Corrosion

DECHEMA FORSCHUNGSINSTITUT

Cyclodextrins - biobased corrosion protection for metallic materials by EPS analogues

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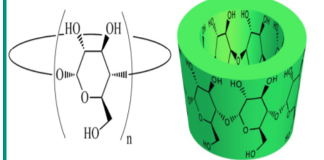
BACKGROUND & OBJECTIVES

Microbial biofilms and bacterial extracellular polymeric substances (EPS) can induce and speed up corrosion (microbially influenced corrosion, MIC) or even inhibit corrosion processes (microbially influenced corrosion inhibition, MICI) /1, 2, 3, 4/. Both effects are influenced by the interaction of the substrate with the EPS. Specific functional groups of the EPS are crucial for their interaction with the surface and the subsequent corrosion (inhibition) /5, 6/. It is believed that these end groups prevent the bacterial chemotaxis to iron ions and reduce the biofilm formation by complexing the decomposition products (iron ions). They can also block electrochemically active areas of the substrate (anode, cathode).

Use of EPS or EPS- analogues

- Composition of EPS is complex and their extraction is work-intensive
- Application of pure substances rather than complex EPS mixtures

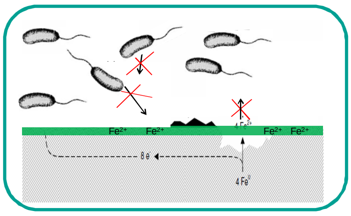


n=6 α-cyclodextrin
n=7 β-cyclodextrin
n=8 γ-cyclodextrin

- Synthesizeable
- Directed modifiable
  - ✓Functional groups
  - ✓Fluorescence - labelled
  - ✓Ring size (α-, β-, γ-CD)

Fig. 1: Structure and space filling model of Cyclodextrins

One approach is to use Cyclodextrins as EPS-analogue substances for reducing MIC and abiotic corrosion as well as biofilm formation on metals.



RESULTS

Influence of "self-polymerizing" CD films on surface properties of stainless steel & on biofilm formation by SRB

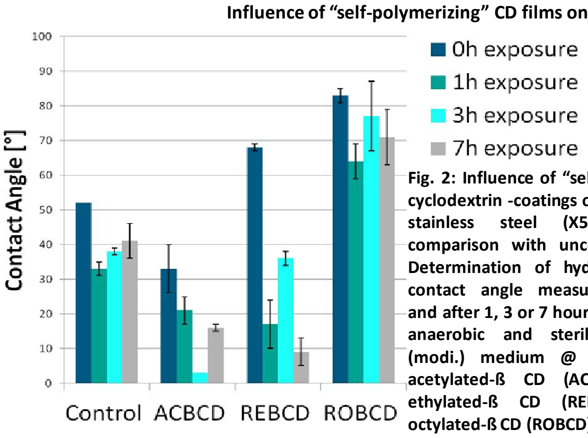


Fig. 2: Influence of "self-polymerizing" cyclodextrin -coatings on wettability of stainless steel (X5CrNi18-10) in comparison with uncoated controls. Determination of hydrophobicity by contact angle measurement before and after 1, 3 or 7 hours of exposure in anaerobic and sterile Postgate C (modi.) medium @ 37 °C. Abbr.: acetylated-ß CD (ACBCD), random ethylated-ß CD (REBCD), random octylated-ß CD (ROBCD)

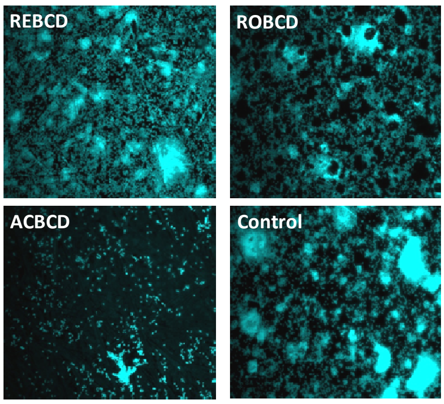
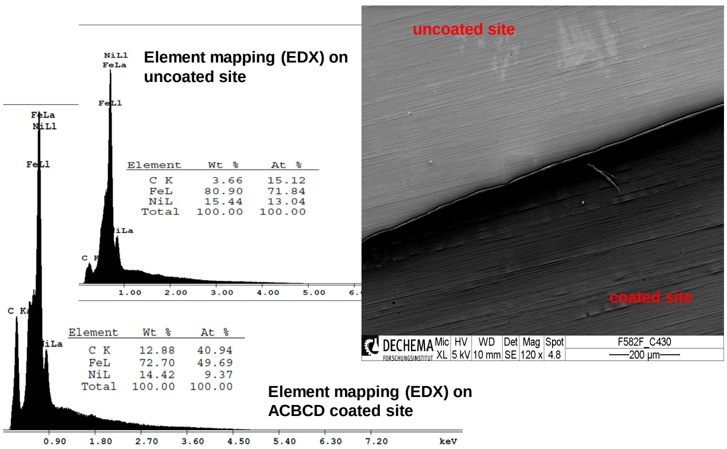


Fig. 3: Influence of "self-polymerizing" cyclodextrin - films on biofilm coverage of stainless steel (X5CrNi18-10) by corrosive SRB *D. vulgaris* after 7 days of exposure in Postgate C (modi) medium @ 37 °C and under anaerobic conditions in comparison with biofilm coverage of uncoated controls. After exposition the coupons were carefully rinsed with dH_2O, overlaid with DAPI solution (0.01 %) for 5 min, carefully rinsed again and visualised by EFM.

Elucidation of distribution of „self-polymerizing" CD´s and surface coverage



Element	Wt %	At %
C K	3.66	15.12
FeL	80.90	71.84
NiL	15.44	13.04
Total	100.00	100.00

Element	Wt %	At %
C K	12.88	40.94
FeL	72.70	49.69
NiL	14.42	9.37
Total	100.00	100.00

Fig. 4: REM & EDX investigation of stainless steel (X5CrNi18-10) surfaces modified with ACBCD. Depicted results are representive for all „self-polymerizing CD´s as REBCD and ROBCD show the same distribution pattern and surface coverage behaviour.

CD Influence on pitting potential of stainless steel under (a)biotic conditions

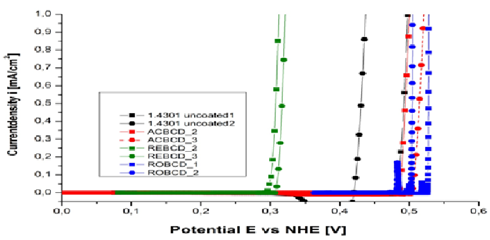
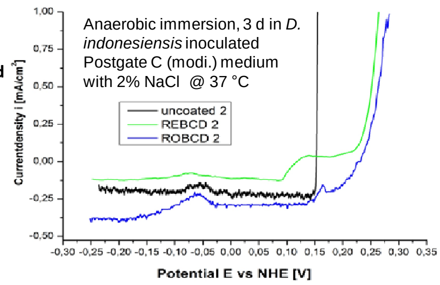


Fig. 5: Pitting potential of stainless steel (X5CrNi 18-10) modified with „self-polymerizing" CD´s after 1 hour of exposure in 1M NaCl @ room temp. in comparison with uncoated controls (Black curve).

Fig. 6: Pitting potential of stainless steel (X5CrNi 18-10) modified with „self-polymerizing" CD´s after immersion in SRB inoculated growth medium in comparison with uncoated controls (Black curve).



SUMMARY

- Homogeneous distribution pattern and coverage of the whole treated surface, but highest CD concentration at the edges of samples (coffee ring effect)
- Hydrophobic effect for ROBCD coated stainless steel during short exposure time
- ACBCD coated samples reduce the adhesion of harmful microorganisms (*D. vulgaris*)
- electrochem. measurements during
  - abiotic conditions: slightly shift of E_{pit} to anodic direction by ROBCD
  - MIC conditions: REBCD and ROBCD seem to inhibit the formation of pits

LITERATURE

References:
/1/ I. B. Beech, J. A. Sunner: Biocorrosion – Towards understanding interactions between biofilms and metals. Curr. Op. Biotech. 15: 181-186, (2004)
/2/ I. B. Beech, J. A. Sunner, K. Hiraoka: Microbe- surface interactions in biofouling and biocorrosion processes. Int. Microbiol 8 (3): 157-168, (2005)
/3/ H. A. Videla, L. K. Herrera: Understanding microbial inhibition of corrosion. A comprehensive overview. Int. Biodet. Biodegrad. 63(7): 896-900, (2009)
/4/ R. Zuo: Biofilms – strategies for metal corrosion inhibition employing microorganisms. Appl. Microbiol Biotechnol 76: 1245-1253, (2007)
/5/ G. M. Ferrari, H. J. A. Breur: Biopolymers for the corrosion protection of steel. Proc. ICC, Peking, PRC, (2005)
/6/ R. Stadler, A. Kuklinski, W. Fürbeth, W. Sand: Schützende Biofilme - Korrosionsschutz durch Bakterien. Biospektrum 17: 2 – 5, (2011)

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