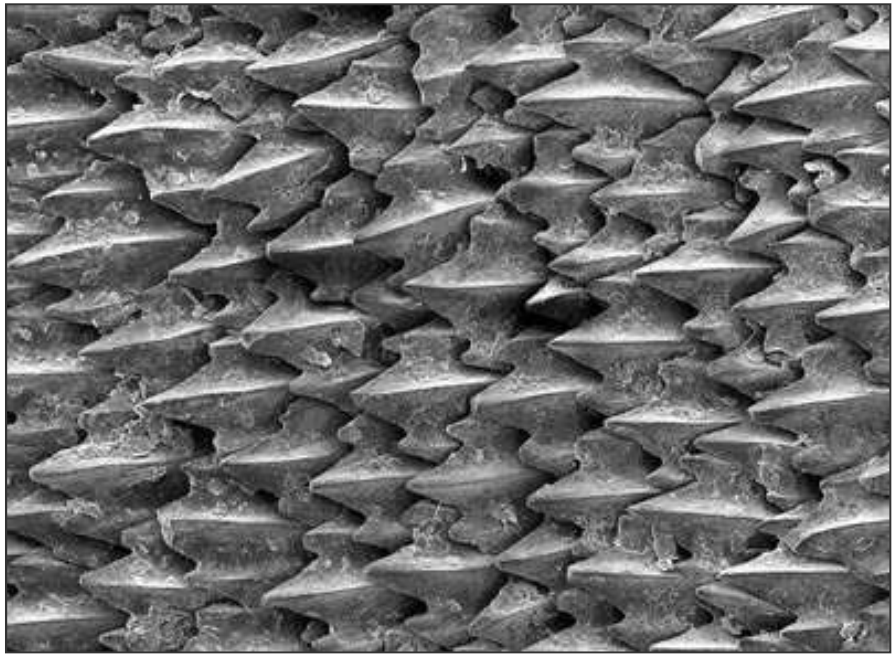
a. Lead
b. Steel
c. Bronze
d. Copper

What do you see?



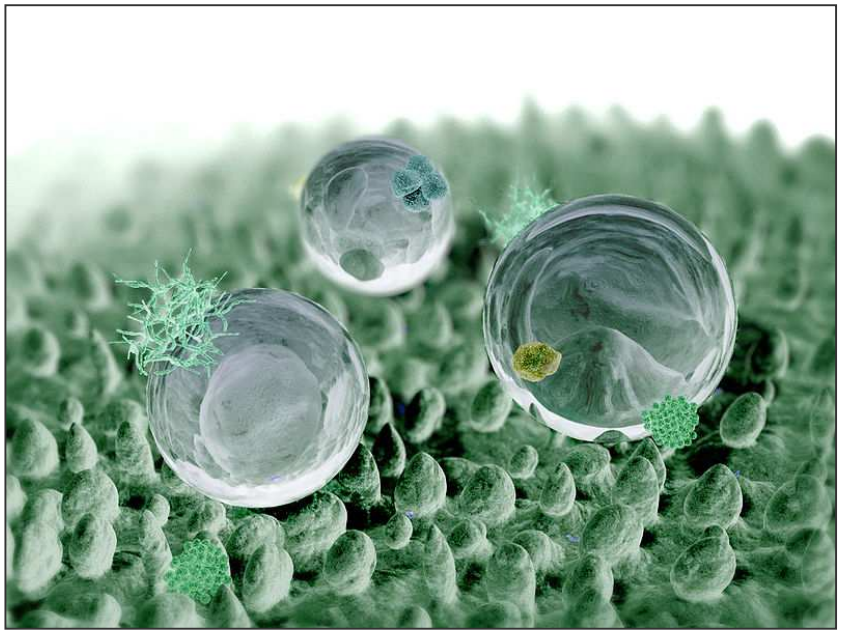
a. Shark skin
b. Riblet varnish
c. Lotus flower
d. Surface treated coating

What do you see?



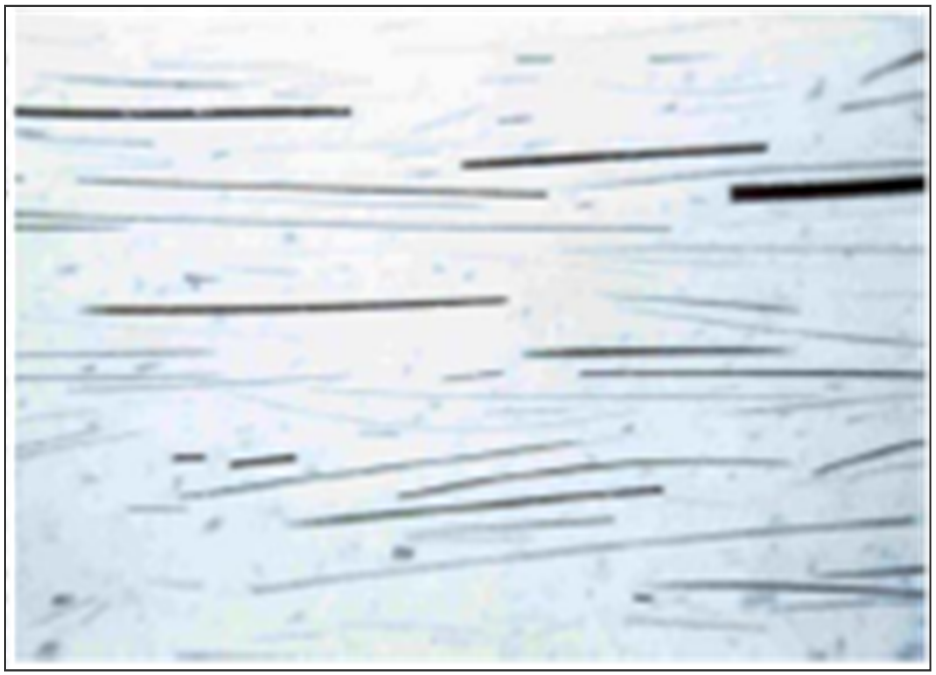
a. surface treated coating
b. lotus flower
c. shark skin
d. riblet varnish

The “Lotus Effect” is used in...



a. surface treated coatings
b. antifouling coatings
c. nano-coatings
d. low surface energy coatings

What do you see?



a. Surface treated coating
b. Low surface energy coating
c. Nano-coating
d. Self-polishing copolymer