Scratch Interfacial Adhesion Failure of TiN Coatings on Steel Substate

Ceramic coatings are incredibly important to the worlds of machining, medical devices, and consumer electronics. Hard ceramic coatings protect surfaces such as the cutting edge of tools or complex surfaces in medical implants from frictional wear. These coatings can also be inert enough to protect valuable materials from corrosion, oxidation or exposure to harsh environmental conditions. The ceramic coating studied here is titanium nitride, or TiN. TiN is prized for its hardness, easy deposition methods, and its yellow-gold like appearance. The method used to deposit TiN onto a substrate can dramatically affect the coating's adhesion strength; and less than adequate adhesion to the substrate will result in a coating failing much sooner than expected.

In order to quantify the adhesion strength of a TiN coating on steel specimen, an instrumented scratch test method was used. This scratch test was carried out on a Revetest Scratch Tester manufactured by Anton Paar. During the scratch test a sharp conical probe, made of diamond, is being dragged across the sample surface under an increasing normal force. The diamond probe is progressively penetrating into the coating. Eventually, the coating shows cracking, chipping or delamination. The minimum load at which the coating separates from the substrate is called the critical load of coating interfacial adhesion failure. This critical load makes it possible to quantify the adhesion strength of the coating itself or compare adhesion strength among coatings.

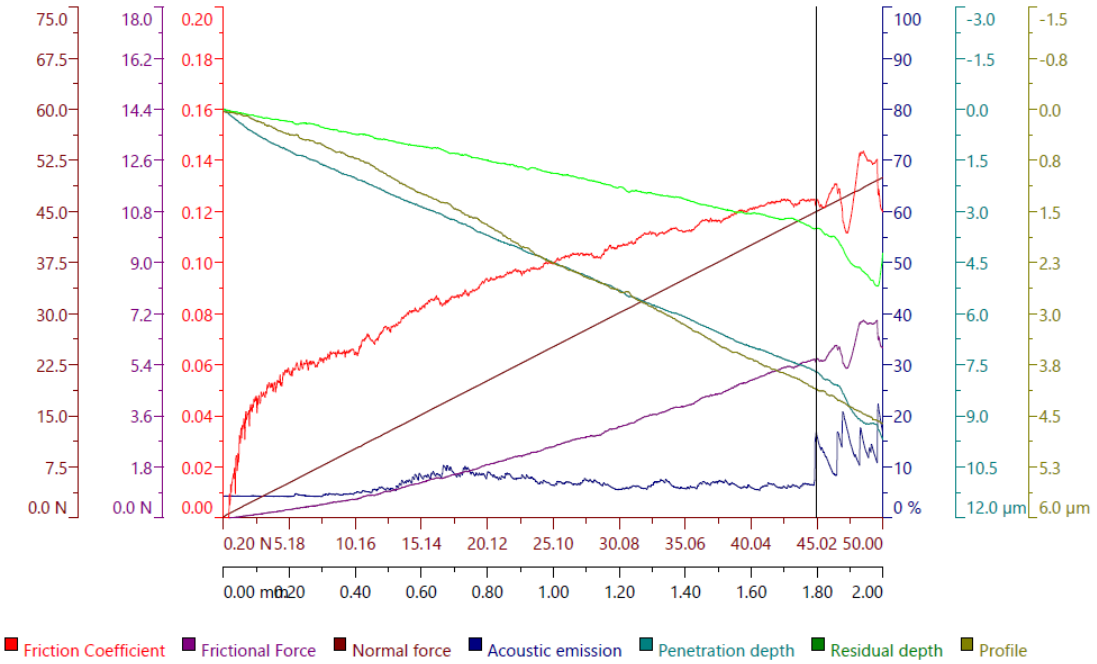

Figure 1. Scratch test curves of the TiN coating on steel substrate. The black vertical line marks the critical point of coating interfacial adhesion failure.

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There are several ways to identify critical loads when performing scratch tests. The most common techniques involve looking for sharp changes in acoustic emission, scratch coefficient of friction, penetration depth, or residual depth signals and relating that to optical microscopy images. Figure 1 shows the scratch test data obtained on the TiN coating on steel substrate specimen. From Figure 1, it can be seen that there are small slope changes in the coefficient of friction and acoustic emission curves starting at 13.01 N of normal force. This indicates some type of failure event may have occurred. Optical microscopy image, as shown in the inset of Figure 2b), confirms that the failure event is cracking along the outside edges of the scratch track. This cracking is a cohesive failure within the coating; the coating itself is still adhered to the substrate. At 44.95 N of applied force though, significant changes in the acoustic emission, coefficient of friction, penetration depth and residual depth signals are obvious. This points to a major failure event, and is proved by optical microscopy. As shown in Figure 2c large sections of the coating has chipped off and some of the steel substrate is exposed. This is coating delamination event and the normal force at the starting point of the event is the detected critical load of coating interfacial adhesion failure.

Scratch testing is a readily-available technique that can be used to evaluate coating interfacial adhesion strength and to study failure mechanisms of coating/substrate systems. In general, the higher the critical load of coating interfacial adhesion failure is, the higher the coating interfacial adhesion strength is, assuming the coatings have similar mechanical properties and thickness.

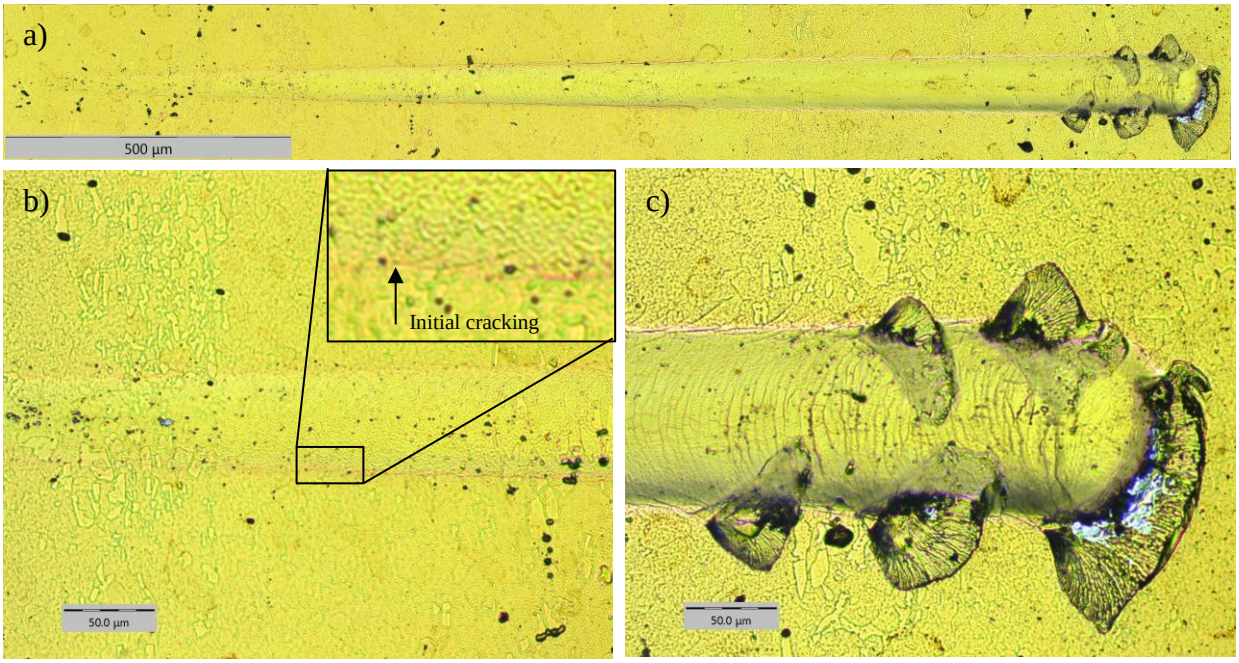

Figure 2. A 2 mm long scratch made on a titanium nitride (TiN) coating on steel substrate specimen imaged using a 20x objective lens: a) the entire scratch track, b) zoom in of the onset of cohesive failure/cracking, and c) zoom in of interfacial adhesion failure.