4/2009

CHEManager EUROPE

GIT VERLAG GmbH & Co. KG, Darmstadt, Germany www.gitverlag.com

THE NEWSPAPER
FOR THE CHEMICAL AND
LIFE SCIENCES MARKETS

Combating Biofouling And Soiling

A Roadmap to Tomorrows More Durable Coatings

Guidelines – Biofouling and soiling is expensive for the society. Bacterial adhesion on medical implants before operation can cause complicated infections. Barnacle adhesion on tankers increases the friction to water and more fuel is needed to move the tanker. Adhesion of soil on a painted house decreases the value of the property. Hence a roadmap for fast development of coatings providing true antibiofouling properties will decrease cost for society and provide a market opportunity for the coating company.

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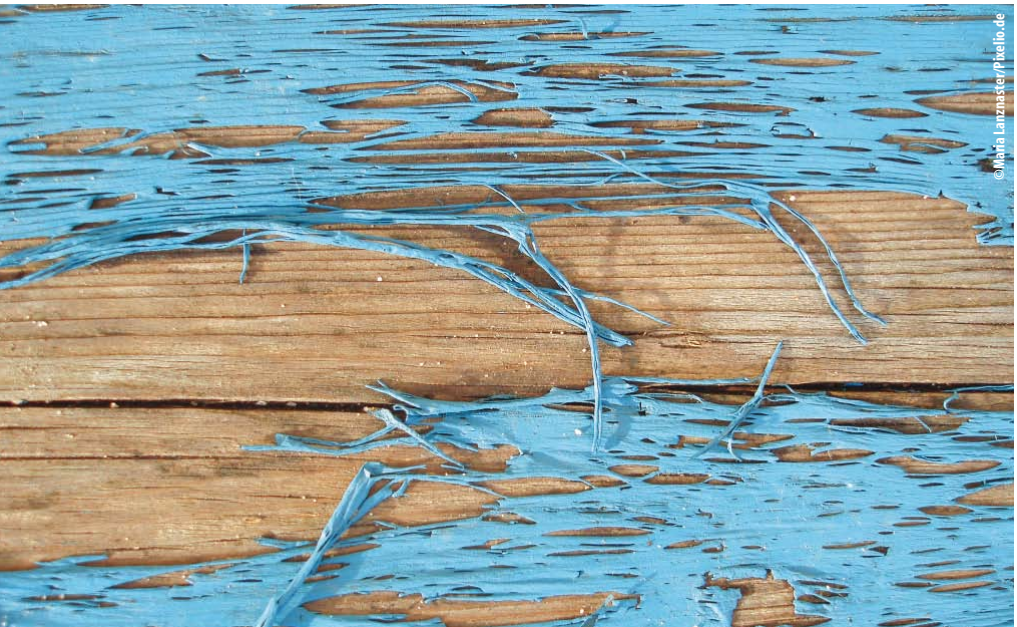
Any surface, whether natural or synthetic, is coated initially with local environmental constituents such as water, electrolytes and then organic substances. The presence of this conditioning film can provide the impetus for microbial growth and further colonization. Microbial adherence and biofilm production proceed in two steps: first, a reversible attachment to the surface followed by a second irreversible chemical step, which involves the multiplication of cells and the synthesis of an extracellular polymeric film.

Dust particles are generally spread around by air movement and rainwater or, in the case of the finest particles by Brownian movement and thus come into contact with the exterior coating. Hence the amount of suspended dust in the air at the weathering location has a determining effect on the dirtiness of the coating. That is why coatings in cities which have a high concentration of suspended dust become dirty much more quickly than in a rural environment with a lower overall dust concentration.

The following map can provide guidelines for future research giving tomorrow's competitive solutions to handle biofouling and soiling.



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1. Prolonged Effect of Existing Biocides

Biocides that pass the biocide directive in Europe are potent in the function to inhibit growth of mould, algae etc. on painted surfaces. The problem today is that the biocides leak too fast from the coating leaving the surface available for growth of micro-organisms. Biocides are presently formulated directly into the paint. If the biocide instead is loaded into a container providing sustained release properties it can more slowly be released into the paint. A test of the concept verified that this approach can prolong the protection against biofouling.

2. Novel Biocides

Developing new biocides with antibiofouling properties can be a way to improve the protection of coated substrates. The drawback with new molecules at least in Europe is that a costly procedure for testing must be conducted before novel molecules can be used.

3. Self-cleaning Coatings

The Hydrophobic Route

A good cleaning by water on hydrophobic low-energy surfaces requires a microstructure so that the water can roll and not only glide on the surface. The dirt

must not be well adhered and be on the hills and not valleys of the microstructure to be easily washed away. The mechanical durability can be an issue as well as remaining spots of dirt.

The Hydrophilic Route

A good cleaning by water on hydrophilic high-energy surfaces requires a complete wetting of the surface creating a water film dragging the dirt with it. If the surface is oleophobic it will further improve the cleaning results.

4. Paint Chalking/Erosion

Sun light in air and hydrolysis in water can degrade polymeric bonds causing flakes of paint to fall off and adhered dirt/microbes will passively follow. Sun light can be absorbed by TiO_2 particles leading to a photo-induced reaction at the particle surface breaking down bonds in coating polymers and dirt/microbes. In decorative applications these approaches often give too fast paint chalking. A slow erosion of paint could be acceptable if it does not create a disturbing appearance. It could be obtained by having a limited number of hydrolytic bonds in the coating or addition of small amount of a rosin-based polymer.

5. Paint Surface Hardening

Mobile polymer chains are important to fuse particles together forming a continuous paint film and to allow a coating to follow movements from the substrate without cracking. However mobile chains at the coating surface can be a disadvantage if they flow over adsorbed microbes/dirt increasing the contact area and adhesive strength. Good flexibility in the bulk of the coating and a harder surface might be an advantage. That can be achieved either having air-reactive crosslinkable groups at the surface or introducing nanoparticles affecting the surface rheology.

6. Weak Dirt Adhesion

Liquid or deformable dirt can spread on the surface increasing the contact area if the surface energy of the substrate is larger than the dirt. The maximum adhesive force is obtained when the surface energy of the dirt and surface is equal in size. Hydrophilic polymers such as polyethylene glycol at the coating surface give a surface energy very different from the dirt providing a weak adhesive strength. The hydrophilic segments can also swell under humid and rainy conditions decreasing the van der Waals attraction further lowering the adhesive strength making it easier for the rain water to clean away dirt from the surface.

7. Minimize Coatings Nitrogen Content

One of the growth factors which can limit the growth of micro-organisms is the access to nitrogen. Nitrogen is an essential part of amino acids which in turn is the building block of proteins. Nitrogen in a form accessible for life is a limiting factor in nature. Hence using nitrogen-free coatings can reduce the level of biofouling by reducing the micro-organisms growth on the coated object if the object itself does not contain nitrogen compounds.

"Fast development of coatings providing true antibiofouling properties will decrease cost for society and provide a market opportunity for the coating company."

8. Reduce Oxygen Level in Water

Many macrofouling species in water such as barnacles, algae, mussels etc need oxygen in their metabolism. Therefore an interesting opportunity is to allow biofilms to establish themselves on coatings. The growth of the biofilm will require the consumption of oxygen. If the oxygen level is low enough macrofouling species will prefer to establish themselves on other substrates than the coated object.

9. Block Enzyme Activity which Enhances Micro-organisms Glue Production

Micro-organisms are always sending out an extracellular polymeric matrix which is used to adhere better to the substrate and protect from poisons in the environment. In this process enzymes are used to speed up the polymerization process. If the enzymes activity is blocked the polymerization process will be slowed down or stopped. Hence the biofilm formation will be damaged.

10. Introduce Enzymes Degrading Biofoulers Glue

Some enzymes are used to polymerise polymers other enzymes are used to depolymerise polymeric compounds. Industrial enzymes are used in washing powders to improve the cleaning performance of the powder. Potentially this kind of enzymes can be incorporated in paint to provide a depolymerisation mechanism of the micro-organisms adhesives. The result would be a detachment of the micro-organism from the surface.

11. Avoid Surface Recognition

In water hydrogels with high water content might be difficult for macrofoulers to recognize as a surface. It may provide an interesting opportunity in under water applications to avoid macrofouling.

12. Use Secondary Metabolites

There is always a fight for space to live in nature. Many micro-organisms send out secondary metabolites to protect themselves from enemies. The secondary metabolites are natural biocides that could be used in coatings to protect them from biofouling. However also these biocides would need a substantial testing according to the EC:s biocide directive.

13. Manipulate the Micro-organisms Communication

Micro-organisms such as bacteria are either moving around in liquid or air or forming a bio film and grow on a substrate. The bacteria release various signal substances (molecules) used for communication. By the number of signals when moving around in a liquid they can realize if they are many enough to establish themselves on a substrate. They also communicate when to leave a biofilm community, how to react towards various enemies, food availability etc. This communication known as quorum sensing can be used to give wrong signals to lure the enemy.

Summary

We have in this article provided a unique roadmap of strategies to combat biofouling and soiling for various applications where a coated surface is of importance. Some of the roads are well studied while others are more open for innovative research and the development of novel products. YKI, Institute for Surface Chemistry, work extensively together with companies with various strategies to provide tomorrows solutions.

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