

# Fischer-Cripps Laboratories Pty. Limited

ABN 26 000 551 459

[www.ibisonline.com.au](http://www.ibisonline.com.au)

## VIDEO PRESENTATIONS: FAQ

These video presentations use the actual instrument and software in demonstrating the IBIS nanoindentation system. We do not show animations of what “should happen”, but only what “does happen” when you use the IBIS system.

### 1. Indentation on Silicon.

In this video we perform a low and high load test on a silicon wafer. The silicon is uncoated. The instrument is used in a non-airconditioned laboratory on the standard rubber mountings, on a four-wheeled trolley. There is no anti-vibration air table.

The indenter screws into the end of the indenter shaft with fingers. It is not necessary to clamp the shaft. The indenter shaft is capable of moving several mm in the vertical direction and withstand significant sideways forces and torque. The indenter is then nipped up with a small plastic tool. The tool is made from plastic to avoid damage to the end of the indenter should a slip occur. The indenter can be changed in just a few seconds. The indenter is a carefully ground pyramid made from diamond and sintered into a stainless steel chuck. The sample is mounted on to a flat magnetic specimen mount which is held in place by a magnet in the stage plate. Samples can be mounted using super glue, hot melt specimen bonding glue, or using an optional vacuum chuck.

A few seconds of the approach phase are not shown to reduce the size of the video file. Prior to the indenter beginning to move, there is a certain amount of electronics initialization which typically takes about 10 seconds. There is another 10 second delay as the PZT expansion unit moves through a “safety gap”, and then the approach proceeds at the rate shown in the video.

The low load tests show a maximum penetration depth of about 15 nm. This is of the same order of magnitude as the surface roughness of the material and so it is necessary to take a few indentations in different parts of the sample surface to get a representative value of material properties. This is because the contact mechanics theory used to analyse the results assumes an atomically flat surface. At higher loads, it is not necessary to take an average reading although occasionally it is found that the indenter will land on a piece of dust or a scratch in the surface and so a repeat indentation at that load may be necessary.

Silicon exhibits a crystalline phase change under hydrostatic compression and this is most clearly shown in the unusual shape or kink in the unloading curve. For this reason, to enable quantitative measurement of elastic modulus and hardness, one usually selects the upper 40% or so of the unloading data for curve fitting.

The Berkovich indenter used here was calibrated (area function) against fused silica with modulus 72.5 GPa. This demonstration shows that even though the indenter is calibrated with a different material than the one being tested, the instrument provides realistic values of E and H for the test material at depths as low as 15 nm.

### 2. Finite element analysis

The IBIS nanoindentation system interfaces to the Sstrand7 Finite Element program. Strand7 is a general purpose FEA system used by engineers and scientists all over the world. It is possible to setup an indentation model directly in Strand7, but this is very complicated due to the geometry of the non-linear contact and material properties boundary conditions. Using the front end provided by the IBIS program,

one can assemble and solve this type of model without even opening the Strand7 application. Further, changes to indenter or model geometry can be made and the model rebuilt in a few seconds.

The non linear solver applies load in a series of increments. Both the expanding area of contact and the non-linear material properties are accounted for in the solution to the model at each load step. The inputs to the model are the elastic modulus and the yield stress. A bi-linear stress strain response is specified as part of the model input. Some judgement is required to estimate the yield stress to use, but information about this can be found from the measured hardness of the material in a normal nanoindentation test.

The output from the solver can be formatted as a regular IBIS data file and the load displacement curve can be read alongside associated experimental curves. Alternately, data from the stresses strains in the material can be output as a text file and then imported into a third party graphics program. The contour maps and animations shown in this demonstration were done with the Strand7 program after the model had been built and solved using the IBIS interface.

The Strand7 program supplied with the IBIS system is not restricted to use with the IBIS program, but can be used for nearly any usual FEA application such as structural analysis and heat flow. There are no on-going licence fees with the Strand7 system. There is the option of a paid subscription support for program updates and assistance.

The Strand7 interface is an optional accessory with the IBIS system. The cost of the accessory depends upon whether the final customer requires a full commercial licence or if the use is for academic research/educational purposes.

### **3. Dynamic nanoindentation with Fourier analysis**

This demonstration gives a very brief overview of measuring the dynamic properties of a lossy material using nanoindentation. Unlike competitor instruments that use a single frequency oscillation, IBIS has the additional facility of applying a multiple frequency spectrum of frequencies and then using sophisticated Fourier analysis to back out the single frequency response for the material. This is particularly important for lossy materials such as polymers because the elastic moduli can, and often change, with the rate of application of strain (that is, the frequency of the deformation).

In IBIS, we analyse the data in “k” space because the frequency characteristics of the instrument (as measured with a linear spring) can be conveniently subtracted from the sensor readings whereas if this were done in the time domain, the convolution of the specimen and instrument responses would be very difficult to separate.

In the demonstration shown here, the variation in stiffness (the storage modulus) in the frequency range 0.1 to 12.8 Hz is real and not an artefact. This is easily demonstrated by examining the reference spectrum (on the linear spring) which is flat in this frequency range.

In IBIS, there is a resonant peak at about 40 Hz. This limits the range of frequencies that can be used for this type of testing. However, as can be seen in the present demonstration, it is the low decades of frequency that are usually the most important for plastics and lossy structural materials.

The technique can also be applied to rheological measurement of fluids by replacing the indenter with a flat circular plate.