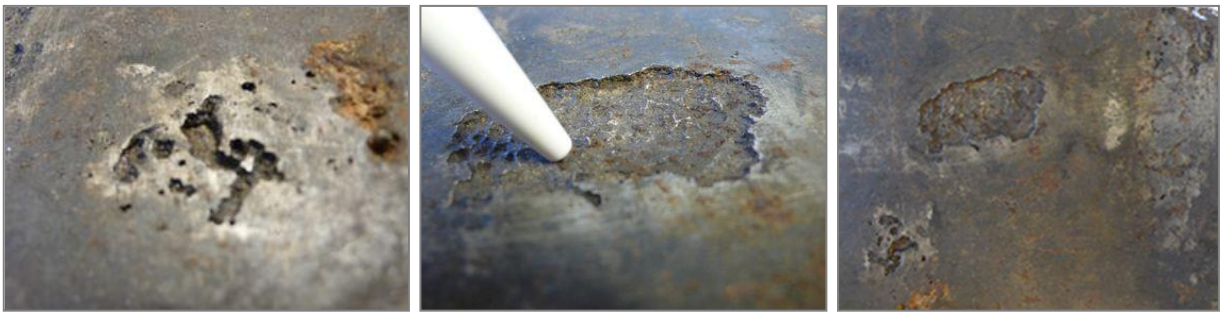
NEWSLETTER MAY 2011

Mechanism of anaerobe bio corrosion induced by SRB bacteria

When considering the definition of “corrosion“, you first think of aerobe corrosion where metal is distroyed under the influence of oxygen and water. However, a major part of all corrosion damages occur under full exclusion of oxygen, for instance in the bottom area of filled storage tanks or in pipeline systems.

Sulfate reducing bacteria (SRB) are mainly responsible for the anaerobe corrosion. These micro-organisms accelerate corrosion of steel in crude oil tanks and other technical installations, which come in contact with water and organic materials. Such surfaces have to be cleaned continuously; otherwise, gel-like bio films form due to the rapid propagation of SRB bacteria. This process causes bio fouling with a strong smell and slime formation which could be a precursor of bio corrosion.

Ferrous metals, when corroded in that way, show on their surface black spots of iron sulfide. By removing these films, anodic cavities of bare iron appear which rapidly induce pitting corrosion and therefore extreme damages.



Pictures: *Heavy corrosion damages of steel tank by SRB bacteria, cleaned surface*

How do the SRB bacteria get into crude oil tanks?

Crude oil contains, beside carbon compounds, plenty of surface water because of the extraction procedures. The water itself is contaminated with microbes and contains a number of sulfur compounds, especially sulfates, which can be used by the SRB for their metabolic processes.

How do sulfate reducing bacteria operate?

In the hydrous crude oil the SRB carry out a dissimilatory (energy releasing) reduction[1] of relating sulfur compounds, e.g. sulfate to sulfide, which are the electron acceptors for the simultaneous redox reation[1]. The preferred adequate electron donors are normally hydrogen and/or carbon sources such as: lactates, pyruvates, malates, high-molecular fatty acids, aromatic hydrocarbons and unsaturated hydrocarbons. These donors are then oxidized into acetates. During SRB population of ferrous surfaces, an oxidation of metallic iron to iron-2+-ions is possible. A detailed description of bio corrosion processes is demonstrated hereinafter.

[1] Oxidation is a chemical reaction, in which an oxidizing material (reducing agent) releases electrons. Hence, it displays an electron donor. (The formal oxidation number of the atom in the molecule is increased). Another material (oxidizing agent) receives electrons (electron acceptor) and is reduced as a result. That means the oxidation number of the atom in the molecule is decreased. This process ist called reduction. An oxidation is always related to a reduction. Both reactions together are part of a redox reaction.

Ceramic Polymer GmbH
Daimlerring 9
(Industriegebiet Ostkilver)
D-32289 Roedinghausen

Phone: +49 (0)5223-96 276-0
Fax: +49 (0)5223-96 276-17
eMail: info@ceramic-polymer.de
Web: www.ceramic-polymer.de

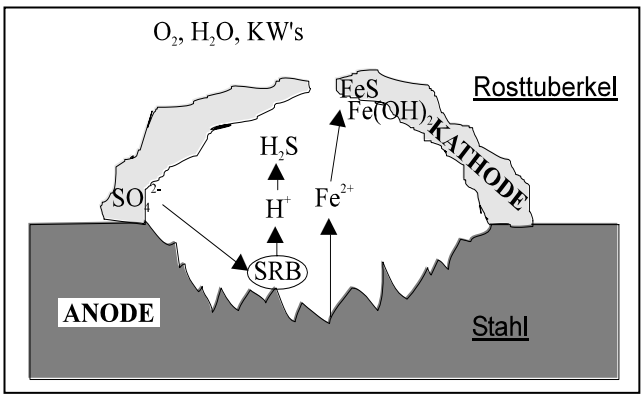
Geschäftsführer: Matthias Roehl
UST-Ident-Nr.: DE 248044614
Registergericht Bad Oeynhausen
HRB-Nr. 9750

First phase of bio corrosion: First population by oxygen tolerating SRB

The first population takes place by oxygen tolerating SRB. This occurs in oxygen-containing areas, but at a moderate speed ("hibernation"). These oxygen-tolerating SRB proliferate best in areas without convection. They find the niches with less circulation in lower areas of oil tanks and in cracks and pores of the coating. Thus, every area of storage tanks and even pipelines can be populated. These oxygen-tolerating SRB produce enzymes such as catalase and superoxide dismutase which form an aggravated lack of oxygen.

Second phase of bio corrosion: Tubercle formation and resulting destruction of iron

In these aggravated anaerobe areas, sulfate reducing bacteria (SRB) grow extremely fast and produce for their preservation O_2-independent metabolism hydrogen sulfide (H_2S). The SRB settle down primarily as tubercle-shaped colonies. Next, the physical-chemical conditions near the ferrous surface of the tank alter. Whereby the enzyme hydrogenase, which is produced by SRB, the resulting iron(II)sulfide (FeS) and the hydrogen film caused by autoprotolyses[2] of water are important.



Picture: *Simple illustration of the processes in a rust tubercle. The building of tubercles is a microbial induced complex process. It occurs as a kidney-shaped tubercle.*

The enzyme hydrogenase dismantles the protecting hydrogen film and releases the hydrogen as an electron donor. Hence, the above discribed redox reaction begins, where mainly iron is oxidized to iron-2^+ and sulfate is reduced to sulfide. The iron-2^+ions are intercepted by sulfide-ions to iron(II)sulfides and build a black crust around the rust tubercles.

The emerged iron(II)sulfide turns into a cathode and the galvanic cell iron / iron sulfide develops (conversion of chemical into electric energy). The hydrogen could reduce the electric potential of this cell, but the enzyme hydrogenase impedes also this protective mechanism and regenerates the layer of iron(II)sulfide constantly.

Evidentially anaerobe bio corrosion causes a 10-times higher oxidation rate in comparison to atmospheric corrosion.

[2] Autoprotolyses of water and its consequence: Generally (also in absence of SRB), a water molecule can release a proton onto another water molecule. Because of this proton transfer two ions occur: An oxomium ion (H_3O^+) and a hydroxide ion (OH^-). Very few water molecules carry out this reaction. The chemical balance of the autoprotolyses is biased toward the water's side. The H_3O^+-ions oxidize the iron to iron-2^+-ions, which can connect with the OH^--ions. During this oxidation process hydrogen is formed as a film, which prevents further decomposition of the iron (depolarizing effect).

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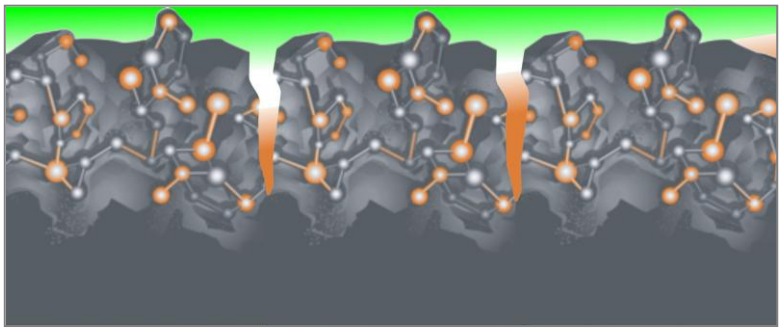
Why does the unique Ceramic Polymer coating systems provide a long-term protection against SRB- induced bio corrosion?

The description of the bio corrosion processes shows that it is primarily important to avoid the first population of oxygen tolerant SRB bacteria to prevent building of rust tubercles and resulting bio corrosion. The patent pending procedure of integrating the special biocide crystals into the ceramic polymer matrix destroys the SRB bacteria before they can settle in micro cracks which have occurred. Extensive test series by an independent institute has proven clearly that most thorough prevention of SRB-induced bio corrosion is provided by using our special products.



Picture: *Effect of the new tank lining products. As soon as micro cracks occur in the coating, the special biocide crystals burst and unfold their effect within the whole crack. The SRB are killed before their settlement. The existing depot effect causes a long-lasting biocidal corrosion protection without localized erosion.*

Ref:

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[Bryant, R., et al, Applied and Environmental Microbiology, 57/10, (1991), 2804-2809].

Author: Torsten Angermann, INNOVENT e.V., Jena/Germany