Mechanically Assisted Electrochemical Degradation of Alumina-TiC Composite

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Statement of Purpose: Mechanically assisted electrochemical degradation of many alloy implants is often associated with implant failure under extremely loading conditions. Here we show that a mechanically assisted electrochemical process can be initiated even in a very gentle abrasive condition as long as a galvanic condition is favored. To demonstrate this we use Al_2O_3-TiC, an extremely hard ceramic composite with high hardness and wear resistance, as the testing material. By subjecting the ceramic specimens to a gentle abrasive (brushing) condition in a heated aqueous environment (in an accelerated test), we set out to test the ***hypothesis*** *that the high electrical conductivity and tendency in electrochemical activation of TiC as compared with Al_2O_3 would facilitate mechanically assisted electrochemical degradation in the ceramic composite material.*

Methods: Fig.1 shows the apparatus we developed for the brushing tests. In each test run, a sheet specimen is first sonicated in ethanol for 10 minutes, then connected to the working electrode (WE) lead with a copper tape. All surfaces except the top one are covered with lacquer for electrical insulation. A bundle brush is brought into contact with the top surface of the specimen while the contact force is maintained at 45 gram of force with the Flexi-Force sensor. After that, test solution (Micro-90, pH-9.5) is added to the beaker and heated to an elevated temperature of 75 C°. To start a test, the motor is turned on and the current response at the WE is monitored. For the brushing activation, the time to ramp up the rotary speed from 0 rpm to the maximum set speed of 800 rpm was controlled at 10, 40, 70 seconds, respectively.

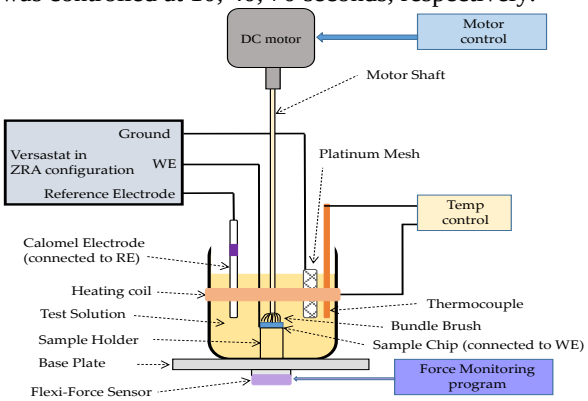


Fig.1- Schematic of the testing apparatus for assessing mechanically assisted electrochemical processes.

Results: Fig.2 shows a typical set of electrochemical responses, consisting simultaneous traces of the open circuit potential (OCP) and oxidation current, measured from a brushing test. Clearly, the OCP drops and oxidation current rises sharply at the onset of brushing and then both signals decay quickly, indicative of a repassivation process. Fig.3 shows the measured current responses in the three-ramping speeds, respectively. In all cases, there exists an underlying current even without brushing abrasion, albeit at a very low level, suggesting a dynamic electrochemical process going on at the surface in an aqueous heated (75 C°) environment. The case with the shortest ramping time (10 s) yielded the highest the peak current (a rise of > 10 µA from its baseline level of ~1 µA) and the case with the longest ramping time (70 s) the lowest peak current (a rise of approximately 5 µA from its baseline). Since the acceleration for the rotary brushing is the highest in the 10 s case and the lowest in the 70 s case, it is reasonable that the induced current in these cases follows a descending order. The gradual decay of the current indicates a repassivation process going on to repair the electrochemical disruption. Fig.4 shows the corresponding SEM images of the test specimens.

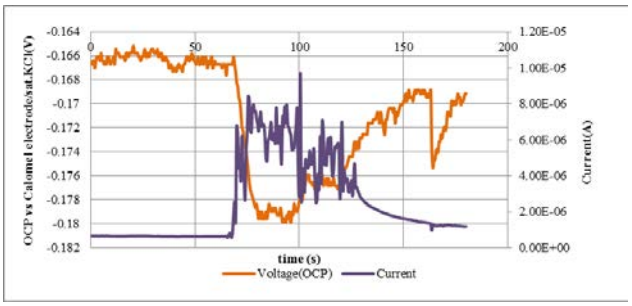


Fig.2 - Current and OCP responses in a brushing cycle of 60 s of resting, 60 s of brushing and shutting off.

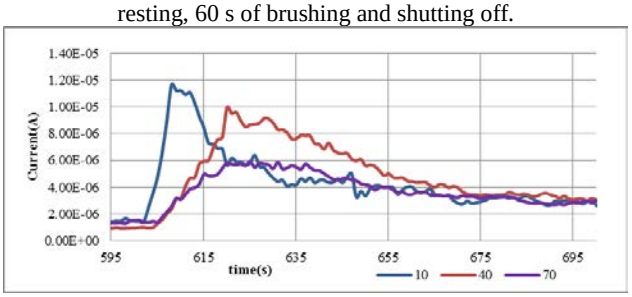
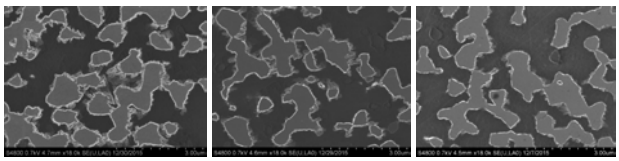


Fig.3- Electrochemical current responses to the onset of brushing abrasion at a ramping time of 10, 40 and 70 s.



(a) (b) (c)

Fig.4 - SEM images of Al_2O_3-TiC under a brushing test at a ramp time of: a) 10, b) 40 and c) 70 seconds to reach the maximum brushing speed of 800 rpm.

Conclusions: Under a gentle abrasive condition, we observed a transient oxidative current surge event occurring at the surface of Al_2O_3-TiC ceramic in solution upon brushing abrasion. The peak current reached is higher and the oxide precipitation at the edges of the TiC domain is more severe when the ramping time is shorter. These results support our hypothesis.