CSM Instruments
Advanced Mechanical Surface Testing

APPLICATIONS BULLETIN

Impact testing with the CSM Nanoindentation Tester

Investigation of the surface fracture resistance of a SiN coating by Impact testing

The Nano Impact testing module is a recent addition to the CSM Instruments Nano Hardness Tester and has been developed for studying the impact response of materials at ultra low loads. The principle is simple: a load oscillation step is applied at a predefined point during a pause in the indentation load-unload cycle. The indenter tip can therefore be used to impact the sample surface in a controlled way and the speed of impact can be accurately defined.

Thin coatings which are subjected to repetitive stresses can often fail sooner than when only subjected to a monocycle stress. Many thin film applications demand that the coating be able to withstand many impacts over the lifetime of the device, this being of particular importance in critical applications such as semiconductor micro-switches and MEMS devices. Repeated impact stresses in a thin film will lead to fatigue of the material as well as significant cracking and delamination.

The material tested here is a Silicon Nitride (SiN) coating on a Stainless Steel substrate which exhibits no residual imprint after a standard quasi-static indentation to a maximum applied load of 5 mN using a Berkovich indenter. However, if a load oscillation step is added during a pause at maximum load, the coating can be fatigued, leading to significant cracking as shown in Fig 1.

In this example, the impacts have been produced by adding a load oscillation step of 11.7 mN during the pause at maximum load of 5 mN. Several independent tests were performed with increasing numbers of impacts (1, 3, 5, 7, 10, 15, 20, and 30 cycles). The residual imprint was imaged after each test in order to correlate the length of the cracks emanating from each corner of the Berkovich impression to the number of impacts performed. From the applied load and the indentation crack size, the fracture toughness (Kc) can be calculated (see Applications Bulletin No. 8, July 1998 for a more detailed overview of this method).

The instrumented indentation technique used by the Nano Hardness Tester plots the penetration depth of the indenter as a function of the applied load over the entire loading and unloading portions of the test. Fig. 2 shows the load and penetration depth plotted as a function of time for 7 impacts at a maximum paused load of 5 mN. The increase in penetration depth with each subsequent impact is clearly visible. The applied load trace (dotted line) confirms that the applied impact load has been maintained steady at 11.7 mN over each cycle.

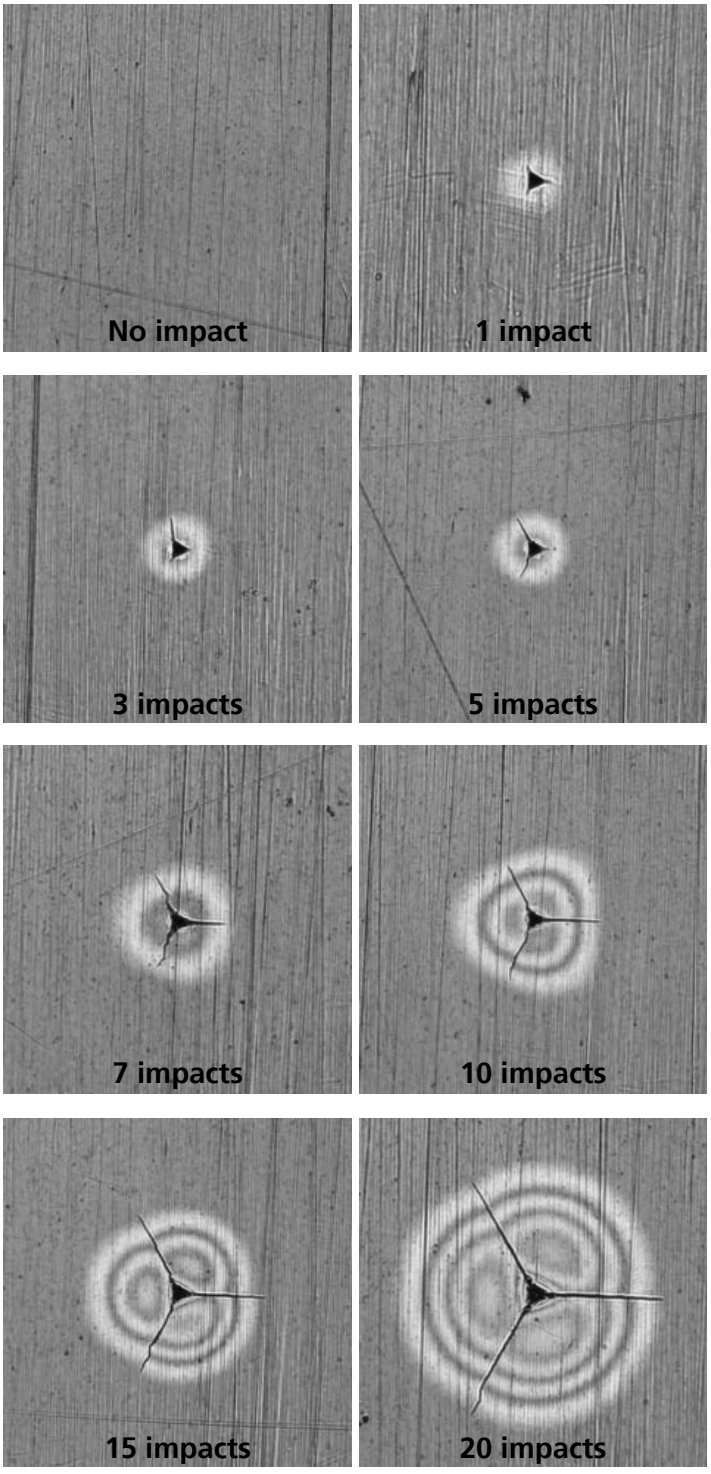

Fig 1 – Optical micrographs of imprints in a SiN coating showing the increasing crack length as a function of number of impacts.

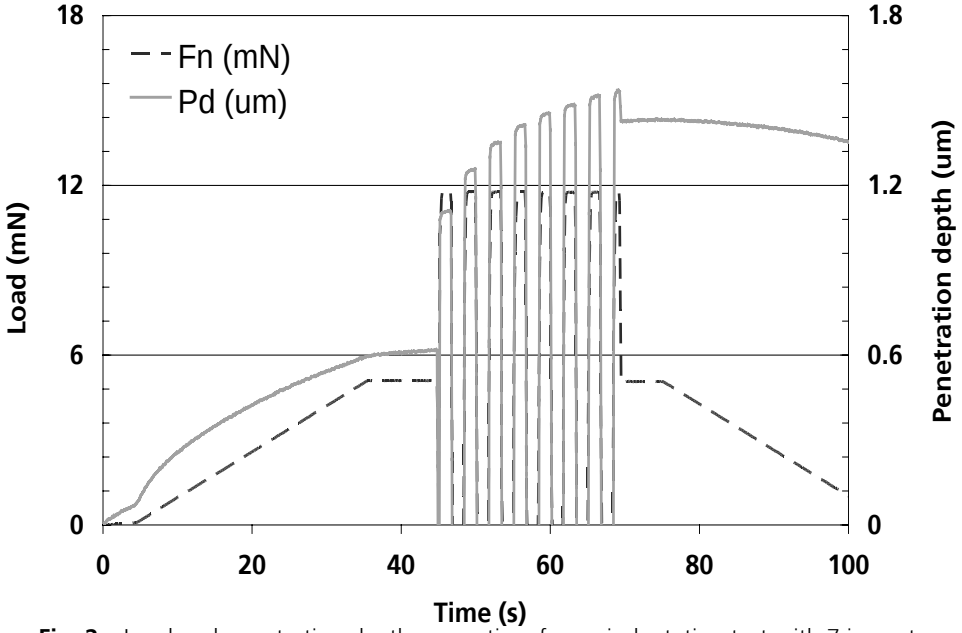

Fig. 2 – Load and penetration depth versus time for an indentation test with 7 impacts.

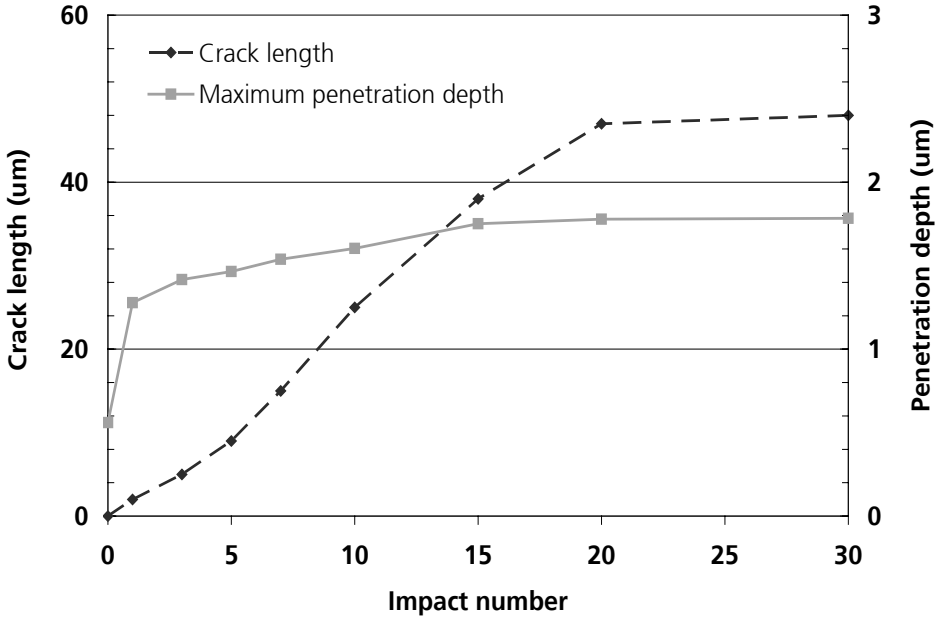

Fig. 3 – Crack length and penetration depth versus number of impacts

Fig. 3 summarises the median crack lengths (as measured by optical microscopy) plotted as a function of the number of impacts. One can see that the penetration depth increases dramatically during the first impact (from 625nm at 5mN to 1115nm after the first impact).

Subsequent microscopic observation shows the residual imprint of the Berkovich tip in the material but the crack lengths seem very small at this stage in the experiment. Further impacts then cause the crack lengths to increase significantly, whereas the corresponding penetration depth increase is less significant.

Finally, when the Berkovich tip reaches the substrate (after 20 impacts in this example), the crack length and penetration depth both seem to reach a plateau which is relatively flat.

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This Applications Bulletin is published quarterly and features interesting studies, new developments and other applications for our full range of mechanical surface testing instruments.

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