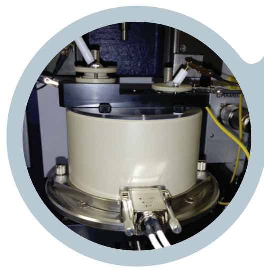
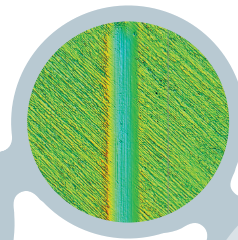
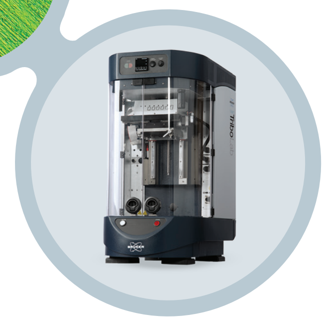


3-Electrode Tribocorrosion Cell



Wear Scar on Stainless Steel



UMT TriboLab

Application Note #1010

Evolution of OCP During Tribocorrosion

Open circuit potential (OCP) and its evolution during a tribocorrosion test gives insight into the materials degradation process that sets in with the synergistic action of mechanical and electrochemical components. Unlike traditional electrochemical measurements, Bruker's UMT TriboLab™ provides a means to track the evolution of OCP during a tribocorrosion test, combining tribology and electrochemistry capabilities into one system. It is designed to help scientists and engineers develop novel materials that resist tribocorrosion, and thus are more reliable and durable in aggressive environments.

OCP in Tribocorrosion

Tribocorrosion is an important R&D endeavor that leads to the development of novel materials for biomedical, chemical, dental, marine, mining, and petrochemical applications.[1] It involves mechanical and electrochemical interaction between tribological contacts. The mechanical components in tribocorrosion are usually sliding wear, abrasion, cavitation damage, fretting, and solid particle erosion. The presence of such mechanical and chemical components enhances the material degradation[2] process synergistically. For example, a material surface, otherwise protected by a passive film, may exhibit a high rate of degradation due to the presence of a mechanical interaction that breaks the barrier layer periodically.

Research in tribocorrosion encompasses tribology and electrochemistry.[1, 2] It is important to monitor the OCP during any electrochemical process to have an idea of the electrochemical potential at which the cathodic and anodic reaction rates are balanced. In such condition, the net electrical current is zero.[3] Bruker's UMT TriboLab test system utilizes a tribocorrosion module to monitor the evolution of OCP during a tribocorrosion test.

Bruker's Tribocorrosion Evaluation Tool

Tribocorrosion studies require a tribometer and a potentiostat to perform electrochemical measurements. The tribometer provides controlled mechanical loading and relative motion between a metallic specimen and a counter-surface such as a ceramic ball. Bruker's universal tribocorrosion test system, the UMT TriboLab, uses bulk or coated metallic test specimens, and the tests can be performed in the presence of a chemical solution (acidic, alkaline, oxidants, salt solution, body fluids, ionic lubricants, etc.). The tribometer measures friction force (Fx) and normal force (Fz). The value of coefficient of friction (COF) is obtained as a function of time from such force data. The potentiostat is integrated with the tribometer to perform electrochemical polarization tests and to provide results in terms of corrosion potential (E_{corr}), corrosion current (i_{corr}) data, and finally materials removal rate due to corrosion. It can also record the OCP data along with data in force channels during the tribocorrosion test.

The TriboLab platform provides precision control of load, speed, and position, and the modular form of its design ensures the flexibility to cover a very wide ranges of test parameters. The tester has three major drive systems: Carriage, Slider, and Y-stage for Z-, X-, and Y-motion, respectively. Integrated intelligent hardware (TriboID™) and software (TriboScript™) interfaces make the tester an extremely user-friendly, versatile, and productive tool. TriboID not only automatically detects the various components attached to the system that are necessary for its proper functioning, but it also configures them. TriboScript offers an enhanced and secured scripting interface for easy compilation of test sequences from the built-in test blocks. The system is also equipped with a real-time control and data analysis software.

Measurement of OCP Evolution

Figure 1 shows an OCP (V_0) plot as a function of time before, during, and after a tribocorrosion test on AISI 316 stainless steel in sodium chloride solution. During the initial 300 seconds, no load was applied and the OCP value was about -0.220 volts. After the initial period, a load of 5 newtons was applied and the tribocorrosion test in sliding mode was performed over next 900 seconds. During the initiation of the tribocorrosion test, a gradual change in OCP toward cathodic direction and a corresponding increase in friction force were observed. The friction force and the OCP were stabilized after about 400 seconds. At this point, the passive film that protects stainless steel from further corrosion was completely removed at the wear track, and a dynamic equilibrium of friction and OCP was attained. The maximum change of OCP from the start to the stabilization was about 0.080 volts. Such a change in OCP during tribocorrosion test was due to the removal of the passive oxide film on the specimen surface, thereby creating a galvanic coupling between the passivated and un-passivated regions. When the sliding motion was stopped and the load was released, the OCP returned near to the initial level, where it was at the start of the tribocorrosion test. AISI 316 stainless steel forms a passive chromium oxide film. The film, which is adherent, tenacious, and self-healing, can protect from corrosion.

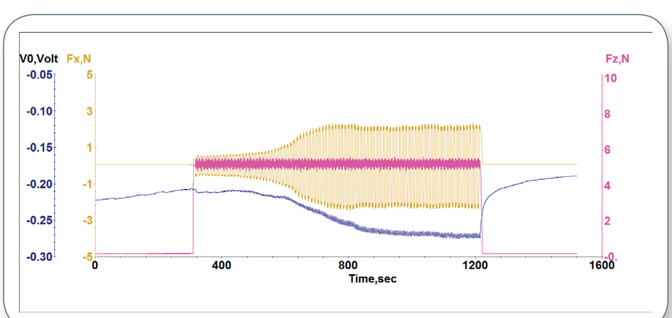


Figure 1. Plot of evolution of OCP (V0) during a tribocorrosion test on AISI 316 stainless steel in sodium chloride solution; initial 300s there is no load and no sliding; next 900s there is sliding with a normal force of 5 N; next 300s the sliding stopped and the load was removed.

The film was compromised due to mechanical wear during the tribocorrosion test. Upon stopping the mechanical sliding, the protective film covered the wear track area and eventually the OCP returned to its normal level.

The wear track formed on the sample was evaluated using a Bruker ContourGT® 3D optical microscope after the test. Figure 2A presents the profile of the entire wear scar. The depth profile of the wear scar along the horizontal line in Figure 2A is shown in Figure 2B. The width and depth values of the wear scar were about 188 microns and 0.436 microns, respectively.

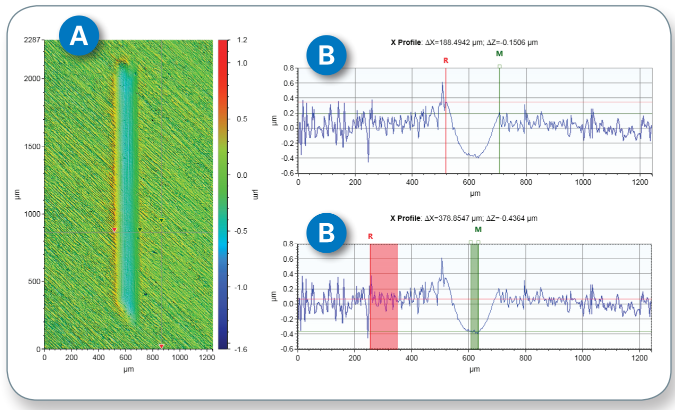


Figure 2. (A) Wear scar profile on the stainless steel surface after the tribocorrosion test, (B) depth profile of the wear scar along the horizontal line in 2(A).

The tribocorrosion test was repeated in cathodic condition, where 1 volt cathodic potential with respect to OCP was applied to the specimen to keep the electrochemical corrosion rate at its minimum.[2] Under such cathodic condition, the materials removal rate is mostly due to the sliding wear. Figure 3A shows the profile of the entire wear scar obtained under cathodic condition using the ContourGT optical microscope. The depth profile of the wear scar along the horizontal line in Figure 3A is presented in Figure 3B. The width and depth values of the wear scar were about 232 microns and 0.217 microns, respectively. The depth of the wear scar in cathodic condition was almost half of that observed under normal tribocorrosion test (Figure 2B). Such results confirm that materials degradation rate due to combined action of mechanical and chemical agents is low under the cathodic condition. In other words, tribocorrosion proceeds in a reduced rate under cathodic condition.

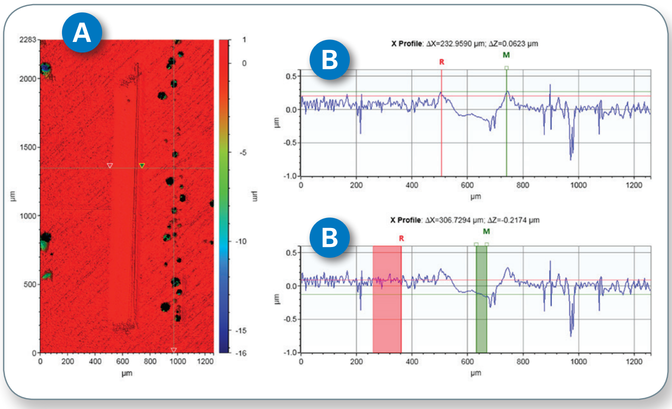


Figure 3. (A) Wear scar profile on the stainless steel surface after the tribocorrosion test under cathodic condition; (B) depth profile of the wear scar along the horizontal line in (A).

Bruker's tribocorrosion module can be successfully used to monitor the evolution of the open circuit potential during a tribocorrosion test. Such data can be generated and compared among various materials for applications where tribocorrosion can be a concern for materials degradation in service causing durability and reliability issues.

Conclusion

Evaluation of metallic materials for their susceptibility to degradation due to synergistic effect of corrosion and wear is an important step toward selection and development of new materials for biomedical, chemical, dental, marine, mining, and petrochemical applications. Bruker's TriboLab test system is particularly capable of performing tribocorrosion test and monitoring of the evolution of OCP during tribocorrosion evalutation.

References

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