Doctoral Dissertation
Doctoral Program in Metrology (32^{nd} cycle)

Measurement techniques for microbial corrosion assessment

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Summary

This dissertation presents a research work related to innovative measurement approaches to study microbial corrosion. Microbial corrosion, also known as MIC (Microbiologically Influenced Corrosion), is an electrochemical process in which microorganisms are able to promote metals degradation. The main motivations for this research are related to the great relevance of this form of corrosion in many industrial applications and to the lack of specific laboratory methodologies to study it. Actually, even if electrochemical measurements can give an important insight on the involved mechanisms, traditional experimental setups for corrosion tests often are not able to reproduce conditions found in a real environment and thus the obtained results can often be not representative for a real application.

This topic has been addressed from a dual perspective: a new experimental setup specifically tailored for microbial corrosion testing has been proposed, then an imaging system to assess the effects of bacteria on sample surface has been developed. The main innovation in the new methodology is related to the use of Microbial Fuel Cells (MFCs) as environment to carry out the test. Actually they can be conveniently used to perform the experiment in controlled conditions, monitoring many of the test parameters simply measuring the current flows in the MFC. Because of this, an *ad-hoc* measuring system has been developed in order to monitor the experiment. Thanks to this new setup, the corrosion resistance of different metals can be compared, providing useful information to researchers. Moreover, one of the main advantages is that using MFCs it is possible to carry out an accelerated test without the risk of altering the microorganisms metabolism. Finally, biofilm formation on sample surface, an important information but difficult to obtain from other electrochemical techniques, can be monitored in continuum during the test.

The imaging algorithm that has been developed can be used at the end of a corrosion test in order to assess the bacteria attachment on sample surface. Using imaging techniques can be of great interest because they can provide information that can not be derived from other measurements. The main innovation in the proposed algorithm is given by the use of micrographs taken at Scanning Electron Microscope (SEM) to assess biofilm coverage. Actually, using this instrument, staining techniques are no more required and sample preparation is easier. Manifold information can be derived from the micrographs analysis, such as number of bacteria aggregates on sample surface and

their dimensional distribution.

This research work has been completed with two studies: one concerning the use of electrochemical measurements to investigate the microbial corrosion resistance of stainless steel in hypersaline environment and the other related to the characterization of innovative hybrid coatings for corrosion protection. The former aims at showing the reader an overview of electrochemical measurements and morphological characterizations used in the microbial corrosion field, presenting a real case study. It has been inserted in the same chapter where the new technique is presented in order to give a comprehensive picture of the current methodologies and of the possible ways to innovate them. Then, in the final part of the dissertation, the characterization of innovative hybrid coatings is presented. They represent one of the possible strategies to protect metals from microbial corrosion; in particular, the bacteriostatic effect of silver nanoparticles has been investigated. This characterization uses both traditional electrochemical techniques and some of those presented in this dissertation, in order to show their application.

Thus, the objective of the research work presented in this dissertation is to propose new tools to study microbial corrosion. It has been pursued developing a new experimental setup to perform corrosion tests and an imaging algorithm to characterize the material at the end of it. Future work could further investigate the possibility of having different setup for the MFCs. For example, a configuration using a dual chamber MFC could be developed, so that different conditions can be established during the test.