Micro Materials

Excellence in Nanomechanics

NanoTriboTest – see more from a superior Vantage point

Introduction

As single-asperity contacts, nanotribological tests provide unique insights into the roles of test severity and type, surface topography and mechanical properties on friction and wear. Taking advantage of the high lateral rigidity, high sensitivity and high stability of the NanoTest Vantage system, Micro Materials have developed a range of nanotribological modules including scratch, impact and fretting, and combined these with additional multi-sensing capability.

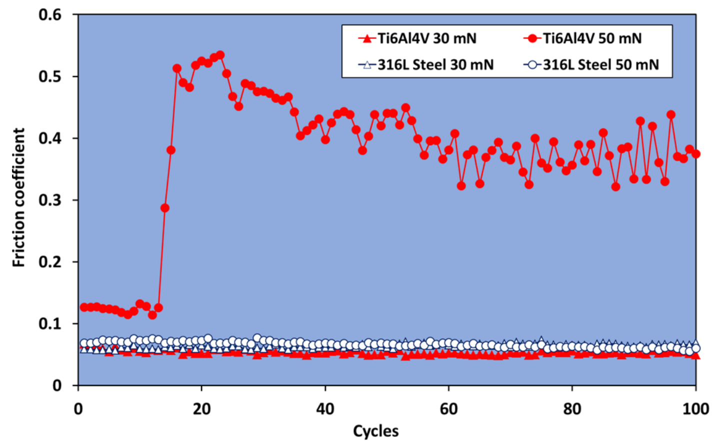
This superior Vantage point is enhanced with the addition of the new NanoTriboTest module. Two recent publications [1-2] have highlighted interesting results with this new capability.

	Nano-scratch	Nano-fretting	NanoTriboTest
Motion	Unidirectional	Reciprocating	Reciprocating
Sliding speed (mm/s)	0.001-0.1	0.01	1-10
Track length (mm)	0.01-1	0.02	1-10
Number of cycles	1-20	1000-200000	100-30000
Total sliding distance (m)	0.00001-0.01	0.01-0.1	1-300
Probe radius (µm)	5-25	10-200	25-5000

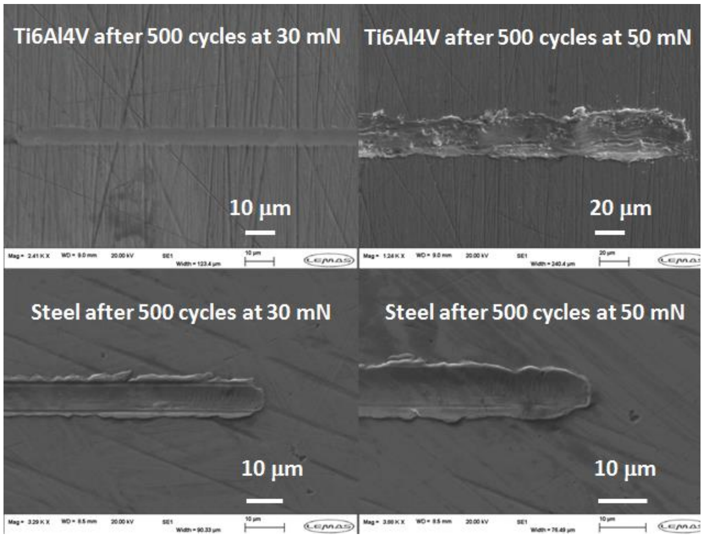
The NanoTriboTest extends the range of nano/micro-tribology tests possible in the NanoTest Vantage, with typical test conditions shown in the Table. Simultaneous measurements of depth, friction and electrical contact resistance are possible, with analysis software for determining energy dissipation and friction loops.

Understanding changing Friction and Electrical Contact Resistance in wear of metallic materials

In a collaborative study with researchers at Manchester Metropolitan University and the University of Leeds in the UK, ENIM in France and Central South University in China, the friction and electrical contact resistance in reciprocating nano-scale wear testing of metallic materials was investigated. The results showed extremely load and cycle-dependent friction and wear behaviour on Ti6Al4V which was not found for 316L stainless steel.



Breakage of the passive oxide on Ti6Al4V causing exposure of the underlying alloy that resulted in a dramatic increase in friction and wear resistance was supported by EDX measurements showing tribo-oxidation.

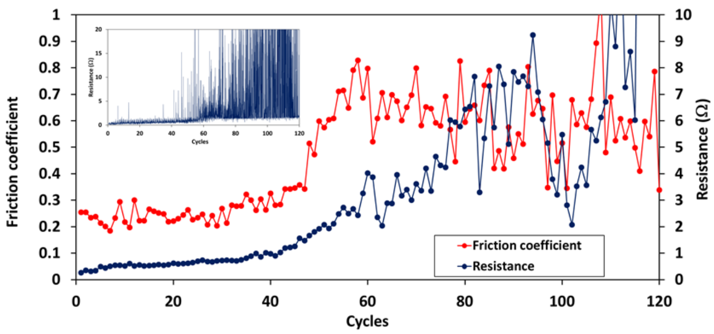


By switching to metallic probes and combining with the ECR module – developed at Micro Materials for studying phase transformations on silicon – multi-sensing nanotribological capability is now possible. In the paper, results are described on the wear of multi-layer electroplated sliding connectors and on the behaviour of bulk noble metal alloys in longer tests.

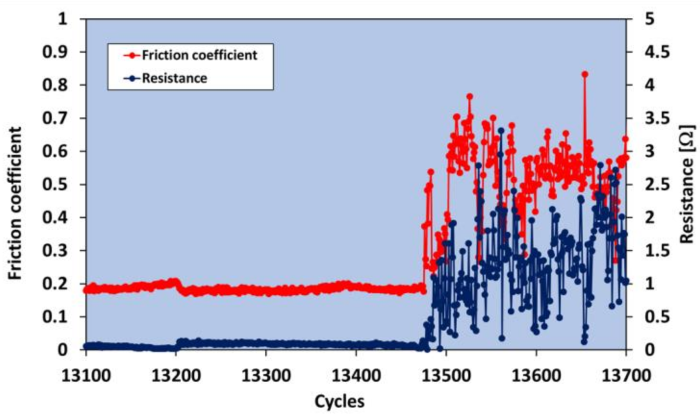
Sample	Probe	Load (mN)	Track length (mm)	Set I (A)	Cycles	Time (s)	Sliding distance (mm)
Au multilayer	Steel	10	5	0.1	200	1000	2000
Ag alloy	Ag alloy	50	10	0.5	1221	5746	24420
Au alloy	Au alloy	200	5	0.5	11532	54908	115320
Ag alloy	Ag alloy	200	5	0.1	35000	166482	350000

The stability to perform long duration reciprocating tests, including a 35,000 cycle (46 hr) test, was demonstrated. Integrating the capability for high cycle, long duration reciprocating nano-/micro-scale tests into the NanoTest Vantage greatly extends the capability of the multi-functional Vantage Platform.

In reciprocating tests Au-Au and Ag-Ag contacts showed much longer endurance than gold-steel contacts. Improved detection of the onset of wear and the subsequent failure mechanisms was possible by simultaneously monitoring friction and ECR. Changes in electrical contact resistance showed a complex correlation with changes to the measured friction, through changes in the electrically conductive contact area.



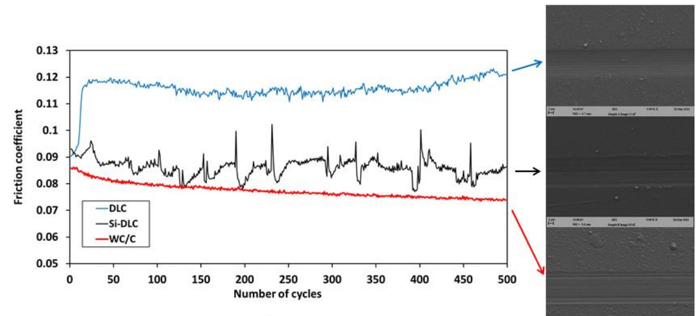
The mean friction and contact resistance over each cycle were determined in the NanoTest software. This approach shows clear correlation between friction and contact resistance in the failure of a multi-layer sliding metallic connector (raw resistance vs. cycles data shown in the inset above).



As part of the study repetitive nano-scratch tests were performed on a silver alloy. A new approach involving taking friction measurements from loads during the ramp was proposed. Good agreement was found to friction coefficients measured from mean values in constant load scratches. The approach has the potential to provide significantly more data on the evolution of the friction with cycling than the constant load repetitive scratch test.

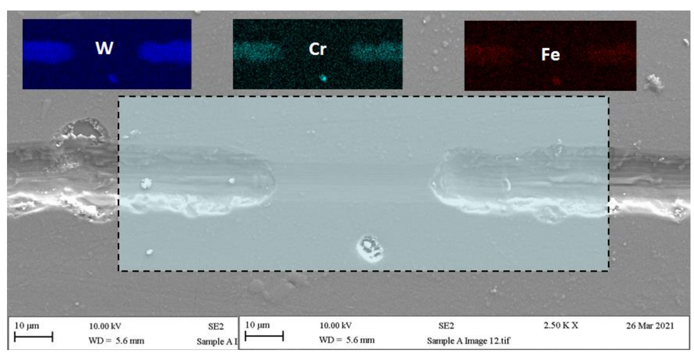
Do Friction and Wear correlate? – Reciprocating tests on DLC, Si-DLC and WC/C coatings

In this collaborative study with Manchester Metropolitan University and the University of Leeds, the friction and wear behaviour of DLC, Si-DLC and WC/C coatings in reciprocating tests was investigated. The same coatings were also tested with the new micro-impact module and the authors showed how the performance of the coatings was dependent on the type of test, with WC/C showing the lowest reciprocating wear resistance but the best resistance to impact-induced fracture.



P = 500 mN; *R* = 25 µm; *v* = 0.5 mm/s

The Figure shows the variation in friction with wear cycles for three coatings. Although the friction is initially similar (as reported in scratch tests with same load, probe sharpness) with continued cycles significant differences emerge. These are due to the relative importance of fracture and deformation on the wear process. In one test on the DLC there was fracture over part of the track. EDX measurements confirm interlayer failure.



Summary

These publications show that the new NanoTriboTest module has greatly extended the range of characterisation tools in the NanoTest Vantage platform. When combined with Electrical Contact Resistance measurement it provides unique insights into the influence of surface topography and mechanical properties on friction, wear and endurance of sliding metallic connectors, biomaterials such as Ti6Al4V, stainless steel and multilayer coating systems.

References

[1] *Friction and electrical contact resistance in reciprocating nano-scale wear testing of metallic materials*, BD Beake, AJ Harris, TW Liskiewicz, J Wagner, SJ McMaster, SR Goodes, A Neville, L Zhang, Wear, 474-475 (2021) 203886.

[2] *Influence of Si- and W- doping on micro-scale reciprocating wear and impact performance of DLC coatings on hardened steel,* BD Beake, SJ McMaster, TW Liskiewicz, A Neville, Tribol Int 160 (2021) 107063.