

Nano Friction Testing
Nitinol Wire



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INTRO

Nitinol wire is a metal alloy made up of nickel and titanium at equal atomic percentage. Popular for its unique properties, shape memory and super-elasticity, along with its cooperative nature with the human body, nitinol has become the leading material used in medical device design. Applications range from stents, to sutures and orthodontics, each requiring specific mechanical properties to achieve its intended use. One such mechanical property vital to medical device design is controlled low load friction measurement.

IMPORTANCE OF NANO FRICTION TESTING FOR RESEARCH & QUALITY CONTROL

A major concern with medical device design is the amount of friction created during contact on the body or other materials or parts that come in contact with each other. Precise friction measurement gives control to reduce friction which can cause inflammation or infection from wear debris. It can also be used to minimize insertion force, such as with stents, to maximize patient comfort. Quantifiable, reproducible and reliable friction measurement is therefore crucial to control the machineability of medical devices.

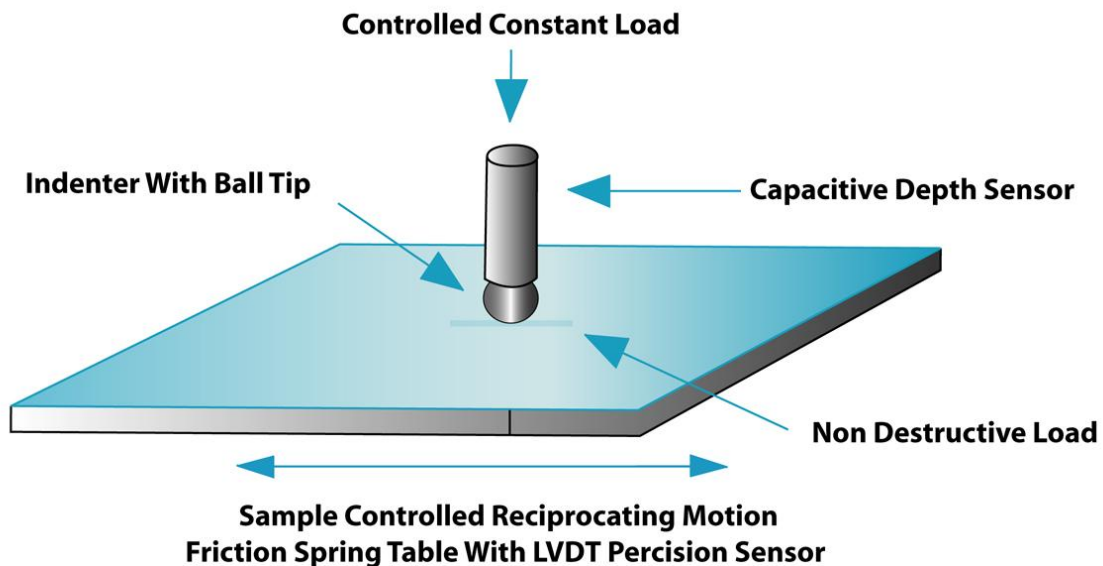
MEASUREMENT OBJECTIVE

To measure friction, we must apply a controlled low load and measure precisely the lateral forces resulting from the friction between the ball tip and sample. For most medical device applications, controlled low load capability requires the precision of nano mechanical testing. An integrated 3D non contact profiler will also be used to obtain surface roughness and surface area measurement to study their correlation to friction results. Additionally, because many medical devices are used in immerse conditions; it is important that the system also be capable to test properties while the sample is immersed in liquids such as bovine serum. This was not the case in our application here, but the process is optional.



FRICITION MEASUREMENT PRINCIPLE:

During the test, the indenter makes contact with the surface at a very low controlled load. The nano module uses a fast piezo electric system and a load cell to quickly adjust the ball position as to keep a constant applied load. The sample is, then, moved at a controlled speed and the lateral force is plotted versus displacement. In general a steel ball of a large diameter (3mm) is used but other materials/shape/size can also be used to measure friction coefficient. On the Nano Mechanical Tester, friction is measured from the deformation of a very sensitive spring inside the base table. The deformation of the spring is measured using a precision LVDT sensor.



Additional Tools Related to Friction Measurement

Depth Sensing

Gives information on the profile of the surface which can affect the friction measured. . Depth information pre and post scratch can also give information on plastic versus elastic deformation during the test. 3D Non-Contact imaging such as white light axial chromatism technique and AFM's can be useful to measure exact depth of scratch after the test.

Microscopic observation or Optical Profile

Used to define test area and to observe and measure possible wear on the surface.

Atomic Force Microscope

Used to measure the plastic deformation, if any, caused by the ball passing on the surface of the sample.

Test parameters

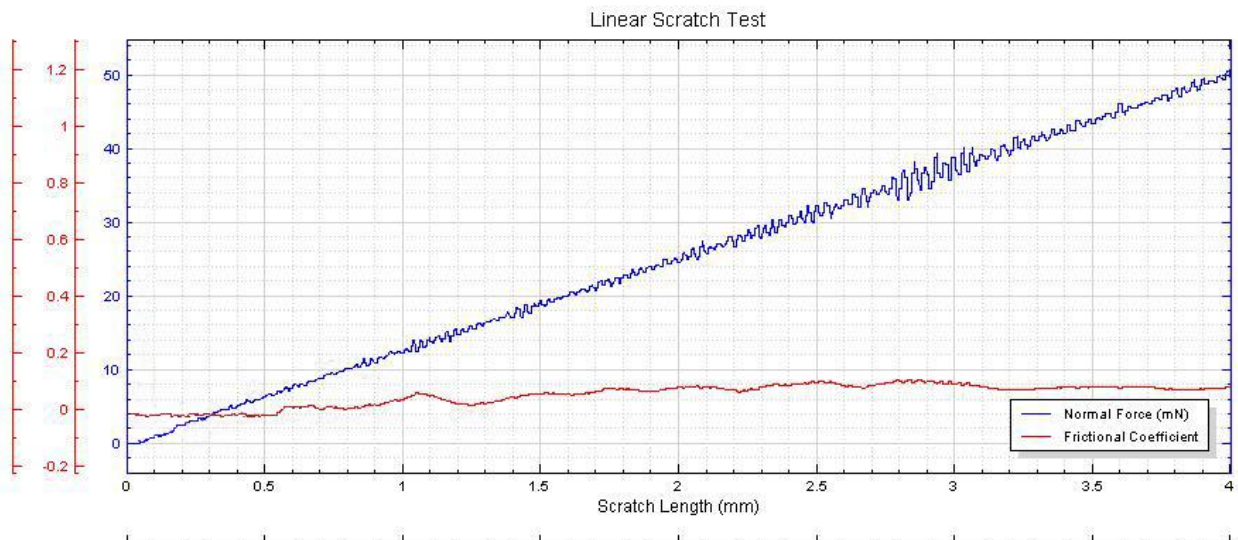
Sample	Dark Wire
Load	50 mN
Speed rate	50 (mN/min)
Amplitude	4 mm
Ball Diameter	3 mm
Ball Material	440 SS

Lubricant	n/a
Atmosphere	Air
Temperature	23°C (room)
Humidity	35%

Results

Coefficient of friction

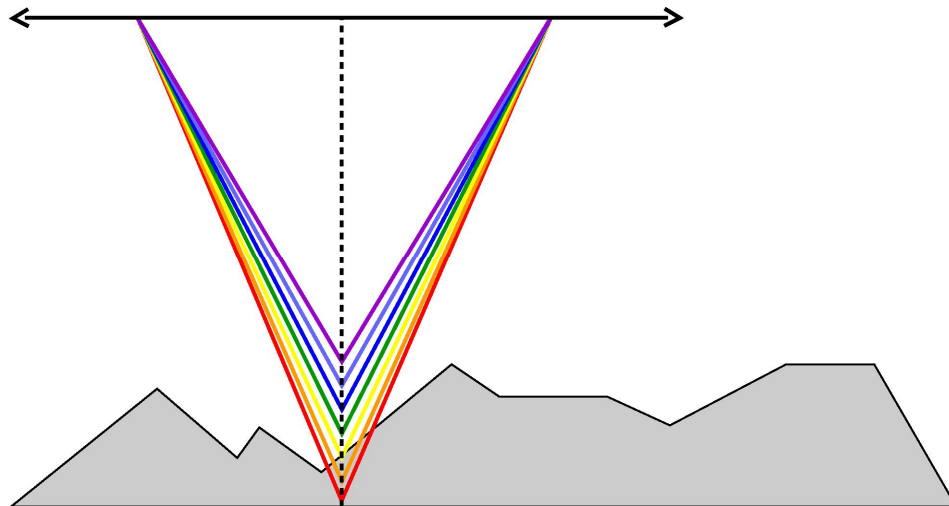
Dark Wire	Maximum COF (μm)	Minimum COF (μm)	Average COF (μm)
Test 1	0.123	0.029	0.091



COF Graph Results

OPTICAL PROFILER MEASUREMENT PRINCIPLE:

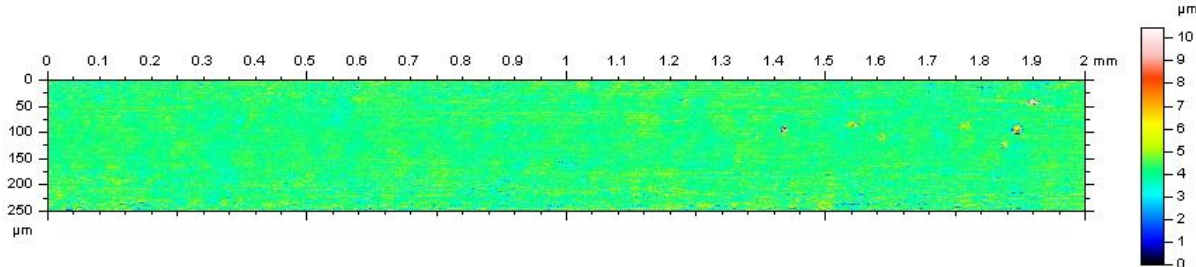
The axial chromatism technique uses a white light source, where light passes through an objective lens with a high degree of chromatic aberration. The refractive index of the objective lens will vary in relation to the wavelength of the light. In effect, each separate wavelength of the incident white light will re-focus at a different distance from the lens (different height). When the measured sample is within the range of possible heights, a single monochromatic point will be focalized to form the image. Due to the confocal configuration of the system, only the focused wavelength will pass through the spatial filter with high efficiency, thus causing all other wavelengths to be out of focus. The spectral analysis is done using a diffraction grating. This technique deviates each wavelength at a different position, intercepting a line of CCD, which in turn indicates the position of the maximum intensity and allows direct correspondence to the Z height position.



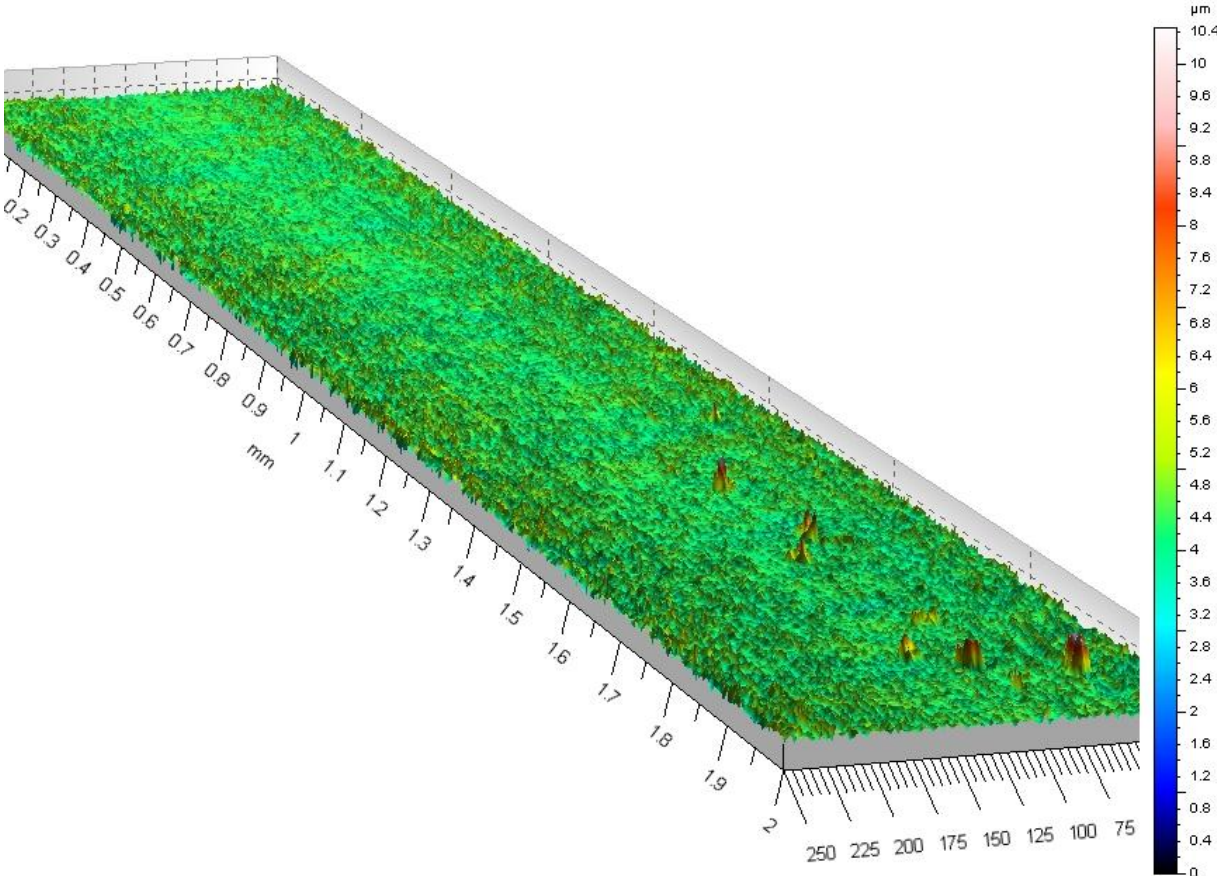
Nanovea optical pens have zero influence from sample reflectivity. Variations require no sample preparation and have advanced ability to measure high surface angles. Capable of large Z measurement ranges. Measure any material: transparent/opaque, specular/diffusive, and polished/rough.

Results

Surface Roughness Measurement

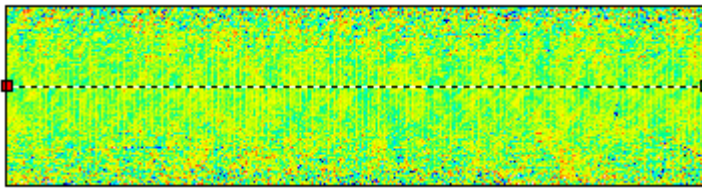
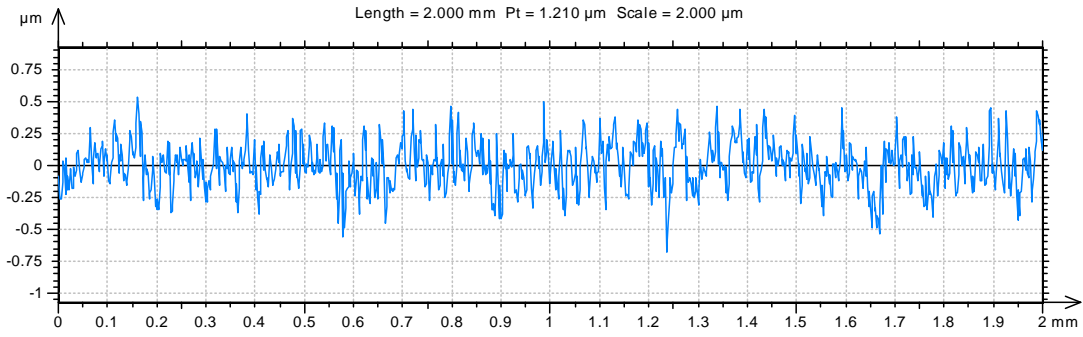


Top Surface View of Nitinol Wire



3D Image of Nitinol Wire Surface

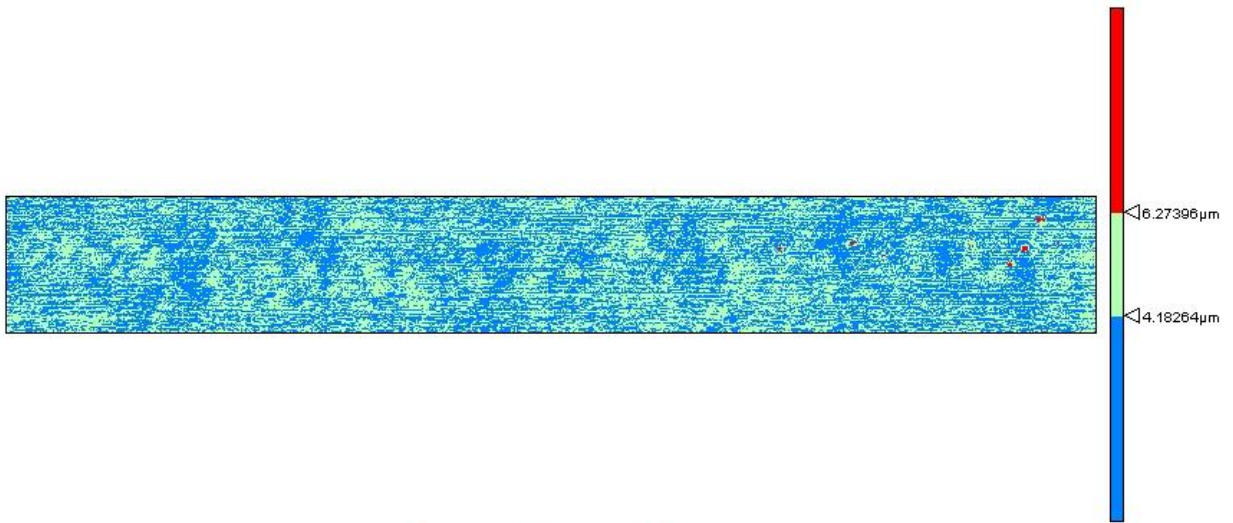
Roughness Profile Extracted From Nitinol Wire Surface



ISO 25178
Height Parameters

Sq	0.505	µm
Ssk	0.302	
Sku	8.147	
Sp	6.290	µm
Sv	4.165	µm
Sz	10.456	µm
Sa	0.376	µm

Surface Area Contact



	■	■	■
Projected Area (%)	51.3613	48.5229	0.115757
Volume of void (%)	4.70742	91.4856	99.9665
Volume of material (%)	95.2926	8.51436	0.0335267
Mean thickness of void (µm)	0.196931	1.91182	4.18202
Mean thickness of material (µm)	3.98640	0.177929	0.00140256

Conclusion

As seen in our analysis, the friction level of the Nitinol wire has been identified during nano mechanical testing. Contact area is a critical aspect of studying the frictional force of two materials in contact. Therefore, using the integrated optical profiler, it is possible to study the correlation between the surface roughness, area and friction. Since the nano mechanical tester is equipped with a high resolution capacitor, one can apply a very low contact force (less than 0.3mN) and determine the change in depth when applying the low force that will be used to measure the coefficient of friction. This difference in depth can then be used to determine the precise surface area of contact during the friction test. As can be seen in the surface area contact graph, the blue and red area would be in contact while the yellow part would not. This allows better calculation of the true contact area during the friction measurement. The shape of the contact, which is the spherical tip, needs to be taken in account for calculating the true contact area; this has not been done in the context of this application note. Using a ball with very low friction ensures that the roughness parameter comes only from the sample under study. It would however be possible if roughness information was also taken from the static partner to study the effect of two surfaces of similar range of roughness in contact. In conclusion, the combination of optical profiler or AFM and a high precision Nano Mechanical Tester, in friction mode, are invaluable tools for advanced research with friction mechanism.